Is the Proportion of Per Capita Fat Supply Associated With the Prevalence of Overweight and Obesity? An Ecological Analysis

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Abstract

Background: Although it is reported in numerous interventional and observational studies, that a low-fat diet consists an effective method to combat overweight and obesity, the relationship at the global population level is not well established. This study aimed to quantify the associations between worldwide per capita fat supply and prevalence of overweight and obesity and further classify this association based on per capita Gross National Income (GNI).

Methods: A total of 93 countries from four GNI groups were selected. Country-specific overweight and obesity prevalence data were retrieved from the most recent WHO Global Health Observatory database. Per capita supply of fat and calories were obtained from the United Nations Food and Agricultural Organization database; FAOSTAT, Food Balance Sheet for years 2014-2016. The categorizations of countries were done based on GNI based classification by the World Bank.

Results: Among the selected countries, the overweight prevalence ranged from 3.9% (India) to 78.8% (Kiribati), while obesity prevalence ranged from 3.6% (Bangladesh) to 46.0% (Kiribati). The highest and the lowest per capita fat supply from total calorie supply was documented in Australia (41.2%) and Madagascar (10.5%) respectively. A significant strong positive correlation was observed between the prevalence of overweight (r=0.64, p<0.001) and obesity (r=0.59, p<0.001) with per capita fat supply. The lower ends of both trendlines were densely populated by the low- and lower-middle-income countries and the upper ends of both lines were greatly populated by the high-income countries.

Conclusions: Per capita fat supply per country is significantly associated with both prevalences of overweight and obesity.

Background

The global prevalence of overweight and obesity has increased in both children and adults during the past 20 years. Overweight and Obesity are the medical conditions in which excess body fat has accumulated to an extent that it may have important public health problems associated with an increased risk of type-2 diabetes mellitus, dyslipidemia, hypertension, and cardiovascular disease (CVD). The World Health Organization (WHO) describes overweight and obesity as amongst the most visible, yet neglected public health problems.3 They threaten public health in both developed and developing countries. Parameters that contribute to variations in the development and consequences of overweight and obesity have been related to multiple risk factors, but the recent epidemic is mainly due to the changes in the lifestyle, namely the lack of physical activity and changes in the dietary habits. Chronic overfeeding is one of the fundamental risk factors that have been identified, as it accumulates energy stores and leading in the development of overweight and obesity. Therefore, a common approach to combat overweight and obesity has been to limit energy intake.

Sources of energy are macronutrients and alcohol and most foods and beverages contain combinations of carbohydrates, proteins and fats macronutrients in varying amounts. Dietary fat intake often has been claimed as responsible for the increase in adiposity. However, total energy balance is what matters most and the focus on dietary fat consumption must be seen through its effects on total energy intake (TEI). A significant positive relationship has been found between the amount of energy from fat and the proportion of the population who are overweight in epidemiological studies and in clinical studies between the level of dietary fat and body-weight gain as well as between the reduction in the dietary fat and weight loss.

People from different countries have distinctive food consumption patterns due to variations in availability, affordability, and local dietary habits. At the same time, food production modernization and rising income levels in the last decades have made a range of foods easily available and affordable with less seasonal variation in some countries. Although it is widely reported that a low-fat diet is an effective method of weight loss, its relationship with overweight and obesity trend at the global population level is not well established. Meanwhile, global patterns, distributions, and heterogeneity of consumption of dietary fat have been exhibited. Therefore, it is useful to look at this relationship with nationally representative data. This study explored the associations of per capita fat supply with the worldwide prevalence of overweight and obesity. Furthermore, we aimed to quantify this relationship further based on per capita Gross National Income (GNI) classifications by the World Bank.

Methods

Data sources

Country specific data were collected for this ecological analysis. The Country selection was based on data availability for all variables selected for the study. The prevalence rates for overweight and obesity were obtained from the WHO Global Health Observatory (WHO-GHO) database for the year 2016. Per capita fat and calorie supply were obtained from the United Nations (UN) Food and Agricultural Organization database; FAOSTAT Food Balance Sheet (FAOSTAT-FBS) data for years 2014-6 which was backdated to reflect exposure with delayed presentation. The categorization of countries was done based on the world's economies classified by the World Bank. FAOSTAT-FBS data by country from 2014-6 with WHO-GHO data in 2016 under four income groups are presented in Supplementary Material: Table 2. Detailed information on the country-level prevalence of overweight and obesity and per capita fat supply and total calories

The WHO-GHO data

The WHO-GHO is an initiative of the WHO to share data on global health, including statistics by country and information about specific diseases and health measures. The WHO-GHO specifically assembles prevalence data of biological risk factors, including mean Body Mass Index (BMI), overweight and
obesity for WHO member states using standardized protocols. WHO-GHO data on estimated prevalence rates of overweight and obesity (percent of the population aged 18+ with BMI ≥ 25 and ≥ 30 kg/m² respectively) by country was obtained for the most updated and recent datasets version (2016).

**The FAOSTAT FBS data**

The FAOSTAT database disseminates statistical data collected and maintained by the FAO. FAOSTAT data are provided as a time-series in most domains through a FBS. The FBS presents a comprehensive picture of the pattern of a country's food supply during a specified reference period. The FAOSTAT-FBS provides annual figures by country on the daily supply of total calories (in kcal per day), daily supply of protein (in gram per day), and daily supply of fat (in gram per day). The daily caloric supply and macro-nutrients of fats (animal and plant, in gram/capita/day) were extracted from the FAOSTAT FBS data by country for the period between 2014-2016.

The number of calories from fat was calculated based on the energy density based on the Atwater system. We calculated the mean values for calories and fat per person per day over a period of 3 years (2014-2016) to represent typical exposure to dietary fat, because obesity develops after cumulative exposure to dietary risks and the mean of three years of fat may also reduce the random errors during the data collection and calculation by FAO. The rationale for this decision is that studies have shown that three years is a practical period to estimate a country's obesity prevalence after exposure to dietary risks. The share of calories derived from fat could then be calculated by dividing the number of calories derived from fat by the total daily caloric supply.

**The World Bank data**

The World Bank classifies the world's economies into four income groups, namely "high", "upper-middle", "lower-middle", and "low". The World Bank's official estimates of the size of economies are based on per capita GNI converted to current U.S. dollars ($) using the World Bank Atlas method. These four classifications of countries are determined by a country's GNI per capita, which can change with economic growth, inflation, exchange rates, and population. For the current 2020 fiscal year, low-income economies are defined as those with a GNI per capita of $1,035 or less in 2019; lower-middle-income economies are those with a GNI per capita between $1,036 and $4,045; upper-middle-income economies are those with a GNI per capita between $4,046 and $12,535; high-income economies are those with a GNI per capita of $12,536 or more.

**Data extraction and analysis**

All data were extracted and saved in Microsoft Excel (version 2013 for Windows) for analysis by one reviewer (HS) using a standardized form and checked for accuracy by a second reviewer (PR). Discrepancies in the extracted data were resolved by discussion, with the involvement of a third reviewer when necessary. Data for 93 countries matched the prevalence estimates of overweight and obesity to the year- and country-specific fat consumption variable. An income stratum which is based on GNI was classified based on the World Bank dataset. The relationship between the per capita fat supply and other dependent variables the prevalence of overweight and the prevalence of obesity was explored with a correlation coefficient. Countries were grouped for correlation analyses using the World Bank income classification. Pearson's correlation coefficients (r) were calculated to evaluate the strength and direction of the associations between per capita fat supply and overweight and obesity prevalence. Scatter plots were utilized to gain a visual representation of the correlation and the outcome was analyzed by drawing a regression line. All countries were represented by a 3-letter country code based on the ISO (International Organization for Standardization) 3166, retrieved from the Terminology Bulletin Country Names and the Country Codes for Statistical Use maintained by the United Nations Statistics Divisions.

**Results**

Data were analysed for a total of 93 countries among the 4 income groups (low-income=23; lower-middle-income=26; upper-middle-income=23; high-income=21). With regards to overweight and obesity prevalence data, Kiribati showed the highest overweight and obesity prevalence (78.8% and 46.0% respectively), while India showed the lowest overweight prevalence (3.9%) and Bangladesh showed the lowest prevalence for obesity (3.6%). For the period 2014-2016 years, the per capita percentage of fat supply ranged from 10.5-41.2% of total caloric supply, whereas the lowest and highest percentages of per capita fat supply were reported for Madagascar and Australia, respectively.

Table 1 summarizes the correlations based on economic status as defined by the GNI for the included 93 countries. A strong positive Pearson's correlation coefficient was observed between both the prevalence of overweight (r=0.64, p<0.001) and obesity (r=0.59, p<0.001) with per capita fat supply. When countries were categorized based on income, significant positive correlations were exhibited for both overweight and obesity prevalence (r=0.42, p=0.03 for both) in the lower-middle-income countries whereas, a significant positive correlation was observed only for overweight prevalence (r=0.53, p=0.01) in the high-income countries.

| Table 1: Correlation coefficient and coefficient of determination between per capita fat supply and dependent variables of overweight and obesity based on the economic strata classification. |
Analysis of all countries

The relationship between per capita fat supply and prevalence of both overweight and obesity for all the countries is noted to be logarithmic with strong correlations (Figures 1a and 1b respectively). The overweight prevalence of all included countries showed a significant positive correlation ($r=0.64$, $p<0.001$) and 41% of the data fit the regression model between per capita fat supply and overweight prevalence ($R^2=0.41$) (Figure 1a). The obesity prevalence of all included countries also showed a significant positive correlation ($r=0.59$, $p<0.001$) with the per capita fat supply and 34% of the data fit the regression model between per capita fat supply and obesity prevalence ($R^2=0.34$) (Figure 1b). The regression lines generated from the correlation analysis showed an upward trend, and as expected, almost all included countries scattered around both lines, with very few countries as outliers (including Egypt and Kiribati). The lower end of these both lines was densely populated by most of the low-income and lower-middle-income countries, except for a few countries as outliers (including Kiribati, Egypt, Algeria, El Salvador, Bolivia). The upper ends of both lines were greatly populated by most of the high-income countries. All upper-middle-income countries (excluding China) scattered around the middle to the upper end of the regression line.

Analysis based on GNI

Scatter plots showing the relationship between the above variables in each income category based on GNI were also produced (Figures 2a-2h). All regression lines generated from the correlation analysis also showed an upward trend.

Analysis of low-income countries

Among the low-income countries, Haiti showed the highest prevalence of both overweight (54.9%) and obesity (22.7%) while Ethiopia showed the lowest prevalence of both overweight (20.9%) and obesity (4.5%). However, Gambia and Madagascar showed the highest (27.3%) and lowest (10.5%) per capita fat supply among the low-income group respectively. Both overweight and obesity prevalence were not significantly correlated with per capita fat supply ($r=0.23$, $p=0.28$ and $r=0.29$, $p=0.17$ correspondingly) (Figure 2a and 2b). However, the correlation effect significantly changed after removing the outliers (Yemen, Haiti) from the analysis, which then gave a significant correlation at both overweight ($r=0.49$, $p=0.02$) and obesity ($r=0.67$, $p<0.001$) prevalence with 24% and 45% of variations for overweight ($R^2=0.24$) and obesity ($R^2=0.45$) respectively (Supplementary Material: Table 3).

Analysis of lower-middle-income countries

The prevalence of overweight ranged from 19.7% (India) to 78.8% (Kiribati), while obesity ranged from 3.6% (Bangladesh) to 46.0% (Kiribati). A wide range of per capita fat supply, representing 11.3% Bangladesh and 30.3% Kiribati was found in this group. It is noteworthy that Kiribati had the highest prevalence of overweight and obesity, as well as the highest per capita fat supply. In this income category, both overweight and obesity prevalence were significantly correlated with per capita fat supply ($r=0.42$, $p=0.03$ and $r=0.42$, $p=0.03$ respectively) with the variation of 17% for overweight ($R^2=0.17$) and 18% for obesity ($R^2=0.18$) (Figure 2c and 2d).

Analysis of upper-middle-income countries

Fiji had the highest prevalent country of both overweight (30.2%) and obesity (63.8%), while China was the lowest country for those values (32.3% and 6.2% respectively). Per capita fat supply was ranged from 16.2% (Peru) to 35.7% (Belarus) among the upper-middle-income group. Countries in the upper-middle-income group did not show a significant correlation between per capita fat supply and prevalence of both overweight and obesity ($r=0.24$, $p=0.27$ and $r=0.28$, $p=0.08$ respectively) (Figure 2e and 2f). However, after removing one outlier (China), significant correlation reported with obesity prevalence ($r=0.43$, $p=0.04$) with 18% of variation ($R^2=0.18$) (Supplementary Material: Table 3). All upper-middle-income countries expect a couple of countries such as Georgia and China were clustered close to the regression line.

Analysis of high-income countries

Among high-income countries, Japan showed the lowest prevalence for both overweight (27.2%) and obesity (4.3%). New Zealand presented the highest overweight prevalence (65.6%) whereas the Bahamas showed the highest obesity prevalence (31.6%). The per capita fat supply ranged from 27.1% (Chile) to 41.6% (Australia). Only overweight prevalence significantly correlated with per capita fat supply ($r=0.53$, $p=0.01$) with 28% of variation ($R^2=0.28$) (Figure 2g).

### Correlation Table

| Correlation     | Overweight | Obesity |
|-----------------|------------|---------|
|                 | $r$        | $p$     | $R^2$   | $r$     | $p$     | $R^2$   |
| All countries   | 0.64       | <0.001  | 0.41    | 0.59    | <0.001  | 0.34    |
| **Income status** |           |         |         |         |         |         |
| Low             | 0.23       | 0.28    | 0.05    | 0.29    | 0.17    | 0.09    |
| Lower middle    | 0.42       | 0.03    | 0.17    | 0.42    | 0.03    | 0.18    |
| Upper middle    | 0.24       | 0.27    | 0.06    | 0.28    | 0.08    | 0.08    |
| High            | 0.53       | 0.01    | 0.28    | 0.38    | 0.08    | 0.14    |

$r =$ Pearson's correlation coefficient, $p =$ Significance, $R^2 =$ coefficient of determination
However, per capita fat supply did not significantly correlate with the obesity prevalence ($r=0.38$, $p=0.08$) in the high-income group (Figure 2h). Almost all included countries in the regression line generated from the correlation analysis among the high-income group scattered around the line, with two countries, (Republic of Korea and Japan) as outliers.

**Discussion**

The results of our analysis have demonstrated that the per capita fat supply is a very good predictor for the prevalence of overweight and obesity at the country level. The relationship was noted to be linear with a strong correlation between per capita fat supply and both overweight and obesity prevalence. The correlation we have found in this study between fat intake and overweight and obesity is compatible with that demonstrated in epidemiological studies and in clinical studies which also shows the positive relationship between dietary fat consumption and increase of body-weight. Furthermore, our findings of the relationship between fat intake and dependent variables of overweight and obesity show a positive association at all GNI levels.

The correlation of per capita fat supply to overweight and obesity varies based on economic strata. According to that, a significant correlation between per capita fat supply and variables of both overweight and obesity was noted in the lower-middle-income group. At the same time, a significant correlation was also noted in high-income strata as well, but only for the overweight prevalence. Though the correlations were not significant in other sub-categories, that effect significantly changed for several sub-groups after removing few outliers. For example, the correlation coefficient was significantly noted for both variables of overweight and obesity in the low-income group after removing data from Yemen and Haiti, which were considered outliers. And, linear regression models between the per capita fat supply and prevalence of both overweight and obesity also increased after removing those two outliers. Moreover, correlation changed as significant for obesity in the upper-middle-income group after removing one outlier (China). The lack of significant correlation in the remaining two sub-categories (overweight in upper-middle-income and obesity in high-income groups) may have been due to the insufficient data points, with a smaller number of countries.

The joint WHO/FAO consultation on fats and oils proposed that dietary fat should supply a minimum of 15% of TEI, but not exceed 30-35% of TEI for most of the adults. The country-specific analysis of the current study has found a range of 10.5-41.6% of fat energy ratio between 2014-6. According to our analysis, seven countries fell below the minimum recommendation of 15% of dietary energy supply from fat, all of which were in the low-income (Ethiopia, Ghana, Cambodia, and Lao People’s Democratic Republic) and lower-middle-income (Madagascar, Rwanda, and Afghanistan) categories. Thirteen countries exceeded the 35% maximum, with twelve countries being in the high-income group and one in the upper-middle-income group. It seems that those countries with an exceeded level of per capita fat supply are mostly economically industrialized countries.

**When considering the factors determining fat consumption patterns** analyses of fat consumption data have shown that the individuals belonging to the lowest socio-economic group in most developed countries consume more fatty foods. Studies have shown that gender and age differences were also found in consumption of fatty foods. Moreover, urbanization is also strongly associated with the increasing consumption of fat in developing countries. In addition to that, the physical environment, level of education, sociological, and individual factors also affect the altitude of fat consumption. Therefore, this entwined phenomenon is part of an overall change in food habits and then determines the total quantity of fat availability at the country level.

Several physiological mechanisms explain the high-fat diet-induced obesity. Those are low satiating effects, and the alterations in the hormones involved in energy balance. The relationship of more dietary fat leading to greater obesity is because fat contains 9 kcal/g of energy compared with 4 kcal/g for carbohydrate and protein. It is clear that, high-fat foods are high in energy density, and therefore, the overall fat content of the diet is an important factor for the energy balance. Also, weaker satiety signals from fats than from carbohydrates and proteins have been suggested to play a role in overconsumption of energy from fat-rich diets. The extra eating from fat-rich diets is due to their post-ingestive effect which may increase food intake by conditioning sensory preference. Moreover, protein and carbohydrate elicit strong auto-regulatory adjustment in their oxidation in response to changes in intake, but fats at the bottom of an oxidative hierarchy that determines fuel selection.

All information on the two variables we used in this analysis was not uniformly available for all countries in the world due to unavailability from relevant UN agencies. Therefore, the number of countries included in this analysis was restricted for those with relevant data available. FAO, WHO, and the World Bank are inter-governmental organizations with specialized information related to their respective fields. They have evaluated these data in consideration of their possible use such as for scientific research and decisionmaking before they were published. This means that errors are reduced but some inaccuracies related to reporting quality may still be present in the data.

**Limitations**

It must be noted that there are several limitations to this study. Firstly, there may be some potential confounding variables (i.e. prevalence of physical inactivity, total calories intake) that aren’t included in our analysis, which may influence the correlation we have found. It is however difficult to see what such variables may be exactly in the present analysis. Secondly, we could only use an international food database that tracks the general per capita calorie supply and fat supply, not the actual human consumption. However, there are no direct measures of actual human consumption that can account for food wastage and provide precise measures of food consumption internationally. Thirdly, the data analyzed are calculated per capita in each country, so that we could only demonstrate a relationship at a country level, which does not necessarily correspond to the same relationships holding at the individual level. Fourthly, the BMI values of 25 kg/m$^2$ and 30 kg/m$^2$ were considered as the cut-off point for defining overweight and obesity among the sample population here. However, different cut-off points can be employed to define overweight and obesity among different ethnic groups. We used WHO country reports for this study to possibly reduce substantial discrepancies between countries, although recently published data on the prevalence of overweight and obesity are available for some countries.
Future perspectives

Prospective cohort studies and clinical trials are proposed to explore this association further in each country. Also, the assessment of variation in different proportions of animal fat and plant fat is significant to determine the accurate picture of the association at the country level. Country-specific nutrition education messages that provide consumers with information on not to adopt a high-fat diet for the long-term and how best to limit sources of fat intake to maintain the appropriate body weight are vital. Governments should implement food policies, active measures to make populations more aware of the risk of high fat intake and their sources and apply taxes for food industries with the margin of fat used as ingredients so that the masses can make informed decisions accordingly.

Conclusion

Significant positive correlations were observed between the prevalence of overweight and obesity for country-specific per capita fat supply in all the countries. The regression lines generated from the correlation analysis showed an upward trend. The lower ends of both lines were densely populated by most of the low-income and lower-middle-income countries, indicating a low prevalence of both overweight and obesity and a per capita low-fat supply. In contrast, the upper ends of both lines were greatly populated by most of the high-income countries, indicating a high prevalence of both overweight and obesity with the per capita high-fat supply.

Abbreviations

BMI: Body Mass Index
CVD: Cardiovascular Diseases
FAO: Food and Agricultural Organization
FBS: Food Balance Sheet
GHO: Global Health Observatory
GNI: Gross National Income
MUFA: Monounsaturated Fatty Acids
PUFA: Polyunsaturated Fatty Acids
SFA: Saturated Fatty Acids
TEI: Total energy intake
TG: Triglycerides
UN: United Nations
WHO: World Health Organization

Declarations

Ethics approval and consent to participate

All data supporting our findings in this paper were freely downloaded from the United Nations (UN) agencies’ websites. No ethical approval or written informed consent for participation was required.

Consent to publish

Not applicable.

Competing Interest

The authors declare no conflict of interest.

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Authors’ contributions
PR, RJ, and HS made a substantial contribution to design the conception. HS reviewed the literature and obtained the data. PR checked for accuracy of data. HS, PR, and RJ were involved in retrieving data. HS involved in statistical analysis and drafting the manuscript. PR, RJ, and MC critically revised the manuscript. All authors read and approved the final manuscript.

Availability of data and materials

All data for this study are publicly available and are ready for the public to download at no cost from the official websites of the World Bank, the WHO, and FAO. Usage of these data for this research falls within the UN agency’s public permission in their terms and conditions. There is no need to have formal permission to use the data for this study. The sources and data robustness have been described in the section of "Methods". Furthermore, detailed information on the country-level prevalence of overweight and obesity and per capita fat supply and total calories are contained within Supplementary Material: Table 2.

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