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Relationship of Stunting and Overweight in Egyptian children under five years of age: Trends and associated risk factors

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I. Executive Summary

Introduction

According to the Global Nutrition Report of 2014, the coexistence of many forms of malnutrition is the "new normal" worldwide (1). Many forms include under nutrition as manifested by stunting, wasting and underweight as well as over nutrition as manifested by overweight and obesity. While no country is totally free of malnutrition, most developing and emerging economies have to contend with multiple manifestations that pose complex policy challenges to national governments. Egypt has had the biggest rise in overweight and obesity since 1980, and is one of 10 countries that account for more than half of the world's obesity problem (in terms of absolute numbers affected) (2). While overweight/obesity tend to cut across Egypt's regions and, to some extent, its wealth categories, the country stands out as having one of the highest gender disparities in obesity (1). Egypt ranks 8th in the world in terms of adult male obesity and 3rd in the world in adult female obesity (3) . Rates of child overweight and obesity are consistently increasing and while progress has been made in the reduction of stunting during the late 1990s through 2008, as of 2014, Egypt's rate of 21% is still higher than for other countries in the region that have the same levels of GDP (4).

The existence of stunting and overweight/obesity in the same child has been documented globally in Guatemala, Mexico, Russia, China and Brazil (12). This is also being observed in many countries of the Middle East and North Africa. These emerging economies face a dual burden wherein there is co-existence of under and over nutrition, either in the same population, community, household or same individual. The dual burden of disease can be extremely variable in its manifestation. It can, for example, be manifested as stunted children who are concurrently obese, or as stunted children who may not be *currently* obese but who are at risk of early onset chronic diseases – such as diabetes, hypertension, renal dysfunction and cardiovascular disease - due to epigenetic programming.

An analysis conducted on Syrian children (prior to unrest) has shown high rates of stunting in rural children in Aleppo province whilst urban children had significantly higher rates of overweight and obesity (18). In Libya, similarly rates of stunting are high in rural areas with overweight/obesity being recorded in urban areas (19). In Egypt specifically, rates of stunting increased significantly between 2005 and 2008 (23% rising to 29%), especially in Lower Egypt (17% rising to 34%) (15, 16, 20). Rates of overweight and obesity in children are also rising. The political events of 2011 included the return of many now unemployed Egyptians from neighboring countries, which led to food shocks and a likely further deterioration in nutritional status for many people (16).

Aims and Objectives

The aim of this study was to examine and understand the trends and variability of malnutrition in all its forms (defined as both over and under nutrition) in Egyptian children under five, across time, regions and socio-economic status. The study objectives were to:

- Understand the relationship of stunting and overweight in Egyptian children and the changes in this relationship over time
- Understand the relationship of stunting or overweight or both in children and maternal nutritional status.
- Understand the trend in stunting and overweight in Egyptian children across different survey years and
- Examine the effect of change in stunting and overweight by wealth index, geographical location.
- Understand the relationship of different risk factors associated with being stunted, overweight or being a stunted child that is overweight.

Methods

The study utilized the Demographic Health Survey (DHS) data for all survey years starting from 1988 to 2014. Seven data sets including variables on women, children and other household variables were downloaded, cleaned, and analyzed using SAS (Statistical Analysis Software). Anthropometric indicators for all children under five were re-calculated for all survey years using the WHO 2006 growth standard (5). Z scores for height-for-age (HAZ), weight-for-height (WHZ), weight-for-age (WAZ) and BMI-for-age for and the prevalence of stunting, overweight, overweight in children who are stunted, wasting and underweight were computed. The metrics of interest in this study are the prevalence of stunting, the prevalence of overweight and the prevalence of overweight in children who are already stunted (or overweight as a stunted child).

Statistical analysis included computing descriptive statistics of key dependent variables (stunting, overweight, overweight in stunted children, wasting, Z-scores of HAZ, WAZ and WHZ) and key independent variables (maternal BMI (Body Mass Index), occupation, education, birth size, birth order, maternal age at first birth, wealth index, infant and young child feeding practices). Significant bi-variate associations were identified using logistic regressions. Multi-variate analysis was conducted using the log-binomial regression model (PROC GENMOD) to allow for modeling the probability of stunting being 1 and adjust for complex variation structures in the data.

Results

Descriptive Results

The study found that while stunting levels have reduced in Egypt however there has been a concurrent increase in overweight and obesity in Egyptian children under five years of age. While the rates are lower in the current survey year, there was a spike in prevalence in 2005 and 2008, a finding observed at the national level as well as the regional level. As prevalence of overweight has increased, so has the prevalence of overweight in children who are stunted. This pattern in reduction of stunting, increase in overall overweight prevalence and increase in overweight in stunted children is seen across all the geographic regions, the lowest being in Frontier and the highest being in Upper Egypt Rural governorates.

HAZ and WAZ follow an expected pattern of decrease in Z-score by age group as demonstrated by Victora et al (11). Younger children were more overweight than older children. Prevalence of overweight in children who are stunted increases rapidly by survey year especially in the under 6-month age group. Almost 40% of infants under the age of 6 months that are stunted are likely to be overweight while about 30% of infants and young children aged 6-24 months that are classified as stunted are likely to be overweight. Thus the risk of being overweight is higher in younger children whether normal or stunted.

Another significant finding is within the realm of wasting. The study found that while mean WHZ score becomes more positive with every survey year (reflective of the increasing rates of overweight being observed by survey year), this trend lasts only until 2008. In 2014, we find that the mean WHZ score is much lower than the other survey years, implying a population that is at risk of both overweight and wasting. This is concurrent with the sharp increase in wasting prevalence from 2000 through 2014. Wasting prevalence has increased across survey years and more in depth analyses needs to be conducted to understand this juxtaposition of overweight and wasting in the same population.

While stunting has decreased over time, the study found that the prevalence of stunting across wealth categories/income is evenly balanced. This is because prevalence has reduced only in the lower income/wealth categories and not in the higher income categories. This implies a reduction in inequality across wealth categories. This improvement in both relative and absolute inequality in the distribution of stunting by wealth has been documented for the 1995 to 2008 timeframe (8, 9). Our analyses expanded beyond this time (Restrepo- Mendez et al's analysis), examining not only the newer DHS round but also examining the trend of overweight (in all children and in children that are stunted) with reference to wealth index (9). Similar to the reduction in inequality observed in the stunting data, overweight prevalence increased in all income/wealth categories with a similar even line across wealth categories as the stunting prevalence. Overweight in stunted children showed a similar trend across all categories of wealth in 2014.

Regression Model Results

The risk factors tested in the model included maternal BMI, maternal education, maternal occupation, maternal age at first birth, birth size, birth order, age of the child, gender, geographical location (region and urban/rural), wealth index, being breast fed (or not), household size and number of children under five years of age.

Stunting and its Risk Factors

The risk of being stunted was higher in boys than girls and increased with increasing birth order. There is no association between stunting and age of the child. All regions have significantly higher risk of having stunted children compared to Urban governorates, the highest is in Upper Egypt rural where children are 1.6 times more likely to be stunted than children in the Urban governorates. However overall being in a rural versus urban area seems to impose a protective effect with a lower risk of being stunted (about 14%). Maternal education reduced the risk of being stunted (compared to no education), the effect being most significant at the secondary level of education. Neither maternal occupation nor maternal ages at first birth were related to the risk of being stunted. Wealth index was not associated with the risk of being stunted though we do see an effect of the early survey years with the poorest and poorer categories trending to an increased risk compared to the middle-income category. Higher BMI in women was associated with a lowered risk of stunting with obese women having the least likelihood of a stunted child (about 20%) compared to underweight women. Birth size was protective of stunting with very large, larger than average, average babies having a significantly reduced risk of being stunted than very small babies. Number of children was associated with increased stunting while household size was associated with a decreased risk of being stunted.

Overweight and Overweight in stunted children and risk factors

The risk of being overweight was not significantly different by gender but was significantly lower as age and birth order increased. Being a boy is protective (in contrast to stunting) while age of the child lowered the risk i.e. older the child, lower the risk of being overweight as a stunted child. There was no association of being overweight as a stunted child and birth order. The regions that had higher risk of overweight were more likely to also have a higher risk of overweight in children who are stunted. This includes Lower Egypt Rural and Upper Egypt Urban while Upper Egypt Rural has significantly higher risk ratios for stunting but the risk ratios of overweight in stunted children while greater than 1, are not significant. There was no difference in risk of being overweight between rural and urban children or being overweight as a stunted child. Maternal education has no association on the risk of being overweight but it increased significantly the risk of having a stunted child that is overweight. Maternal occupation was associated with an increased risk of overweight and the risk of overweight in stunted children slightly. The risk ratio for being overweight was slightly but significantly higher with an increase in maternal age at first birth. The risk of being overweight child of mothers in all BMI categories was two times or higher compared to mothers who were underweight. This risk is significant at the $p<0.001$ across all BMI categories. Similar to overweight, mothers of any BMI category compared to underweight mothers were 2 or more times likely to have a stunted child that was overweight.

Similar to stunting, wealth index is not associated with the risk of being overweight or on the risk of being overweight as a stunted child. Birth size of very large to average (in contrast to stunting) was linked to increased (significantly) risk ratios of being overweight. Furthermore, larger birth size was significantly associated with an increased risk of being overweight as a stunted child with risk being 1.3 to 1.8 times higher in average to very large infants compared to very small infants. Number of children increased the risk of being overweight while household size seemed to reduce the risk for both indicators. Household size trended towards a reduced risk ratio while survey year increased the risk of overweight in stunted children.

Caveats and Challenges

Our data analysis does have some caveats and there are some challenges encountered in the analysis and interpretation of our findings. Firstly, some of the data are not usable for regression analysis due to differences in definitions and/or sampling strategies. For example, the diet quality data categorization is different across the years (especially the categorization of fruits and vegetables) and hence we are unable to merge these and have one single index for comparability. We do not have diet quality data for children over 24 months of age. This along with an inability to transform the dietary data into a single variable restricted the utilization of diet quality as a variable in any of the regressions. Lastly, the sampling strategy for the frontier governorates is different across the survey years, which again limited its use in the regression analyses.

Conclusions

There are clear trends in stunting and overweight and being overweight in a stunted child. Furthermore, while there are clear risk factors/predictors associated with each form of anthropometric indicator, some of the predictors affect stunting and overweight in the same direction while others in opposite directions. This highlights the complex interactions between the markers and the predictors.

The key findings of these analyses are as follows:

1. There has been a reduction in stunting across survey years and an increase in overweight prevalence. However there has been a spike in stunting prevalence in the late 2000s. Aitsi-Selmi A. (2015), Kavle et al. (2014) and El-Kofali and Krafft (2015)(6-8) all concur that stunting rose in Egypt in the late 2000s (9).
2. There is an increase in overweight with survey years, which includes overweight prevalence in stunted children.
3. There is a decrease in wasting by survey year and the WHZ score is more positive with each survey year until 2014 when we see that the Z-score distribution reflects both overweight and wasting in the population.
4. Wealth does not modulate the burden of being stunted, overweight or being a stunted child that is overweight. Tzioumis and Adair (2014) conclude that wealth may explain variability across countries in the relationships between stunting and overweight, since per capita income is generally inversely associated with stunting and positively associated with obesity (10). Yet, for Egypt this pattern does not hold true – stunting is found more or less equally across all wealth quintiles, but in contrast there is a wider distribution of adult obesity by wealth. However this does not hold true for the rates of overweight in children under five years of age. Our findings imply that the burden of being stunted or being overweight or being overweight as a stunted child is not modulated by wealth.
5. While gender of the child seemed to matter in stunting with boys at a higher risk of stunting, there was no difference in risk of being overweight. In contrast boys who were

stunted were less likely to be overweight. Age of the child was related only to overweight in children with decreasing overweight with increasing age.

6. All regions had a higher prevalence of stunting and overweight compared to the Urban Governorate. In case of overweight in stunted children only Lower Egypt Rural and Urban had significantly higher risk compared to Urban Governorate. While being a rural child was protective towards stunting, it did not seem to matter for the other two markers.
7. While birth size is protective of stunting, large and very large birth sizes are linked to higher rates of overweight in all children as well as children who are stunted.
8. While maternal BMI was protective of being stunted but increased risk of being overweight (in all children) and being overweight as a stunted child.

The analysis shows the geographic and time associated changes in stunting and overweight in Egyptian children under five. While stunting has gone down, overweight has increased in the population and more concerning is that there is increasing prevalence across all regions, urban versus rural that these two co-exist in the same child. It also finds that wealth is not a factor associated with either stunting or overweight. Key factors such as birth size and maternal BMI that have traditionally been used in policy initiatives as markers of reducing stunting on the other hand could increase overweight. Thus any recommendations for increasing birth size and maternal BMI needs to consider the upper bounds of these two markers. A clear finding is that wealth does not modulate stunting, overweight or overweight in stunted children. Factors at the individual (child and maternal) and household are more important when considering policy initiatives around addressing these anthropometric deficits or excesses. In conclusion, the relationship of anthropometric indicators and their prevalence in Egypt is complex and prospective studies are needed to understand how the factors particularly those that contradict each other within the context of stunting and overweight.

II. Introduction

According to the Global Nutrition Report of 2014, the coexistence of many forms of malnutrition is the "new normal" worldwide (1). While no country is totally free of malnutrition, most developing and emerging economies have to contend with multiple manifestations that pose complex policy challenges to national governments. Egypt has had the biggest rise in overweight and obesity since 1980, and is one of 10 countries that account for more than half of the world's obesity problem (in terms of absolute numbers affected) (2). While overweight/obesity tend to cut across Egypt's regions and, to some extent, its wealth categories, the country stands out as having one of the highest gender disparities in obesity (1). Egypt ranks 8th in the world in terms of adult male obesity and 3rd in the world in adult female obesity (3). Rates of child overweight and obesity are consistently increasing and while progress has been made in the reduction of stunting during the late 1990s through 2008, as of 2014, Egypt's rate of 21% is still higher than for other countries in the region that have the same levels of GDP (4). In this report we present findings of analyses conducted using DHS (Demographic and Health Survey) data for Egypt from the years 1988 to 2014 particularly on the incidence of concurrent stunting and obesity among children under five years of age in Egypt and its related factors across the survey years.

III. Co-occurrence and Concurrent Stunting and Overweight/Obesity

The existence of stunting and overweight/obesity in the same child has been documented globally in Guatemala, Mexico, Russia, China and Brazil (12). There is emerging literature around the long-term effects of fat accumulation/increased overweight/obesity in children who are stunted. Children in developing countries may also be particularly at risk to lifestyle changes due either to undernutrition during fetal and early life and/or cycles of undernutrition throughout the life cycle (13). Under conditions of inadequate nutrient supply during prenatal life, modifications in insulin sensitivity, energy metabolism and vulnerability to weight gain may be programmed (14). Studies in Latin America have shown that childhood nutritional stunting is associated with impaired fat oxidation, a factor that predicts obesity in at-risk populations (15). Furthermore, studies done in Brazil on stunted and non-stunted children have shown higher fat mass accumulation in stunted boys and less lean mass (3 year follow up) compared to their baseline. Similarly, stunted girls also gained less lean mass and had significantly higher values of fat mass when compared to their baseline(16). This is a significant public health issue since co-existence of the double burden within the same child is related to significant risk of metabolic syndrome and later risk of chronic diseases such as diabetes mellitus and cardio-vascular diseases (12). A recent analysis shows that stunting in the first year of life is associated with an impaired lipid profile at 3-4 years of age (17).

The issue of stunting is compounded by the co-existence of overweight/obesity in many countries of the Middle East and North Africa. These emerging economies face a dual burden wherein there is co-existence of under and over nutrition, either in the same population, community, household or same individual. The dual burden of disease can be extremely variable in its manifestation. It can, for example, be manifested as stunted children who are concurrently obese, or as stunted children who may not be *currently* obese but who are at risk of early onset chronic diseases – such as diabetes, hypertension, renal dysfunction and cardiovascular disease - due to epigenetic programming.

An analysis conducted on Syrian children (prior to civil unrest) has shown high rates of stunting in rural children in Aleppo province whilst urban children had significantly higher rates of overweight and obesity (18). In Libya similarly rates of stunting are high in rural areas with overweight/obesity being recorded in urban areas (19). In Egypt specifically, rates of stunting increased significantly between 2005 and 2008 (23% rising to 29%), especially in Lower Egypt (17% rising to 34%) (15, 16, 20). Rates of overweight and obesity in children are also rising. The political events of 2011 included the return of many now unemployed Egyptians from neighboring countries, which led to food shocks and a likely further deterioration in nutritional status for many people (16).

IV. Study aim and objectives

The aim of this study was to examine and understand the trends and variability of malnutrition in all its forms (defined as both over and under nutrition) in Egyptian children under five, across time, regions and socio-economic status. The study objectives were to:

- Understand the relationsip of stunting and overweight in Egyptian children and the changes in this relationship over time
- Understand the relationship of stunting or overweight or both in children and maternal nutritional status
- Understand the trend in stunting and overweight in Egyptian children across different survey years and
- Examine the effect of change in stunting and overweight by wealth index, geographical location
- Understand the relationship of different risk factors associated with being stunted, overweight or being a stunted child that is overweight

V. Research questions

- What are the trends in stunting, overweight and wasting in Egyptian children across different eyars?
- What is the change over time in stunting and overweight in the Egyptian population by wealth index and geographical location?
- What is the relationship of stunting and overweight in Egyptian children across different years (within the same child)?
- What is the relationship between stunting/overweight and maternal nutritional status?

VI. Methods

The study utilized existing data sets that were obtained from the DHS website. Datasets were downloaded for all survey years starting from 19988 to 2014. A total of 7 data sets were downloaded for women and children each. Data were cleaned and analyzed in SAS (Statistical Analysis Software). In addition, associated files that contain information of the household were also downloaded. The latter are used for the generation of wealth index variables. Variables of interest from each data set were extracted from the main files and the different survey years concatenated to form one large working data set. During the extraction, we used the data dictionary to ascertain that the variables had the same definition. For variables that had different variable names but the same definition, we renamed them accordingly so all variables were uniform across all the data sets. Data cleaning included renaming and formatting variables, generating new variables and excluding outliers.

Variable generation

Anthropometry indicators

Anthropometric indicators for all children under five were re-calculated for all survey years using the WHO 2006 growth standard (5). Z scores for height-for-age (HAZ), weight-for-height (WHZ), weight-for-age (WAZ) and BMI-for-age for all children under five were computed. Binary variables were generated to determine prevalence of stunting, wasting and underweight. The cutoffs used for estimating prevalence and generating the binary variables (E.g. stunted or not stunted) is presented in Table 1.

All children with HAZ scores less than -2 SD from the WHO median are classified as stunted, while all children with WAZ scores less than -2SD from the WHO median are underweight and those with WHZ scores less than -2SD from the WHO median are wasted. In contrast, children with BMI for age or WHZ scores that are greater than 2 SD from the WHO median are classified as overweight.

Children who had WHZ scores greater than 2 standard deviations and also HAZ less than 2 standard deviations from the median were categorized as both overweight and stunted.

Table 1: Defining anthropometry indicators in children under 5

	Height for Age Z score (HAZ)	Weight for Height Z score	Weight for age Z score	BMI-for-age Z score
Stunting	< -2 SD			
Overweight		>+ 2SD		>+2 SD
Wasting		< -2 SD		
Underweight			< -2 SD	
Stunted and Overweight	< -2 SD	> +2 SD		

Diet Quality (Infant and Young Child)

Diet quality data is available only for children aged 6-24 months of age across all survey years. There is significant variability in how the data are presented in the earlier versus later survey years. For instance for the years 2008 and 2014, DHS utilizes the 7 food group categorization (WHO Infant and Young Child Feeding Indicators). However for all the previous years, a five-group categorization is available. The seven food groups consist of grains, roots and tubers, legumes and nuts, dairy products, flesh foods, eggs, vitamin A rich foods and other fruits and vegetables. The 5 food groups include dairy products, grains, roots and tubers, one category for eggs, fish and poultry, meat and other fruits and vegetables. Furthermore, there were no dietary data collected prior to 1995. Data for 2005 and prior years was recoded from frequency of consumption to consumed or not (Y/N).

Maternal characteristics

Maternal nutritional status is represented by BMI (Body Mass Index). Mothers are classified underweight if BMI <18.5 kg/m^2, normal weight if BMI is between 18.50 and 24.99 kg/m^2, overweight if BMI between 25.00 and 29.99 kg/m^2 and obese if BMI was greater than 30 kg/m^2. In order to examine changes in BMI over time, we plotted graphs and tabulated BMI categories in the different regions, by socio-economic status and DHS survey years.

Wealth Index

Wealth index was calculated using data on a household's ownership of selected assets such as television sets, bicycles, materials used for housing construction and types of water access and sanitation facilities.

For the survey years 2000 and 1995, we merged DHS associate files for wealth index. There is no wealth index variable for the surveys before 1995.

Outliers

All the anthropometric Z-scores had extreme values. We employed two outlier-labeling methods; the Tukey's method and the Standard deviation method. According to World Health Organization (WHO), the expected ranges for standard deviations of HAZ are 1.10 to 1.30, for WAZ are 1.00 to 1.20 and for WHZ are 0.85 to 1.10. The results obtained using the above two methods were not comparable to already published results. The WHO recommends cut-off points of -6 and +6 (HAZ), -6 and +5 (WAZ), -5 and +5 (WHZ) and -5 and +5 (BMI-for-age) z scores which was used in establishing outliers (5).

Handling missing values

Several variables had missing values. These include the anthropometric data Missing values in the dependent variables were particularly important because they affect the denominator in the calculation of prevalence estimates. The table below shows actual number of observations used in all calculations versus the total number of observations available for all other variables across all the survey years. For variables such as wealth index and birth size, we do not have these data for the survey years 1988 and 1992. We did not apply any imputation methods on variables with missing values and we performed complete case analysis in the regression models.

Table 2: Total and actual number of observations used in analysis

	Actual number of observations used				Total Observations
	Stunting	Overweight	Wasting	Both stunted and overweight	All indicators
1988	1997	2006	2006	1985	8419
1992	7116	6993	6993	6939	8273
1995	6925	6854	6854	6784	7879
2000	7428	7360	7360	7305	8011
2005	12784	12726	12726	12490	13851
2008	10025	9840	9840	9623	10872
2014	14589	14188	14188	13847	15848

Statistical Analysis

Statistical analysis includes estimating descriptive statistics of the key dependent variables including stunting, overweight and wasting in children under five as well as the corresponding continuous variables HAZ, WAZ and WHZ. Descriptive statistics were also generated for key independent variables including maternal characteristics, wealth index, infant and young child feeding practices. To further uncover underlying relationships, we calculated the prevalence of overweight children in children who are stunted and severely stunted children over time. All descriptive estimates for the children were adjusted for clustering but not weighted.

To describe the relationship between mother's nutritional status and children's nutrition outcomes, we tested the null hypothesis that there is no correlation between mothers' BMI and child HAZ and WHZ scores for all the survey years. We further looked at the association between HAZ and WHZ in children under 5 with an aim to further understand the relationship between stunting and overweight in children under 5. In order to identify variables that were significantly associated with the malnutrition outcomes over the years, we ran logistic bivariate analysis.

Model Selection and Assessment of Fit

The key outcomes of interest (dependent variables) are prevalence of stunting, overweight and concurrent stunting and overweight. These are all expressed as binary variables. Due to the complex nature of the study design and sampling strategy, the observations were not independent of each other. Furthermore, households within sampled clusters are more likely to be similar. Thus any analytical method employed would need to adjust for intra-cluster correlation or variation. To account for all of the above, the regression model selected for this analysis is a log-binomial model (PROC GENMOD) using the "descending" option and a "repeated" statement. The former would allow for modeling the probability of stunting being 1 while the latter adjusts for complex variation structures in the data. All models run were assessed for fit using QIC and QICu estimates that are generated by the GEE procedure within PROC GENMOD. The closer these two values are to each other, the better the fit and models with smaller QIC values are said to better fit the data. Given the arbitrary nature of how close the QIC and QICu values should be in order to determine a good fit, we used alternative model fit measures.

A ratio of the generalized chi square estimate and degrees of freedom is used to assess model fit by this method. Values close to 1 are ideal. Large ratio values may indicate model misspecification or an over-dispersed response variable; ratios less than one may also indicate model misspecification or an under-dispersed response variable (that is the data values are less variable than expected under the chosen distribution). A consequence of such dispersion issues is that standard errors are incorrectly estimated. Importantly, however, assuming our model is correctly specified, the Poisson regression estimates remain unbiased in the presence of over-dispersion or under-dispersion. (http://www.ats.ucla.edu/stat/sas/output/sas_poisson_output.htm)

VII. Results

Trends in Stunting and Overweight: Pooled

In this section, we present descriptive statistics that allow us to understand the trends in stunting, wasting and overweight over time. All data were re analyzed and standardized using the WHO 2006 growth standards. **Table 3** presents the trends in anthropometric indicators from 1988 through 2014. Data are presented as prevalence defined as the percent of children who are below the WHO established cutoffs (5). Stunting is defined as Height-for-age Z scores < -2 standard deviations below the median, overweight was defined as Weight-for-height Z scores > 2 standard deviations above the median, underweight was defined as Weight-for-age Z scores < -2 standard deviations from the median and wasting was defined as Weight-for-height Z scores < -2 standard deviations from the median.

Rates of stunting have steadily decreased from 36% in 1988 to 20% in 2014 while severe stunting has reduced from 16.5% to 9.6% while overweight went from almost 7 % in 1988 to 13% in 2014. Wasting rates have increased from 2.3% to 11%. It should be noted that the estimates presented in Table 1 deviate from the DHS estimates (extracted from DHS reports) and other estimates. A comparison of the deviation is presented in Table A-1 (Appendix 1), the biggest deviation being for wasting in 2014- estimated at 8.4 % in the DHS report (reference) while our estimate is about 11%. This is not unexpected as a deviation of +/- 5 percentage points is normal when different data cleaning methods are used. Epidemiologically what is observed (Figure 1) is that while prevalence of stunting in children under five years of age has been going down steadily, the prevalence of overweight is going up.

Table 3: Trends in Anthropometric Indicators from 1988- 2014

	Prevalence of stunting (n)	Prevalence of **severe stunting	Prevalence of overweight (n)	Prevalence of wasting (n)	N
1988	35.80(715)	16.47(329)	6.58 (132)	2.34(47)	8419
1992	28.46(2025)	11.75(836)	13.50 (944)	3.53(247)	8273
1995	33.43(2321)	15.77(1092)	12.45 (853)	6.45(442)	7879#
2000	23.09(1715)	9.34(694)	17.98 (1323)	2.95(217)	8011#
2005	27.10(3465)	12.78(1634)	16.09 (2048)	5.34(679)	13851
2008	30.05(3013)	15.31(1535)	19.56(1925)	7.71(759)	10872
2014	20.19(2945)	9.61(1402)	13.26(1881)	11.67(1656)	15848

n= number of children in the column categories
Total number of children includes missing values
**Severe stunting = HAZ score < -3 SD

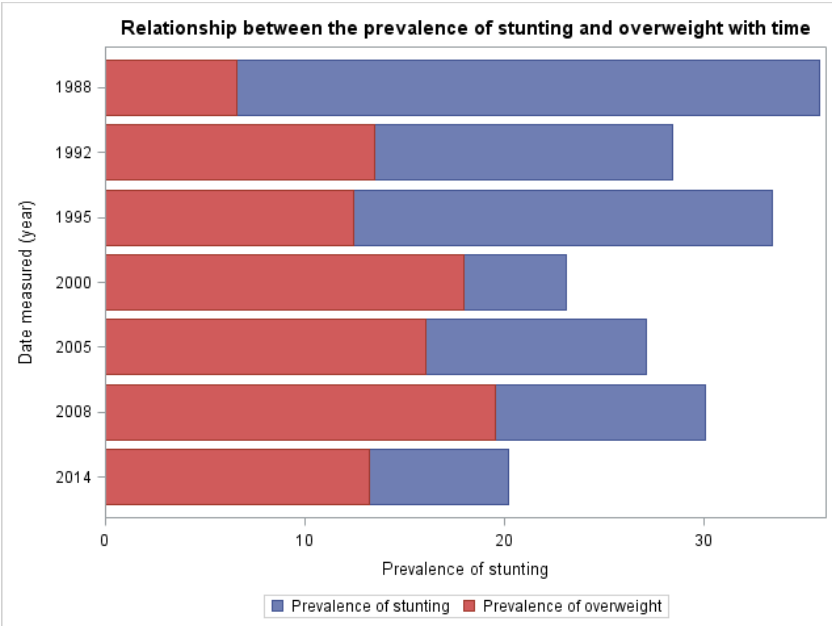

Figure 1: Prevalence of stunting and overweight

We then estimated indicators for both stunted and overweight in the whole population and those that are overweight in the stunted population only. The indicator "prevalence of overweight or prevalence of stunting" is estimated by dividing the total number of children who are classified as stunted (HAZ < -2SD) and overweight (WHZ > 2SD) by the total number of children under five years of age in the survey. In contrast, the indicator "prevalence of overweight children that are stunted" is estimated by dividing the total number of children who are classified as stunted (HAZ <-2SD) and overweight (WHZ > 2SD) by the total number of ***stunted*** children under five years of age in the survey. For all future analyses, we use the prevalence of stunting, overweight and prevalence of overweight in children who are stunted.

As can be noted the prevalence of both stunting and overweight has doubled from 3.2% in 1997 to 6.7% in 2014 (Table 4). Similar to the stunting and overweight only prevalence rates, we find that the years of 2005 and 2008 demonstrate a higher prevalence rate with a drop in 2014 (Table 4). With respect to the indicator "percent of stunted children who are overweight" we find an alarming trend. While in 1988, 9% of all stunted children were overweight; in 2014 an estimated 1/3rd of the stunted children (34%) were overweight (Table 4). This significant increase is clearly observed in Figure 2. The sharp rise seems to occur between the period of 1995 and 2000 (going from about 20% to 30%). Interestingly similar to the stunting rates the percentage of stunted children that are overweight is lower in the 2014 survey compared to the 2008 survey.

This is even more apparent in the severely stunted children – in 1988 13% of all severely stunted children were overweight while in 2014 that number is almost at 50% of all severely stunted children.

Trends in Stunting and Overweight: By Geographic Region

We further disaggregated the data and examined the trends in stunting and overweight by geographic region (governorates) and survey year (Figure 3). Figure 3 represents the shift in anthropometric outcomes that is observed in Figure 1 by region. In 1988, the rates of stunting ranged from 23 to 46% (no data on Frontier governorates) while overweight ranged from 3.5 to 9%. In 1992, rates of stunting ranged from 17 to 33% with rates of overweight ranging from 10-17%. In 1995, stunting rates were higher than in 1992 ranging from 20 to 42% while overweight ranged from 6.3 to 13.3% while in 2000 rates of stunting ranged from 11- 34% with overweight ranging from 10 to 23%. In 2005, rates of stunting ranged from 20 to 34% while overweight ranged from 13 to 17% and in 2008 stunting ranged from 23 to 40% while overweight was as high as 32% and as low as 12.5%. Finally in 2014, the rates are similar to 2005 with stunting ranging from 14-27% while overweight ranging from 10-14%. Irrespective of these shifts in percentages, it seems to appear that while stunting has stagnated in the population, overweight seems to have increased from 3.5% in 1998 to upto 14% in 2014 (Figure 3).

Table 4: Prevalence of co-existing malnutrition burdens

	Prevalence of stunted and overweight **(number)	Prevalence of overweight in stunted children*(number)	Prevalence of overweight in severely stunted children *** (number)
1988	3.27(65)	9.14(65)	13.85(45)
1992	4.18(290)	14.86(290)	20.03(159)
1995	6.34(430)	19.09(430)	26.12(273)
2000	6.91(505)	30.94(505)	44.11(277)
2005	9.07(1133)	34.24(1133)	51.80(778)
2008	10.88(1047)	37.63(1047)	49.89(670)
2014	6.74(933)	33.82(933)	48.81(613)

* = the denominator used is the number of stunted children, ** = the denominator used is the total number of children
***= the denominator used is the number of severely stunted children, Total number of children includes missing values
#only children with the wealth index variable were included

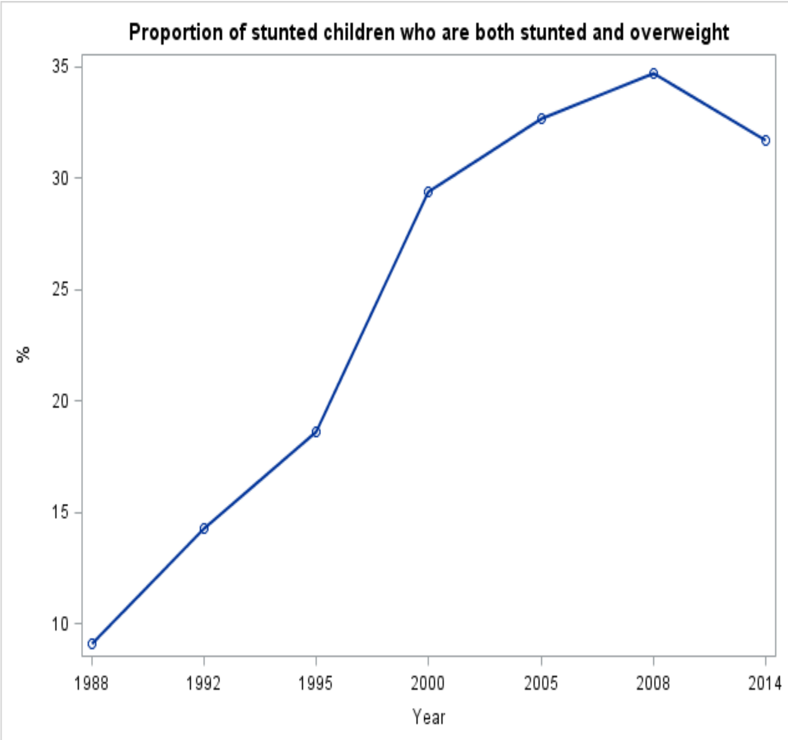

Figure 2: Prevalence of overweight in children that are stunted

From a region/governorate perspective over the years different trends are observed. With respect to stunting in children, urban areas had the lowest rate in 2000 (at 11%) and the highest in 2008 at 23% with the 2014 figures being around 18%. Lower Egypt urban areas had rates of about 21-23% from 1988 to 1995 with a drop to 18% in 2000 and an increase to 40% in 2008. Current rates are at 17%. A similar pattern is observed in Lower Egypt rural areas. Compared to all the other governorates, in 2014, Upper Egypt urban areas had the highest rates of stunting in 2014 (27%). While rates have steadily decreased from 46% in 1988 to 27% in 2014, this is still the highest rate of stunting across all governorates (Figure 3).

In Lower Egypt (urban and rural), low rates of overweight were observed in 1988 (around 8%) while the highest rates were in 2008 ranging from 25-31%. The current rates are 13.5% in the urban areas and 15% in the rural areas. Upper Egypt urban areas had the lowest rates of overweight in 1988 (3.5%) while in 2014, it has the highest rates of overweight at 15%. Upper Egypt (rural) had no data in 1988 and had the lowest rate in 2014 at 12%. The Frontier governorates had low rates in 1988 at 6.3% with very high rates in 2000 and 2008 and the finally a rate of 10% in 2014. It should be noted that amongst all the governorates, the Frontier governorates had a different sampling strategy then the prior years, which makes comparison difficult (Figure 3).

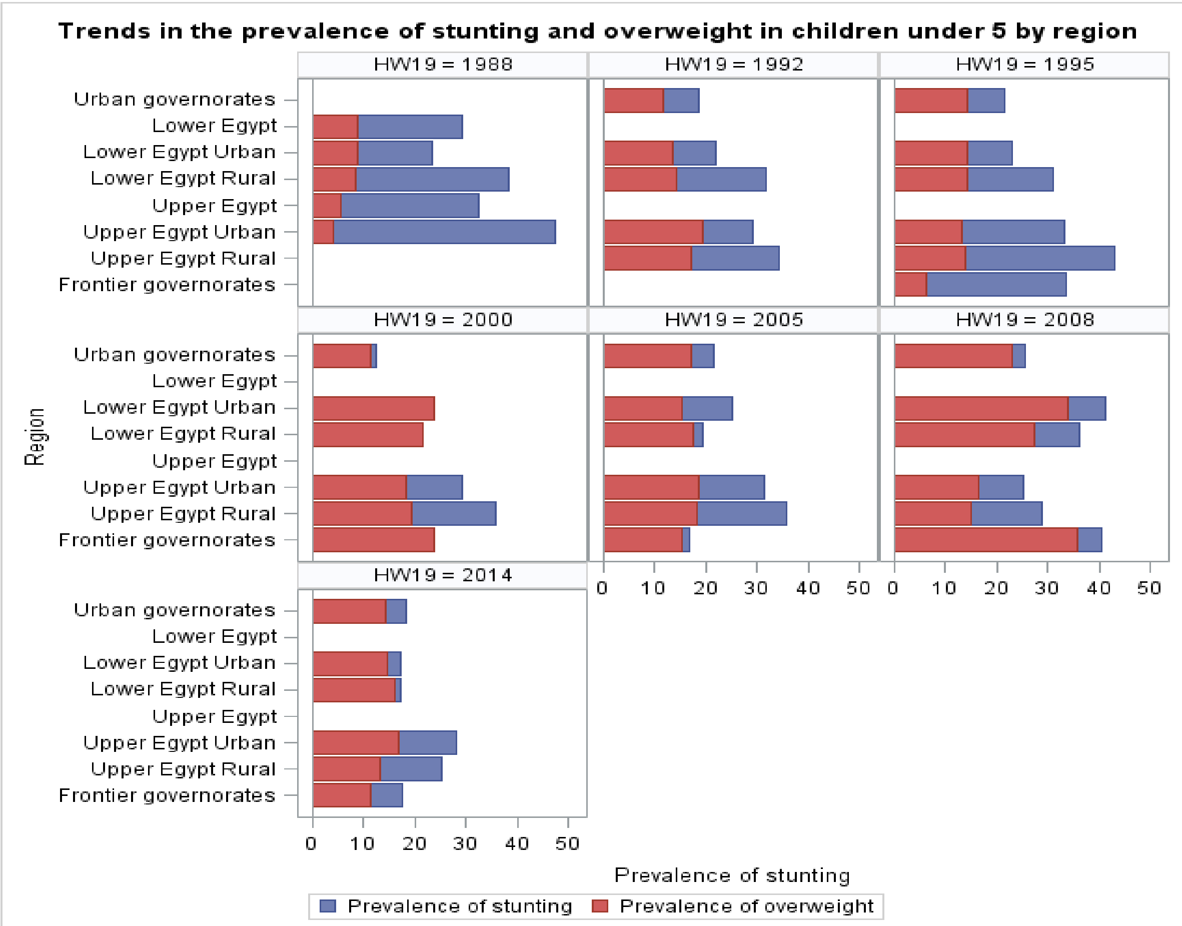

Figure 3: Prevalence of stunting and overweight by governorate and survey year

Figure 4 presents the proportion of stunted children who are overweight by governorate. Similar to the observation in Table 3, as the years increase, the percentage/proportion of stunted children who are likely to be overweight has increased. For the year's 1988- 1995, the data seem to show a low rate of overweight in stunted children. Furthermore, except in the case of the frontier governorates, all the regions have had a steady increase in the proportion of stunted children that are overweight. In the case of the frontier governorates, the rates are much lower in the 2014 data. Again given the difference in sampling strategies, the comparison of these data is difficult.

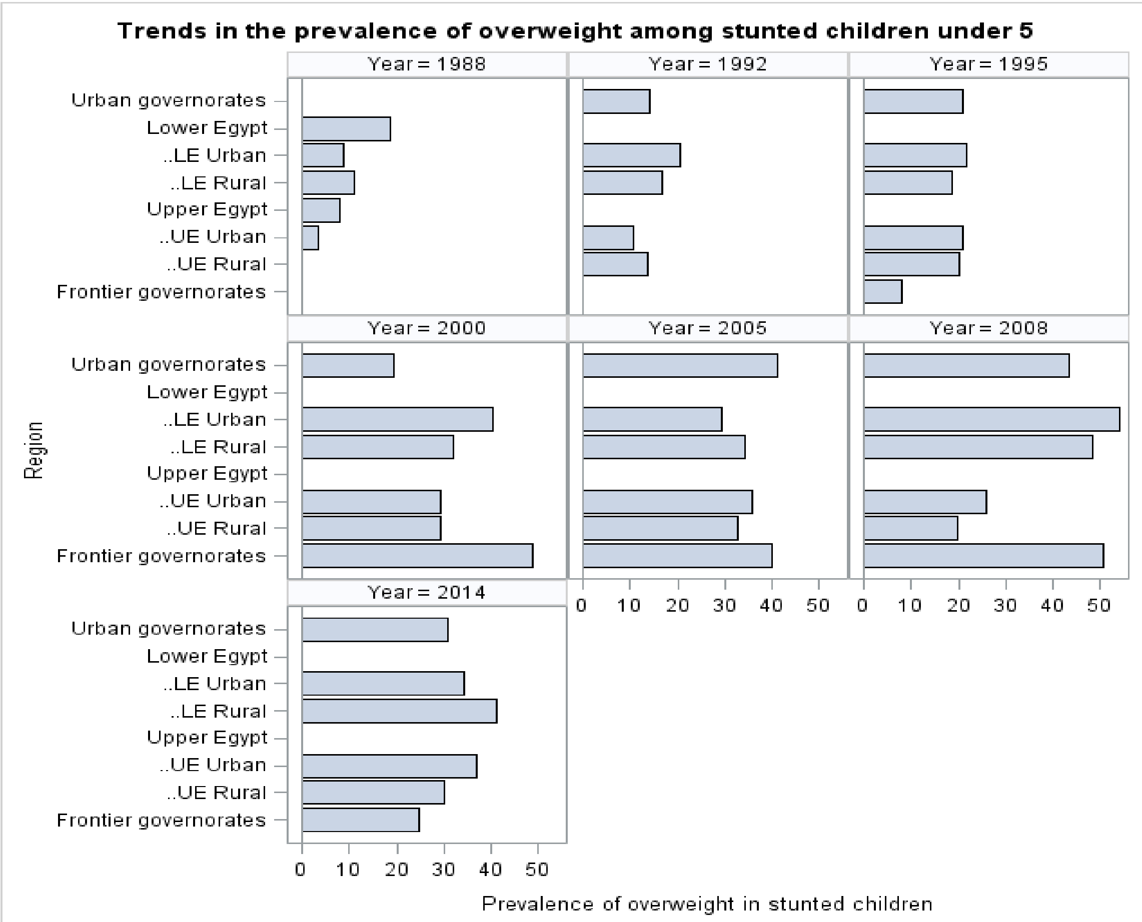

Figure 4: Prevalence of overweight in stunted children by survey year

Specifically for the year 2014, we find interesting results. Across all the regions/governorates, the percentages of stunted children that are overweight range from 24 to 40%. The lowest being the Frontier Governorates and the highest being the Lower Egypt Rural governorates (Table 5). This implies a trend that seems to have some geographic variation (in terms of magnitude of the problem) but that the challenge exists across all regions/governorates. One can also see from Table 5 that the prevalence of stunting and overweight (separately) are almost similar across the regions/governorates.

Table 5: Prevalence of stunting, overweight and overweight in stunted children in DHS 2014

	Prevalence		
Region	**Stunted (Percent)**	**Overweight (Percent)**	**Overweight in Stunted Children (Percent)**
Urban Governorates	18.2	14.4	30.8
Lower Egypt Urban	17.3	14.6	34.2
Lower Egypt Rural	17.2	16.1	40.9
Upper Egypt Urban	28.0	16.7	37.0
Upper Egypt Rural	25.1	13.2	30.2
Frontier Governorates	17.6	11.5	24.8
Total %	21.0	14.6	**33.8**
N	**15213**	**14868**	**2759**

The trends in stunting, overweight and overweight in stunted children under five years of age disaggregated within the governorates is presented in Appendix Table 2.

Trends in Stunting and Overweight: By Wealth Index

Figures 5, 6, and 7 present the data on stunting, overweight and overweight in stunted children by wealth index. In the case of stunting, what we clearly observe is that while the rates of stunting were lower as wealth index increases in the years 1995, 2000, and 2005, starting in 2008, the rates are flattened with really no difference in stunting rates by wealth index/socio-economic status. It seems that the while the rate of stunting has been improving in the lower categories over the survey years, the rates in the higher categories have either stagnated or even increased. There is very little explanation for why this is really happening.

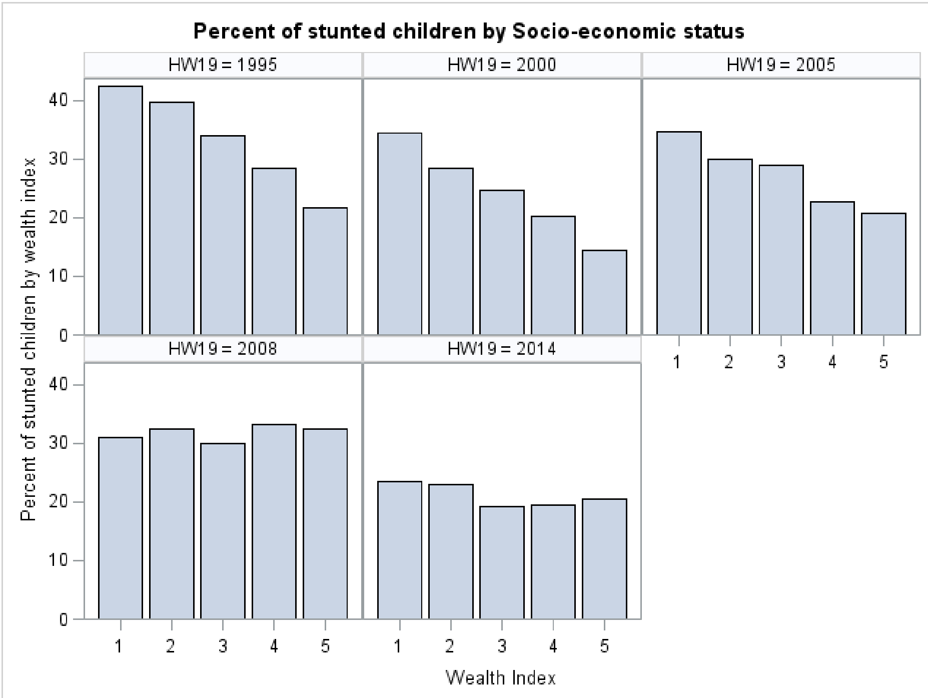

Figure 5: Prevalence of stunting by Wealth Index

With respect to the prevalence of overweight however across all the survey years, one sees a flattened line with all categories exhibiting the same or similar rates of overweight across the survey years except in 2008 when overweight seemed to increase with wealth index (Figure 6). As of 2014 however we find that the rates of overweight across all wealth index categories are similar. This is quite unlike the pattern that is observed with respect to stunting (Figure 5). Similar to Figure 6, we find that the overweight in children that are stunted is a flat line across survey years (except in the case of 2008).

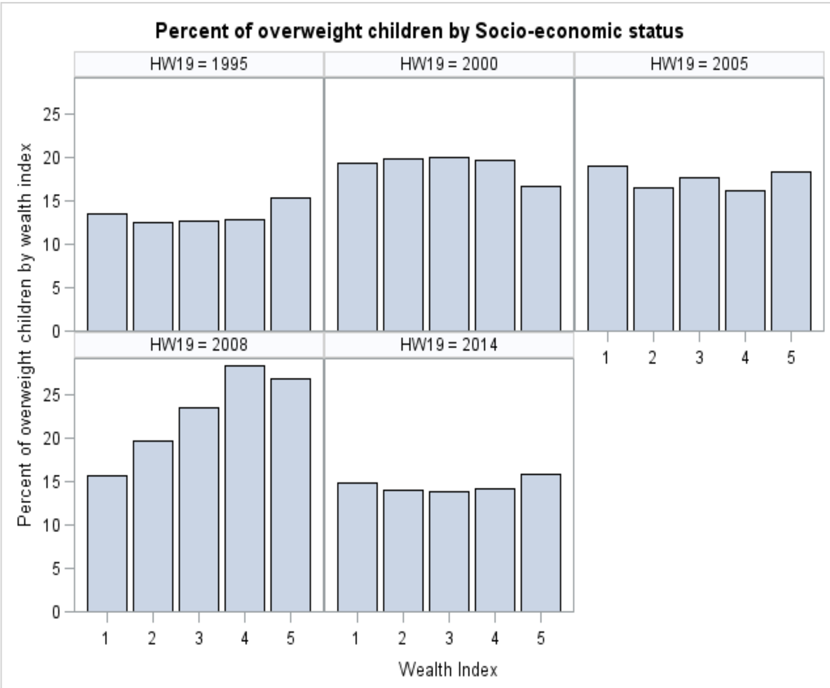

Figure 6: Prevalence of overweight by Wealth index

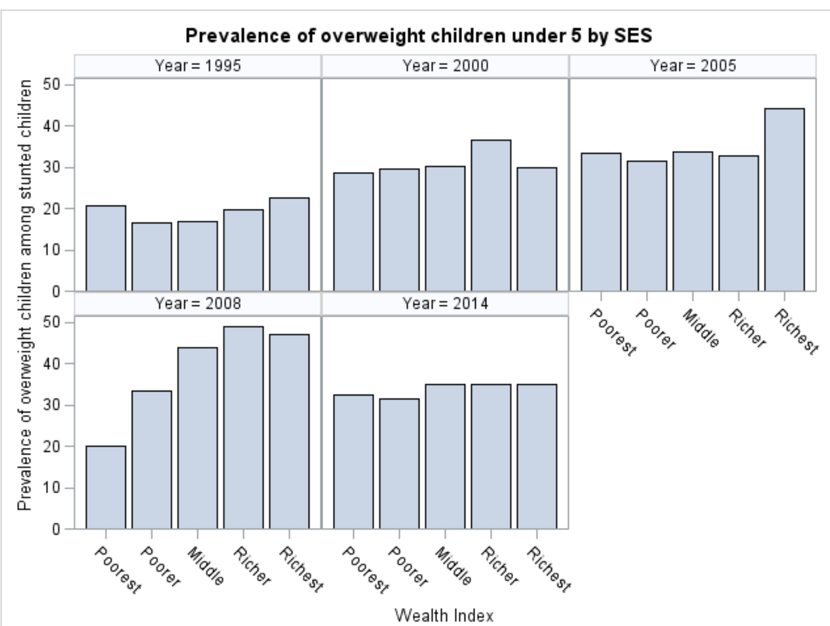

Figure 7: Prevalence of overweight in stunted children by wealth index

Trends in HAZ, WAZ and WHZ distributions by survey year and age group

Following the examination of the data for geographic variation, we looked at the trends in distributions by survey year and age group. The findings of this analysis are presented in Figures 8, 9, and 10. Figure 8 presents the mean HAZ distribution by survey year across age groups. Across all the survey years one can see that most of the children in the younger age groups begin at a higher Z-score and rapidly drop down by five years of age. There is a consistent improvement in the mean HAZ but particularly important is to note the difference in the distribution in 2014 (purple lines) compared to the rest of the survey years.

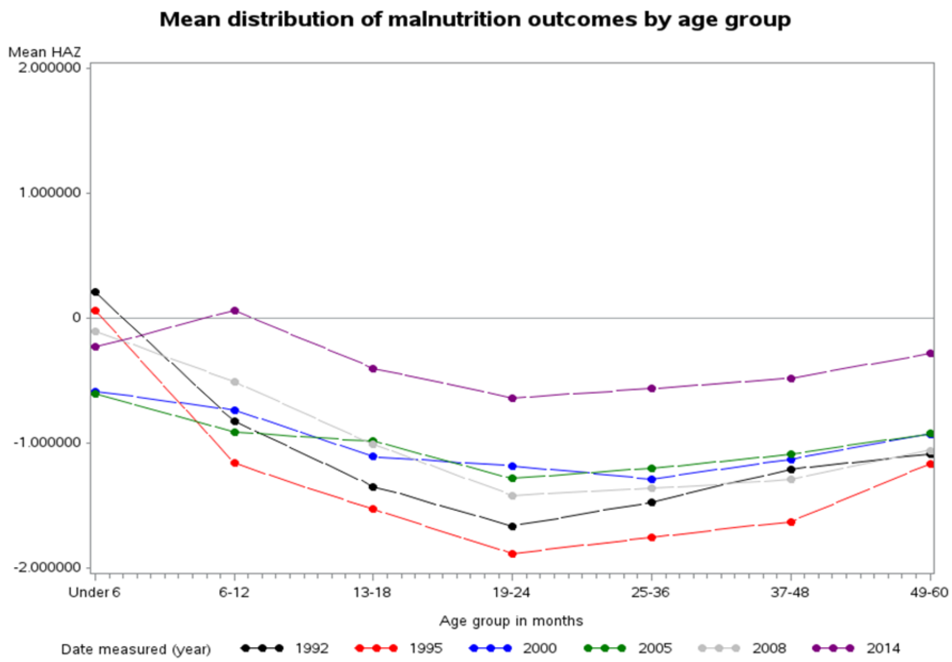

Figure 8: Mean HAZ distribution by survey year and age group

In contrast, mean WHZ distribution has always been over 0, which implies higher weight for height with the mean score being the highest for the year 2000 and lowest for 2014. This indicates that in 2000 there were probably fewer children who had a lower WHZ score compared to 2014. This is illustrated by the percentage of children wasted being around 3% in 2000 versus almost 12% in 2014 (Table 3). Mean WAZ distribution follows a pattern similar to HAZ (Figure 10).

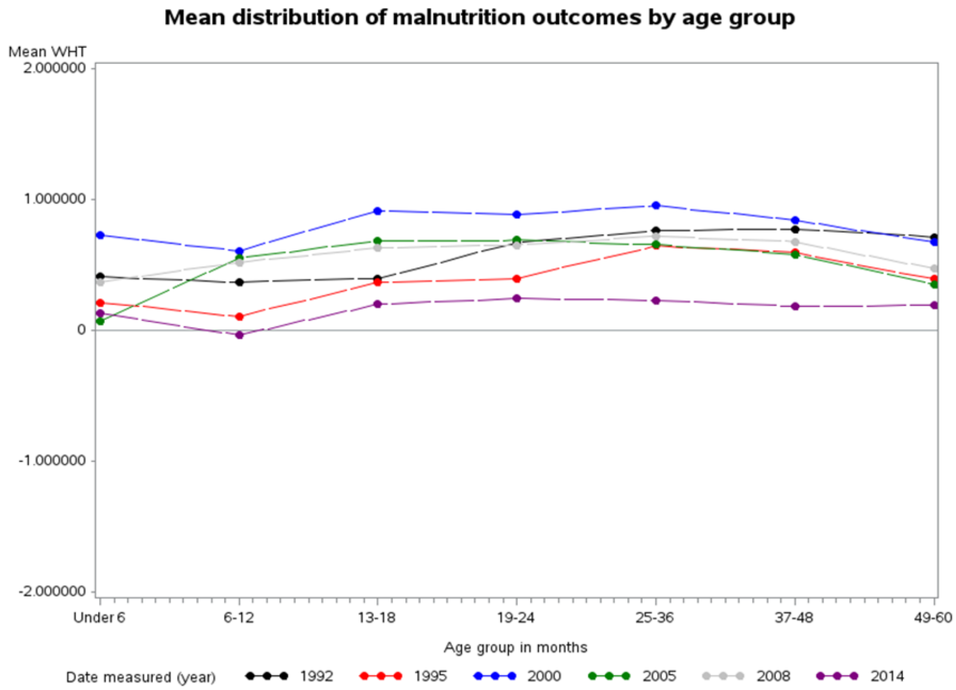

Figure 9: Mean WHZ distribution by survey year and age group

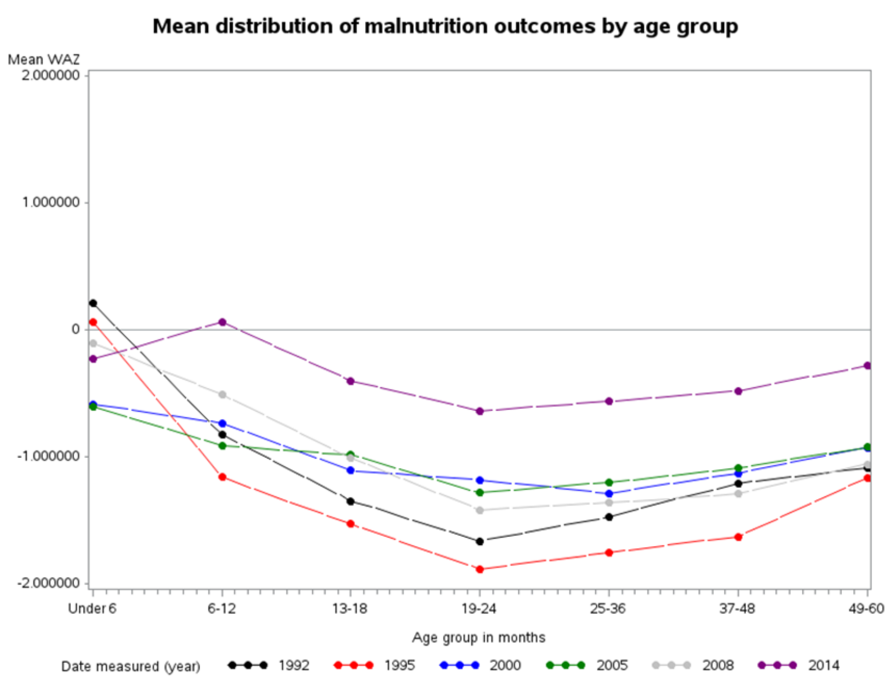

Figure 10: Mean WAZ distribution by survey year and age group

Trends in Overweight by age group

We then examined the trends in prevalence of overweight in normal and stunted children by age group (Figures 11 and 12.). The age group categories are less than 6 months of age, 6-24 months of age and children 6-59 months of age. We find prevalence of overweight in infants under 6 months of age increased gradually over the years with a sudden spike in the year 2000 (at 25%). In the case of infants and young children aged 6-24 months, we find a similar pattern of an increase though this is until 2008 with a drop in 2014. When examining the children 6-59 months of age we find a similar pattern. However as of 2014, infants under 6 months have a higher prevalence of overweight than other age groups. On the other hand, prevalence of overweight in stunted children increased quickly between survey years 1988 and 1992 in the under 6 month age group from just under 10% to over 20% and has steadily increased through the years with the current rates around 40% of infants under the 6 months of age that are stunted also being simultaneously overweight. In the case of 6-24 month of infants and young children, there is more of a gradual increase with about 30% of infants and young children that are stunted being classified as overweight.

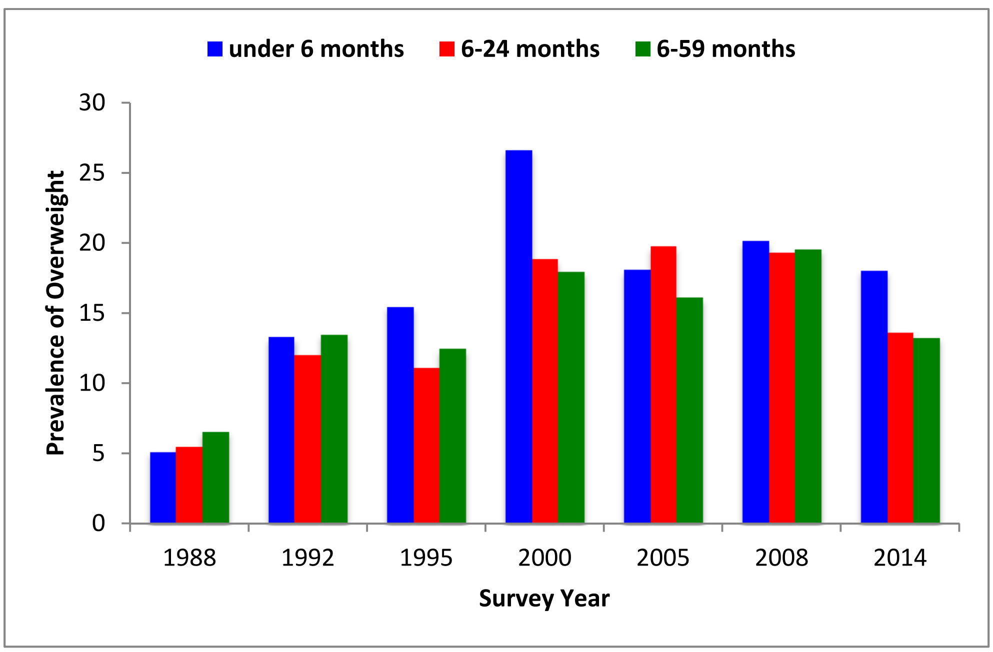

Figure 11: Prevalence of overweight by age group and survey year

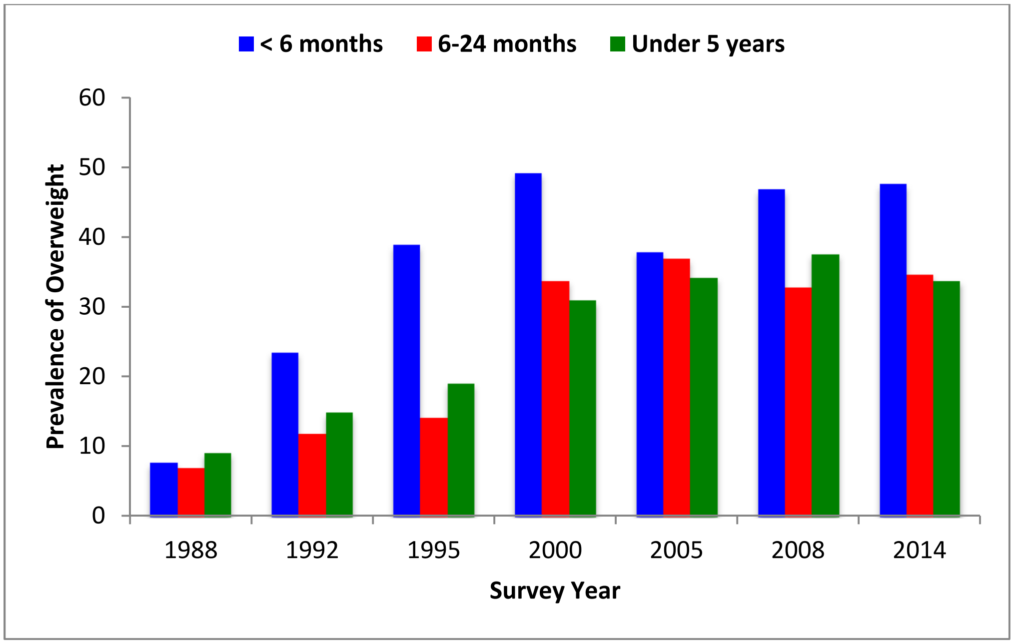

Figure 12: Prevalence of overweight in stunted children under five years of age

Diet Quality by Survey Year

We also reviewed the data on diet quality in the different survey years. These data are available only for the age group 6-24 months and have been collected differently for the survey years 2008 and 2014 compared to 1995 and 2000. There are no dietary data available in any of the other survey years. Furthermore, the classification across these years was quite different that it did not allow us to create a separate diet quality index. In Table 6, we compare food group data availability by survey year. For instance, all years have a classified food group of Grains, roots and tubers however only 2008 and 2014 have a food group legumes and nuts. Due to this variability in the type of data available, while most of the categories could be merged, the lack of data on Vitamin A fruits and vegetables in 1995 and 2000 prevents us from creating a new categorization. The data are thus being presented separately by survey years.

Table 6: Comparison of IYCF Food group data available by survey year

	Survey Year			
Food Groups	1995	2000	2008	2014
Grains Roots and Tubers	Y	Y	Y	Y
Legumes and Nuts	N	N	Y	Y
Dairy products	Y	Y	Y	Y
Meat, Fish, Poultry, Liver/organ meats	N	N	Y	Y
Eggs	N	N	Y	Y
Meat	Y	Y	N	N
Eggs, fish and poultry	Y	Y	N	N
Vitamin A rich fruits and vegetables	N	N	Y	Y
Other fruits and vegetables	Y	Y	Y	Y

Note: The table reflects the presence or absence of data by food group. For instance, all years have a classified food group of Grains, roots and tubers however only 2008 and 2014 have a food group legumes and nuts.

Figure 13 presents the data for the years 1995 and 2000 while Figure 14 presents the data for 2008 and 2014. Across all survey years, it is clear that grains, roots and tubers are consumed by a high percentage of infants and young children. In 1995 and 2000 data we find that consumption of dairy products, meat, eggs/fish/poultry and other fruits and vegetables has increased but only very slightly. Examining Figure 14, we see that consumption of legumes and nuts has decreased from 2008 to 2014 as has consumption of dairy, meats/fish/poultry/organ meats and eggs. Vitamin A rich fruits and vegetables were low in in 2008 and are further lower in 2014 (but slightly). Consumption of other fruits and vegetables has increased but very slightly from 2008 to 2014. Overall, the trend seems to be that most infants and young children are consumption grains/roots/tubers, about 50-60% are consuming some form of dairy with other animal source foods being consumed by less than 40% of the children. Particularly of interest is the very low consumption of Vitamin A rich fruits and vegetables, which is captured in the 2008 and 2014 surveys.

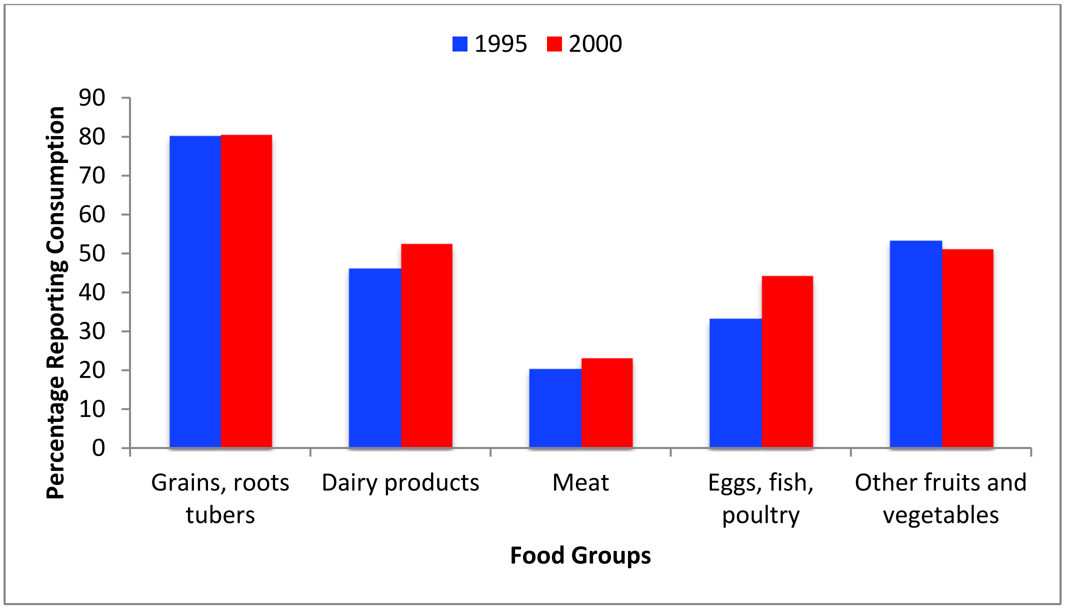

Figure 13: Food groups consumed by 6 -24 months old children (1995 and 2000)

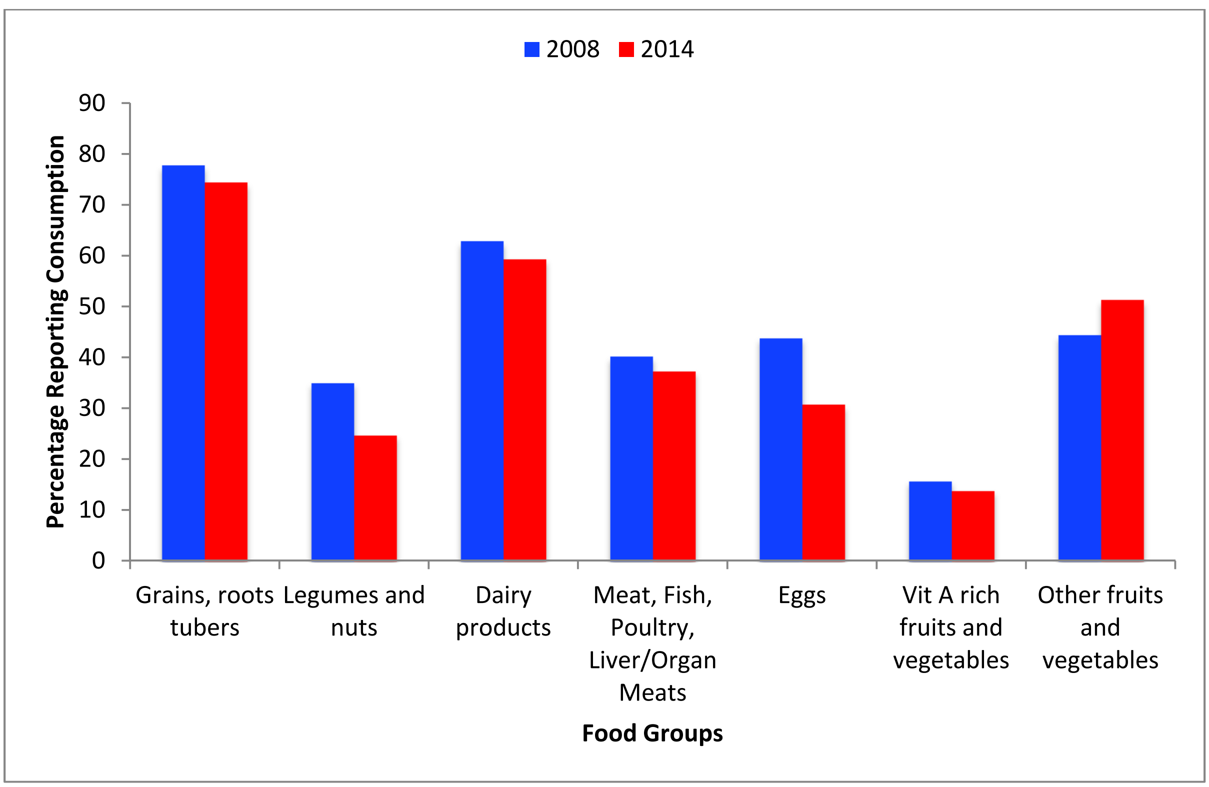

Figure 14: Food groups consumed by 6 -24 months old children (1995 and 2000)

Risk factors associated with Stunting, overweight and being overweight in stunted children under five years of age

We then examined the associations of different risk factors such as geographic location, location of residence (urban/rural), maternal BMI, maternal education, maternal occupation, age and gender of the child, birth order, birth size, diet quality, household size and number of children under five years of age and their bi-variate relationships with the risk of being stunted or the risk of being overweight in normal children and the risk of being overweight in stunted children. Descriptive statistics for the maternal characteristics are presented in Appendix Table 3 while the bi-variate associations are presented in Appendix Table 4. We also examined the relationship of HAZ and WHZ (presented in Appendix Figure 1) by survey year and find that as survey years increase, the relationship is more linear between the two anthropometric indicators, with a decrease in HAZ associated with an increase in WHZ.

Following the examination of bi-variate associations, multivariate analyses were conducted. As noted in the methods sections, the log-binomial approach was utilized to handle this analysis and all data are presented as prevalence risk ratios with standard errors and the corresponding probabilities. Table 7 presents the findings of the log binomial regression analyses conducted. The findings are organized by dependent variable, which are "risk of being stunted", "risk of being overweight" and "risk of being overweight as a stunted child".

Examining the risk of being stunted, we find that boys are more likely to be stunted than girls (Risk ratio of 1.11). Furthermore higher birth order increases the risk of being stunted but age of the child does not seem to be a significant risk factor. With respect to regions and locations, all regions have significantly higher risk of having stunted children compared to Urban governorates, the highest is in Upper Egypt rural where children are 1.6 times more likely to be stunted than children in the Urban governorates. However overall being in a rural area seems to impose a protective effect with a lower risk of being stunted (about 14%). Maternal education reduces the risk of being stunted compared to no education, however this is significant only in the secondary education category. Interestingly higher BMI in women is protective against stunting with obese women having the least likelihood of a stunted child (about 20%) compared to underweight women. Wealth index (not surprisingly) is not associated with the risk of being stunted though we do see an effect of the early survey years with the poorest and poorer categories trending to an increased risk compared to the middle income category.

Being ever breastfed seems to increase the risk of being stunted in children under five years of age as does being inconsistently breastfed, the latter being insignificant. Birth size is protective of stunting with very large, larger than average, average babies having a significantly reduced risk of being stunted than very small babies. Smaller than average babies also exhibited a lower risk, however this was not significant at the 0.05 level. Number of children increased the risk of being stunted while household size seemed to reduce the risk. There was a reduced risk of being stunted with every survey year, a reflection of the reduction in stunting prevalence across survey years (Table 7).

With respect to the risk of being overweight, age of the child and birth order were protective with slightly but significantly lower risk ratios. The regions of Lower Egypt Rural and Lower Egypt Urban and Upper Egypt Urban had significantly higher risk ratios than the Urban governorates while the Upper Egypt Rural and Frontier governorates had higher risk ratio, these only trended towards significance ($p<0.1$). There was no significant difference in risk between all rural and urban children and maternal education did not have a protective effect. Maternal occupation increased the risk slightly as did maternal age at first birth. The risk of being overweight child of mothers in all BMI categories was two times or higher compared to mothers who were underweight. This risk is significant at the $p<0.001$ across all BMI categories. Similar to stunting, wealth index did not seem to have an effect on the risk of being overweight (Table 7).

Table 7: Prevalence Risk Ratios of the risk of being stunted, being overweight or being a stunted child that this overweight (Pooled)

	STUNTING		OVERWEIGHT		OVERWEIGHT IN STUNTED	
	Prevalence Ratio	SE	Prevalence Ratio	SE	Prevalence Ratio	SE
Gender						
Male	1.11***	0.105	1.03	0.021	0.88***	0.027
Female	Reference					
Age of child	1.00	-0.001	0.99***	0.001	0.995***	0.001
Birth order	1.02**	0.020	0.99***	0.007	0.98	0.009
Regions						
Lower Egypt Rural	1.34***	0.296	1.48**	0.109	1.44**	0.150
Lower Egypt Urban	1.28***	0.250	1.33**	0.045	1.15**	0.059
Upper Egypt Rural	1.64***	0.496	1.22*	0.109	1.16	0.149
Upper Egypt Urban	1.44***	0.362	1.11**	0.046	1.00	0.058
Frontier[%]	1.19***	0.170	1.12*	0.066	1.10	0.086
Urban	Reference					
Location						
Rural	0.86***	-0.154	0.90	0.105	0.85	0.143
Urban	Reference					
Maternal Education						
Primary	0.99	-0.012	1.01	0.040	0.96	0.051
Secondary	0.90***	-0.110	1.01	0.033	1.11**	0.040
Tertiary	0.95	-0.049	0.96	0.049	1.08	0.060
No education	Reference					
Maternal Occupation	1.01	0.005	1.009**	0.003	1.01***	0.002
Maternal age at first birth	1.00	0.001	1.001**	0.003	1.00	0.004
Maternal BMI Category						
Normal	0.96	-0.041	2.05***	0.205	2.28***	0.257
Overweight	0.89	-0.115	2.26***	0.205	2.77***	0.257
Obese	0.77**	-0.266	2.36***	0.205	2.67***	0.258
Underweight	Reference					
Wealth Index						
Poorest	1.07*	0.068	1.06	0.039	0.99	0.047
Poorer	1.05*	0.053	0.97	0.038	0.94	0.045
Richer	0.98	-0.019	1.02	0.037	1.02	0.044
Richest	0.93	-0.072	1.09	0.043	1.03	0.053
Middle	Reference					
Breast Feeding Status						
Ever breastfed	1.17***	0.160	1.02	0.052	1.16*	0.077
Inconsistent	1.17	0.160	1.17	0.262	0.73	0.528
Never breastfed	Reference					
Birth Size						
Very large	0.69**	-0.366	1.70**	0.145	1.75**	0.204

Larger than average	0.75***	-0.285	1.35***	0.081	1.39**	0.105
Average	0.80***	-0.219	1.19***	0.063	1.37**	0.078
Smaller than average	0.93*	-0.079	1.05	0.071	1.12	0.087
Very small	Reference					
Number of children under five	1.03***	0.030	1.006**	0.014	0.98	0.017
Household Size	0.99***	-0.008	0.99***	0.005	0.99	0.006
Survey Year	0.99***	-0.012	0.994**	0.002	1.01***	0.002
Number of observations used	46520		45804		11352	

* p<0.01, ** p<0.05, *** p <0.001, % includes only those survey years that can be merged

Being breast-fed did not increase the risk of being overweight however birth size of very large to average (in contrast to stunting) was linked to being overweight. Having more children less than five years of age was linked to increased risk of being overweight while household size reduced the risk. Similar to the stunting regression, we find that as survey year increased the risk of being overweight slightly (but significantly decreased).

When examining the risk of being overweight as a stunted child, we find that being a boy is protective (in contrast to stunting) while age of the child lowered the risk (i.e. older the child, lower the risk of being overweight as a stunted child). With respect to the regions, both Lower Egypt Rural and Upper Egypt Urban have significantly higher risk ratios than the Urban governorates. While the other governorates such as Upper Egypt Rural and Frontier also have higher risk ratios (greater than one), these are not significant. Again similar to the findings of the overweight regression, while the risk ratio for children living in rural areas is lower it is not significant. With respect to maternal education, having secondary education was linked to a significantly higher risk of having a stunted child that is overweight (1.11) compared to no education, the ratio was higher for mothers with tertiary education as well, however this was not significant. In terms of maternal occupation, this was found to increase the risk ratio significantly but at a very small level. Similar to overweight, mothers of any BMI category compared to underweight mothers were 2 or more times likely to have a stunted child that was overweight. Wealth index did not significantly change prevalence risk ratios.

Breast-feeding was associated with an increased risk of a stunted child being overweight but not significantly. Birth size was significantly associated with an increased risk of being overweight as a stunted child with risk being 1.3 to 1.8 times higher in average to very large infants compared to very small infants. Household size trended towards a reduced risk ratio while survey year increased the risk of overweight in stunted children. The latter is clearly seen in the trend figures where the prevalence of being overweight as a stunted child has increased rapidly over the survey years.

VII. Discussion

The aim of this study was to examine and understand the trends and variability of malnutrition in all its forms in Egyptian children under five, across time, regions and socio-economic status. It aimed to understand the relationsip of stunting and overweight in Egyptian children and the changes in this relationship over time as well as the relationship of stunting or overweight or both in a child and maternal nutritional status. The research questions included understanding the trend in stunting and overweight in Egyptian children across different survey years along with the effect of change in stunting and overweight by wealth index, geographical location. It also aimed to understand the relationship of different risk factors associated with being stunted, overweight or being a stunted child that is overweight.

It should be noted that we did not separate between overweight and obesity or moderate and severe stunting, prefering to present estimates if the child is classified as either stunted, overweight or overweight as a stunted child. Particularly important is the latter classification as this is examining the double burden within the same child (i.e. stunting and overweight existing within the same child). The choice of this indicator instead of looking at overall prevalence of stunting and overweight in the same population is explicit and based on our research question

The key findings of our analyses are that while there is an overall reduction in stunting, there is a concurrent increase in overweight/obesity in Egyptian children under five years of age (Table 3). However it should be noted that while the current rates are lower than the early survey years, we see a spike in the stunting prevalence especially in 2005 and 2008, this is observed in the pooled estimates as well as the regional estimates (Table 4, Figures 1 and 3). Aitsi-Selmi A. (2015), Kavle et al. (2014) and El-Kofali and Krafft (2015)(6-8) all concur that stunting rose in Egypt in the late 2000s, and that "the reason for the increase in stunting prevalence requires further research." (9).

Furthermore, prevalence of overweight in stunted children has increased markedly (note this is separate from looking at overall prevalence of overweight in the population). This pattern in reduction of stunting, increase in overall overweight prevalence and increase in overweight in stunted children is seen across all the geographic regions. Specifically in 2014, we find that the prevalence of overweight and stunting is comparable to each other within each region/governorate. Furthermore, overweight prevalence in children who are stunted is high across all geographic regions, the lowest being in Frontier and the highest being in Upper Egypt Rural governorates.

With respect to wealth index, stunting has decreased but only in the lower income/wealth categories, thus causing a flat line in the graphs when plotting prevalence versus survey year. This implies a reduction in inequality across wealth categories. It should be noted that Egypt has shown improvements in both relative and absolute inequality in the distribution of stunting by wealth in the 1995 to 2008 timeframe (8, 9). The distribution changing across wealth quintile for Egypt has been compared with Jordan over four rounds of DHS (9). Jordan shows lower and declining prevalence rates over time, but no decrease in the distribution of stunting across quintiles. However, Egypt shows a decline in the mean rate through 2005 followed by the 2008 reversal (increased stunting), but the trend over all four rounds shows a decline in the stunting distribution by wealth – that is, the gap in terms of risk of stunting fell steadily between rich and poor over time and continued to do so after the recent increase in stunting (2005 and 2008). We are seeing similar trends in the 2014 data with reference to stunting and wealth.

Our analyses was able to expand beyond the Restrepo- Mendez et al's analysis, examining not only the newer DHS round but also examining the trend of overweight with reference to wealth (9). What we find is that similar to the reduction in inequality observed in the stunting data, prevalence of overweight has increased in all income/wealth categories such that the flat line exists even in the early survey years. Overweight in stunted children is also flat lined in the income/wealth categories with similar rates being observed across all categories of wealth in 2014.

Egypt has had the biggest rise in overweight and obesity since 1980, and is one of 10 countries that account for more than half of the world's obesity problem (in terms of absolute numbers affected) (2). In adults, overweight is defined as having a body mass index (BMI) > 25, and obesity is defined as a BMI $\geq$ 30. While overweight and obesity tend to cut across Egypt's regions and, to some extent, its wealth categories, the country stands out as having one of the highest gender disparities in obesity (1). That is, Egypt ranks 8th in the world in terms of adult male obesity, but 3rd in the world in adult female obesity (3).

When wealth is taken into account, an importantly differential appears in Egypt's distribution of malnutrition in that it has greater disparity for obesity by both gender and wealth than for child stunting. Tzioumis and Adair (2014) conclude that wealth may explain variability across countries in the relationships between stunting and overweight, since per capita income is generally inversely associated with stunting and positively associated with obesity (10). Yet, for Egypt this pattern does not hold true – stunting is found more or less equally across all wealth quintiles, but in contrast there is a wider distribution of adult obesity by wealth. However this does not hold true for the rates of overweight in children under five years of age. Our findings imply that the burden of being stunted or being overweight or being an overweight stunted child is not modulated by wealth but rather by other individual and household level factors.

We further examined the data from the perspective of understanding if there was a variation in stunting, overweight or being overweight as a stunted child by age categorization. The first set of analyses was to examine the mean Z-scores of the different anthropometric indices. A review of the distributions of HAZ, WAZ and WHZ show interesting results particularly between 2000 and 2014 data. We find that while HAZ and WAZ follow an expected pattern of decrease in Z-score by age group as demonstrated by Victora et al (11), WHZ is consistently higher than 0 on the distribution scale, implying that the mean WHZ score becomes more positive with every survey year. This is not unexpected given the increasing rates of overweight being observed by survey year. However, this trend lasts only until 2008. In 2014, we find that the WHZ score distribution is much lower than the other survey years. Furthermore, the WHZ distribution for 2014 is lower than that of the other survey years implying a population that is at risk of both overweight and wasting. This is clearly seen in the prevalence data where there has been a sharp increase in wasting prevalence from 2000 through 2014 (Table 3). Wasting prevalence has increased across survey years and more in depth analyses needs to be conducted to understand this juxtaposition of overweight and wasting in the same population.

Younger children are more likely to be overweight than older children as noted in Figure 11 (for the year 2014). Similarly there is a rapid increase by survey year in the prevalence of overweight in children that are stunted, especially in the under 6-month age group. Almost 40% of infants under the age of 6 months that are stunted are likely to be overweight while about 30% of infants and young children aged 6-24 months that are stunted are likely to be overweight. Thus the risk of being overweight is higher in younger children whether normal or stunted (Figure 12). This prevalence increases by survey year.

We examined diet quality of the infants aged 6-24 months however were unable to use the data beyond presenting descriptive statistics. Overall, the trend seems to be that most infants and young children are consuming grains/roots/tubers; about 50-60% are consuming some form of dairy with other animal source foods being consumed by less than 40% of the children. Particularly of interest is the very low consumption of Vitamin A rich fruits and vegetables, which is captured in the 2008 and 2014 surveys.

We then conducted a log-binomial regression analysis to understand the relative contribution of different risk factors to the risk of "being stunted", "being overweight" and the risk of "being overweight as a stunted" child. The risk factors that we found most associated (at a bivariate level) included maternal BMI, maternal education, maternal occupation, maternal age at first birth, birth size, birth order, age of the child, gender, geographical location (region and urban/rural), wealth index, being breast fed (or not), household size and number of children under five years of age. We pooled all the survey years and examined the risk factors controlling for survey year (Table 7).

Risk of being stunted was higher in boys than girls and increased with increasing birth order but there was no relationship with age. Risk of being overweight was not significantly different by gender but was significantly lower as age and birth order increased. When examining the risk of being overweight as a stunted child, we find that being a boy is protective (in contrast to stunting) while age of the child lowered the risk (i.e. older the child, lower the risk of being overweight as a stunted child). There was no association of being overweight as a stunted child and birth order.

We noted that irrespective of survey year, all regions had significantly higher risk of having stunted children compared to the Urban governorates. The highest rates were found in Upper Egypt Rural where children less than five years of age were 1.6 times more likely to be stunted than children in Urban governorates. In contrast with respect to risk of being overweight, rates were significantly higher in Lower Egypt Rural, Lower Egypt Urban and Upper Egypt Urban. Upper Egypt Rural and the Frontier governorates had higher risk ratios with respect to overweight but not significantly higher than the Urban governorates. Both Lower Egypt Rural and Upper Egypt Urban also have significantly higher risk ratios of overweight in stunted children than the Urban governorates. While the other governorates such as Upper Egypt Rural and Frontier also have higher risk ratios of overweight in stunted children but these are not significant.

Effectively, this means that the regions that also had higher risk of overweight (irrespective of the risk of stunting) were more likely to also have a higher risk of overweight in the stunted children. This includes Lower Egypt Rural and Upper Egypt Urban while Upper Egypt Rural has significantly higher risk ratios for stunting but the risk ratios of overweight in stunted children while greater than 1, are not significant. Children in rural areas were 14% less likely to be stunted than children in urban areas, however there is no difference in risk of being overweight between rural and urban children. Similar to the findings of the overweight regression, while the risk ratio for overweight in stunted children living in rural areas is lower, it is not significant.

We find that while maternal education reduces the risk of being stunted (compared to no education), the effect being most significant at the secondary level of education. On the other hand having secondary education was associated with a significantly higher risk of having a stunted child that is overweight. There is no relationship of maternal education with the risk of being overweight. While maternal occupation was not related to the risk of being stunted, it did increase the risk of overweight and the risk of overweight in stunted children slightly. Maternal age at first birth was not associated with being stunted however the risk ratio for being overweight was slightly but significantly higher with an increase in maternal age at first birth. Interestingly higher BMI in women is protective against stunting with obese women having the least likelihood of a stunted child (about 20%) compared to underweight women. On the contrary, the risk of being overweight child of mothers in all BMI categories was two times or higher compared to mothers who were underweight. This risk is significant at the $p<0.001$ across all BMI categories. Similar to overweight, mothers of any BMI category compared to underweight mothers were 2 or more times likely to have a stunted child that was overweight.

Given the flat line observed in the descriptive statistics around the wealth index across survey years, it is not surprising that in the logistic model, wealth index was not associated with the risk of being stunted though we do see an effect of the early survey years with the poorest and poorer categories trending to an increased risk compared to the middle-income category. Similar to stunting, wealth index did not seem to have an effect on the risk of being overweight (Table 7) or on the risk of being overweight as a stunted child.

Being ever breastfed seems to increase the risk of being stunted in children under five years of age as does being inconsistently breastfed, the latter being insignificant however it did not increase the risk of being overweight. Breast-feeding was associated with an increased risk of a stunted child being overweight but not significantly. On one hand, birth size was protective of stunting with very large, larger than average, average babies having a significantly reduced risk of being stunted than very small babies. However birth size of very large to average (in contrast to stunting) was linked to increased (significantly) risk ratios of being overweight. Furthermore, larger birth size was significantly associated with an increased risk of being overweight as a stunted child with risk being 1.3 to 1.8 times higher in average to very large infants compared to very small infants. Number of children increased the risk of being stunted and increased the risk of being overweight while household size seemed to reduce the risk for both indicators. Household size trended towards a reduced risk ratio while survey year increased the risk of overweight in stunted children.

There was a reduced risk of being stunted with every survey year, a reflection of the reduction in stunting prevalence across survey years. Similar to the stunting regression, we find that as survey year decreased the risk of being overweight slightly but the risk of being overweight as a stunted child increased by survey year (Table 8).

Co-existence of under or over nutrition burden has been documented by several studies. For example, at the individual level, Asfaw (2007) reported that the odds of being overweight or obese were 81 % higher for micronutrient deficient mothers in Egypt than for non-deficient mothers (controlling for socioeconomic and health variables)(21).[1] In another study, researchers examined region-specific socio-demographic determinants of the co-occurrence of within-child stunting and overweight using the most recent Demographic and Health Survey (DHS) and Multiple Indicator Cluster Survey (MICS) data (2004-2013) from 16 countries MENA (Middle East and North Africa) and LAC (Latin America and the Caribbean) (22). The prevalence of stunting, overweight, and their co-occurrence within the same children in the MENA was 21%, 12%, and 6.1%. Higher maternal education and household wealth were associated with lower odds of stunting and higher odds of overweight. Post-secondary education among mothers and greater household wealth were not associated with lower odds of concurrent child stunting and overweight in the MENA region. Stunted-overweight children were more likely to be boys in both regions and they found no association between rural/urban residence and any nutritional outcomes in either region.

An analysis conducted on overweight and stunting from large national surveys performed between 2001 and 2004 in 5 Arab countries (Djibouti, Libyan Arab Jamahiriya, Morocco, Syrian Arab Republic and Yemen) assessed the prevalence of overweight and stunting, and the association between stunting and overweight in children under 5 years of age (19). Overall the risk ratio (RR) for overweight in stunted children was highest in Libyan Arab Jamahiriya (3.85) and lowest in Djibouti (2.14). However, within countries the RR ranged from 0.76 in mildly stunted children in Yemen to as high as 7.15 in severely stunted children in the Libyan Arab Jamahiriya and 11.88 in children in the Hadramout region in Yemen. In comparison to urban areas, RR for overweight was higher among stunted children in rural areas of the Libyan Arab Jamahiriya, Djibouti and Yemen. In the Libyan Arab Jamahiriya, Morocco and Yemen. RR for overweight among stunted children was higher in privileged groups, while in the other 2 countries it was highest in the intermediate socioeconomic groups. The risk increased with age except in the Syrian Arab Republic and Djibouti, where it increased initially but decreased at around 4 years of age. In all countries, the increase in risk was evident with increasing degree of stunting (Ibid).

At the household level, the co-existence of stunted children and obese mothers in the same household increased significantly from the early 1990s to the late 2000s. Aitsi-Selmi (2015) found that this pairing rose from 4 % in the 1992 and 1995 DHS rounds, to almost 6 % by 2008 (6). This puts Egypt in the

[1] The author concluded that the co-existence of these nutrition problems is important given "the potential impact of the interaction between micronutrient deficiency and chronic diseases is not well known." (Asfaw 2007)

same realm as Bangladesh which has around 4 % of households with both obese mothers and underweight children, and Indonesia's 11 % of households with such a pairing (23).

Our findings are different from that of Aitsi- Selmi in that stunted children are less likely to be paired with an overweight or obese mother (Table 8). This relationship however reverses when you have both stunting and overweight co-existing in the same child. The existence of stunting and overweight/obesity in the same child has been documented globally in Guatemala, Mexico, Russia, China and Brazil (12, 24). Published analyses of the 2005 Egypt DHS data indicate an interaction of stunting and obesity/overweight within the same individual/child (20). The author noted that simultaneous stunting and obesity is spread across all social and economic classes although the relationship is complex - and recommended further study/analyses to elucidate factors that influence stunting and obesity in Egyptian children. With respect to co-occurrence of stunting and overweight (defined as co-existence of stunting and overweight in the same population) we found that about 8% of children were both stunted and overweight in 2014 (Table 4). Interestingly, there is a drop in this prevalence from 2008 when it was 14%.

Our data analysis does have some caveats and there are some challenges encountered in the analysis and interpretation of our findings. Firstly, some of the data are not comparable given the differences in data collection. For example, the diet quality data categorization is different across the years (especially the categorization of fruits and vegetables) and hence we are unable to merge these and have one single index for comparability. We do not have diet quality data for children over 24 months of age. This along with an inability to transform the dietary data into a single variable restricted the utilization of diet quality as a variable in any of the regressions. There are no data on maternal dietary quality. Lastly, the sampling strategy for the frontier governorates is different across the survey years, which limit its utilization in the regression analyses.

Despite the limitations, the findings of our comprehensive analysis have several key findings. Firstly, while stunting levels have reduced in Egypt, there is a stagnation of the rate of stunting (after a spike in the late 2000s). Next, overweight has increased across the survey years and has similar rates as stunting, whether examined nationally or regionally. What is more important to point out is the rapid increase in overweight within the children that are stunted from 3% in 1988 to 33% in 2014. This along with stagnation of the rates of stunting requires closer examination. Some regions/governorates are worse off than others, however there is uniformity in the presence of overweight in stunted children across all regions/governorates. While birth size is protective of stunting, large and very large birth sizes are linked to higher rates of overweight in all children as well as children who are stunted. Furthermore while maternal BMI was protective of being stunted but increased risk of being overweight (in all children) and being overweight as a stunted child. Last but not the least, we find a plateauing of the prevalence rates of stunting, overweight and being overweight as a stunted child across wealth index categories. This implies a reduction in inequality across wealth categories, something that has been observed by other authors. This study was unable to examine the relationship of stunting, overweight and being overweight as a stunted child with diet quality or examine the intersection of stunting and overweight versus stunting and wasting. The latter is particularly concerning given the higher rates observed in the current DHS survey (2014).

The analysis thus clearly shows the geographic and time associated changes in stunting and overweight in Egyptian children under five. While stunting has gone down, overweight has increased in the population and more concerning is that there is increasing prevalence across all regions, urban versus rural that these two co-exist in the same child. It also finds that wealth is not a factor associated with either stunting or overweight. Key factors such as birth size and maternal BMI that have traditionally been used in policy initiatives as markers of reducing stunting on the other hand could increase overweight. Thus any recommendations for increasing birth size and maternal BMI needs to consider the upper bounds of these increases.

A clear finding is that wealth does not modulate stunting, overweight or overweight in stunted children. Factors at the individual (child and maternal) and household are more important when considering policy initiatives around addressing these anthropometric deficits or excesses. In conclusion, the relationship of anthropometric indicators and their prevalence in Egypt is complex and prospective studies are needed to understand how the factors particularly those that contradict each other within the context of stunting and overweight.

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Appendix 1

X. Appendix I

Appendix Table 1: Comparison of Rate estimates to DHS and other reports

	Prevalence of stunting	Reported Stunting prevalence	Prevalence of overweight	Reported Overweight prevalence	Prevalence of wasting	Reported Wasting prevalence	Prevalence of underweight	Reported Underweight prevalence
1988	35.80	31	6.58	6.80	2.34	1.2	11.67	13
1992	28.46	24	13.50	14.4[ii]	3.53	5	7.6	9
1995	33.43	30	12.45	14.7	6.45	5	11.75	12
2000	23.09	23	17.98	18.2 [i]	2.95	3	4.09	4
2005	27.10	23	16.09	14.1 [i]	5.34	5	6.05	5
2008	30.05	29	19.56	20.5[i]	7.71	7	6.51	6
2014	20.19	21	13.26	15	11.67	8	8.17	6

i-estimates obtained from other sources besides DHS reports
ii-estimates for the year 1993
Source[i]: http://www.indexmundi.com/facts/egypt/child-obesity

Appendix Table 2: Prevalence of different anthropometric indicators disaggregated within governorate

Governorates	Prevalence of stunting(*n)	Prevalence of severe stunting(*n)	Prevalence of overweight (*n)	Prevalence of wasting (*n)	Proportion of stunted children who are overweight (x/n)	Prevalence of both stunted and overweight children (*n)	Proportion of severely stunted children who are overweight (x/n[i])	Total number of children in governorates
Urban governorates								
Cairo	24.18	10.83	12.36	12.84	31.69	7.41	56.45	696
Alexandria	14.32	6.25	21.15	4.44	34.69	4.55	38.89	421
Port Said	11.28	4.04	11.83	11.61	36.73	3.91	58.82	492
Suez	17.74	8.29	8.16	22.16	24.47	4.32	39.47	669
Lower Egypt								
Damietta	12.01	5.83	5.12	67.91	10.17	1.50	10.71	639
Dakhalia	10.85	4.60	16.26	5.05	34.55	3.66	33.33	593
Sharkia	37.67	18.61	32.13	3.45	50.41	18.69	62.71	717
Kalyubia	11.57	2.89	7.52	5.69	12.5	1.48	12.5	599
Kafr El-Sheikh	16.64	9.82	14.72	3.68	50.54	7.98	59.62	635
Gharbia	30.65	18.58	21.96	3.39	43.17	12.22	53.66	559
Menoufia	8.77	5.37	7.59	25.19	30.43	2.71	37.04	614
Behera	10.33	3.66	13.15	10.91	45.59	4.38	66.67	807
Ismailia	10.76	5.96	8.09	10.12	26.98	2.91	40	660
Upper Egypt								
Giza	34.36	20.03	20.00	5.32	37	12.50	40.91	732
Beni Suef	45.22	26.58	29.09	2.45	53.36	23.64	70.78	660
Fayoum	29.39	16.05	21.52	2.25	43.08	12.02	67.35	779
Menya	27.30	8.73	14.22	2.05	22.81	6.21	35.19	668
Assuit	10.53	4.38	3.06	37.00	14.71	1.48	23.08	873
Souhag	33.70	18.48	17.52	9.46	37.12	12.06	48.33	826
Qena	16.43	3.31	3.21	4.87	7.09	1.15	0	842
Aswan	15.14	3.99	3.08	7.79	8.79	1.34	16.67	651

Luxor	14.54	5.07	4.74	4.09	12.36	1.81	22.58	654
Frontier Governorates								
Red Sea	23.02	8.63	6.47	8.99	14.29	3.25	30.43	291
New Valley	6.18	2.32	1.90	39.92	12.5	0.81	33.33	297
Matroh	14.08	8.59	18.75	9.64	42	5.63	53.57	474

*n = denominator is the total number of children in the governorates
x= number of malnourished children
n=denominator used is the number of stunted children
n^i= denominator used is the number of severely stunted children
Stunting was defined as Height-for-age Z scores < -2 standard deviations below the median
Overweight was defined as Weight-for-height Z scores > 2 standard deviations above the median
Underweight was defined as Weight-for-age Z scores < -2 standard deviations from the median

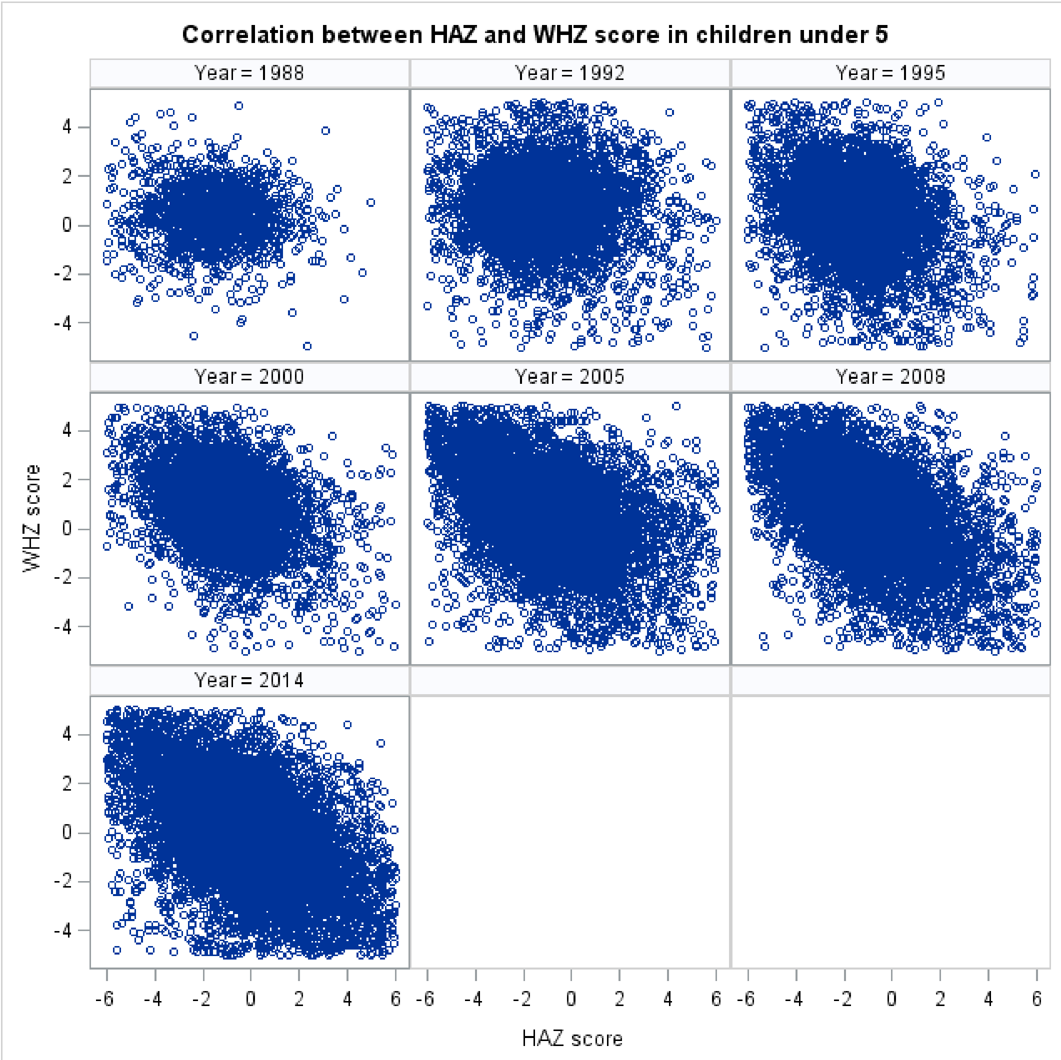
Appendix Table 3: Maternal characteristics by Survey year

	1988	1992	1995	2000	2005	2008	2014
Height in cm ±SD		157.15 ±5.78	157.25 ±6.98	157.59±5 .54	158.47± 5.6	159.43±5 .95	159.35± 5.92
Mean BMI ± SD		26.82±5.4	26.08±5.1	29.09±5. 6	29.49±5 .84	28.7±5.4	29.67±5 .3
Underweight (%<18.5 kg/m^2)		1.7	1.8	0.6	0.5	0.6	0.3
Normal (%18.5-24.9 kg/m^2)		41.3	48.5	24.1	22.7	24.3	16.6
Overweight (% 25-29.9 kg/m^2)		33.4	30.8	36.1	34.6	38.6	40.4
Obese (% >=30 kg/m^2)		23.6	18.9	39.2	42.1	36.5	42.7
Education level							
No education	49.7	47.0	46.0	42.5	35.6	33.5	22.3
Primary	32.28	26.0	24.0	18.2	15.7	12.4	10.0
Secondary	13.02	22.3	24.6	31.3	39.4	43.2	53.0
Higher	4.9	4.6	5.5	8.1	9.3	11.0	14.7

Appendix Table 4: Variables correlated with stunting, overweight or both stunting and overweight by survey year

	1995				2000				2005				2008				2014			
	S	O	B	P	S	O	B	P	S	O	B	P	S	O	B	P	S	O	B	P
Gender	×	×	×	×	✓	✓	×	×	✓	×	×	✓	✓	✓	✓	✓	✓	✓	×	×
Region	✓	✓	✓	×	✓	✓	✓	×	✓	×	✓	×	✓	✓	✓	✓	✓	×	✓	×
Maternal Education	×	×	×	×	×	×	×	×	×	✓	✓	✓	×	×	×	×	✓	×	×	×
Wealth Index	✓	×	✓	-	✓	×	×	×	✓	✓	✓	×	×	✓	✓	✓	×	×	×	×
Ever breastfed	✓	×	✓	×	×	×	×	×	✓	×	✓	×	×	×	✓	×	×	×	✓	✓
Birth size	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	×	✓	✓	✓	×	✓	✓	×	✓	✓
Household size	×	✓	×	×	✓	×	×	×	✓	✓	✓	✓	×	×	×	×	×	✓	✓	✓
Age of child	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓
Maternal BMI	✓	✓	✓	×	✓	✓	×	×	✓	×	✓	✓	×	✓	✓	✓	✓	×	×	×
Rural/Urban	×	✓	×	×	×	×	×	×	✓	×	✓	×	✓	✓	✓	✓	✓	×	×	×
Number of Children under five	×	×	×	✓	×	×	×	×	✓	×	✓	×	×	×	×	✓	×	✓	×	×
Maternal occupation	×	✓	×	✓	×	×	✓	×	×	✓	✓	✓	×	×	×	×	✓	×	✓	×
Maternal Age at first birth	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×	×	×	×	×	✓
Birth order	✓	×	✓	×	✓	×	×	×	✓	×	✓	×	×	✓	✓	✓	×	×	×	×

✓= indicates a p value of 0.1 or less, × indicates a p value greater than 0.1, - indicates missing variable, S=stunting, O=overweight, B= both stunted and overweight and P = proportion of stunted children who are overweight



Appendix Figure 1: Correlation of HAZ and WHZ in children under five by survey year

The Feed the Future Innovation Laboratory for Nutrition is a research and capacity building activity that supports USAID and national government agendas that create rigorous evidence for improved policies and programming at scale. The management entity for the Nutrition Innovation Lab is the Friedman School of Nutrition Science and Policy at Tufts University. It has multiple US academic partners in this work, including Harvard's Chen School of Public Health, Johns Hopkins' Bloomberg School of Public Health, Purdue University, and Tuskegee University, as well as many dozens of institutional partners around the world.

For details please see: http://www.nutritioninnovationlab.org/