

National Food Consumption Patterns: Converging Trends and the Implications for Health

Modes de consommation alimentaire nationaux : tendances convergentes et incidences sur la santé

Nationale Muster des Lebensmittelkonsums: Konvergierende Entwicklungen und die Auswirkungen auf die Gesundheit

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According to the World Health Organisation, the prevalence of global obesity almost tripled between 1975 and 2016. Worldwide, 39 per cent of adults aged 18 years or over were overweight in 2016, and 13 per cent were obese (WHO, 2017). Such is the extent of the problem that even in countries where undernutrition and infectious diseases are prevalent, obesity and overweight have become issues of pressing public policy concern (OECD, 2019). Once the preserve of the world's richest countries, obesity has 'gone global' with over-nutrition more common than undernutrition, even in some of the poorest countries of the world (*The Lancet*, 2019b). With diet-related disease such as cardiovascular illness, Type II diabetes and cancer on the rise, the economic cost of obesity is also increasing. Direct health care costs are similar to that of smoking or armed conflict, and currently account for between 2 and 7 per cent of global healthcare spending (Dobbs *et al.*, 2014) figures that, according to OECD estimates, are set to double by 2030 (Giner and Brooks, 2019).

Obesity and weight gain, in general, are the result of a mismatch between energy consumed and energy expended. Globally, there have been changes in both diet and physical activity, characterised by an increased intake of energy-dense, high-fat foods and a trend towards urban, sedentary

lifestyles. While the latter are believed to have contributed to the majority of surplus calories in some countries, including the UK (Griffiths *et al.*, 2016), the dietary origin of obesity is obvious. Notwithstanding the complex interplay of social, economic and genetic factors that results in obesity, the focus of this article is the identification of distinct patterns of food consumption and the implications that they imply for obesity and health.

The emergence of the obesity pandemic is in contrast to the perception of diet as a seemingly indelible facet of

national identity, reflecting immutable characteristics such as climate, religion and culture, acquired over long periods of time reflecting traditions and traditional ways of life. Diets are also heterogeneous, varying across countries, regions and households. Yet, as pointed out by Oberlander *et al.* (2017), diets are changing rapidly, particularly with respect to fat, artificial sweeteners and animal-sourced foods. Indeed, there is some evidence that national diets are converging on the so-called 'Western diet' (Khoury *et al.*, 2014), characterised by a high intake of refined



The 'Western diet' is high in refined carbohydrates, sugars, fats, processed foods, animal-sourced foods and low in fruit and vegetables.

Box 1: FAO's Food Balance Sheet data

- The FAO compiles a Food Balance Sheet annually providing estimates of food availability covering 100 food groups (including unprocessed and some processed food, but excluding such groups as wild animals and insects, and non-commercial or subsistence production) in 185 countries (See FAO, 2017 for details).
- The Food Balance Sheet gives a comprehensive picture of a country's food supply (production, imports, stock changes) and utilisation (exports, foods fed to livestock, used for seed, put to manufacture for food use and non-food uses, losses during storage and transportation).
- From these data, the average per capita supply of macronutrients (total energy, protein, fats) can be derived for all countries. No information on micronutrients (vitamins and minerals) is provided.
- Balance sheet data are national averages that take no account of food waste at the retail and household level or the unequal access to food (within a calendar year or across subgroups by age, gender or socioeconomic levels) and hence are not well suited to address issues such as hunger, which tend to affect sub-groups of the population.
- Food balance sheet averages are not equivalent to average food intake or average food consumption but are best described as food available for human consumption (often called 'apparent food consumption').
- FBS data have been found to overestimate food consumption in most food groups obtained in dietary surveys particularly in developing countries where homegrown food is important. For detailed comparison with other methods, see FAO (2018).

carbohydrates, sugars, fats, processed foods, animal-sourced foods and an inadequate intake of fruits and vegetables (Popkin *et al.*, 2012).

In this article we summarise the results from a study of national food consumption patterns in 118 countries over the last half a century using Food Balance Sheet (FBS) data collated by the Food and Agriculture Organisation (FAO) of the United Nations. While FBS data have a number of important limitations as a measure of diet, not least that they are national averages of food availability (so called 'apparent food consumption') rather than food actually consumed, they represent a comprehensive and longstanding resource on macronutrient availability and a useful indicator of dietary patterns over time (See Box 1).

Using a recently developed clustering technique, we identify five distinct groups of apparent food consumption based solely on the evolution of national calorie intake, all of which are observed to have become increasingly obesogenic over time

but at rates indicative of convergence (higher growth in the least calorific dietary types). All five groups are also becoming less healthy, due largely to a substitution of plant-sourced foods with animal-sourced foods. As such, our results add to a growing body of evidence from public health researchers and organisations on the urgent need to address the issue in both rich and poor parts of the world (see for example, OECD, 2019; WHO, 2017).

Identifying dietary patterns

In order to facilitate the monitoring of global food consumption patterns it is useful to identify groups of countries with similar dietary characteristics and, subject to the caveats highlighted above, the information collated by the FAO is well suited to this purpose. Specifically, the FAO Food Balance sheet database contains a breakdown, by major food groups, of the per capita calories available for consumption on an annual basis in almost all countries since 1961 (FAO, 2019). However, given the complexity of the data, which varies both across countries and over time, some means of classifying the national trajectories of calorie consumption is warranted. While grouping countries according to geography (say by continent) or economic criteria (say by income level) has the virtue of simplicity, it takes no account of proximate countries (in terms of location or development) with different diets. For example, the calorific intake of the United States of America and Mexico are as dissimilar as the intake of Japan and Germany despite their geographical and economic proximity, respectively. In such circumstances, methods that categorise countries more flexibly offer some appeal. One such tool is *cluster analysis*, a statistical technique that identifies groups (or clusters) of countries that are similar to one another yet dissimilar from countries in other clusters (see Box 2). Here we apply a *fuzzy clustering* algorithm (Disegna *et al.*, 2017) which allows for the possibility that a number of dietary patterns co-exist within a single country. While for some

Box 2: Cluster analysis

Cluster analysis is a tool for data description that seeks to identify common patterns without imposing an aggregation rule (say, grouping countries by continent or income level). In standard cluster analysis, each country is assigned to a single cluster – the group whose trajectory of calorie consumption the country most closely resembles. Hence, clusters are mutually exclusive, and each country belongs to a single cluster with full (100%) membership. However, *fuzzy clustering* algorithms (see Bezdek, 1981) permit each country to belong to more than one cluster simultaneously with different degrees of membership. This is attractive since it captures the possibility that different groups of consumers within a country follow different dietary patterns. Hence, fuzzy clustering allows for cases where a country belongs to say two clusters, with membership degrees of say 80 per cent and 20 per cent.

countries, the notion of a national diet is a reasonable rule of thumb, for many countries a more nuanced view will be more appropriate.

Results from the cluster analysis applied to half a century of annual per capita calorie consumption in the 118 countries in the sample suggest that there are five clusters (CL1 to CL5) each of roughly comparable size whether in terms of countries or population. As such, they all represent common food consumption patterns.

Figure 1 illustrates the geographical dispersion of each cluster globally. In the figure, each cluster has an exemplar country whose trajectory of calorie consumption over the period is most representative of the cluster as a whole. These are Switzerland (CL1), Gambia (CL2), Japan (CL3), Nicaragua (CL4) and Saudi Arabia (CL5). The degree to which all other countries correspond to each of these clusters is indicated by the shade of blue; the darker the shade the higher the membership degree. The figure reveals that while some

countries (depicted in dark blue) are predominantly associated with a single dietary cluster (e.g. Norway (CL3); Canada (CL2); India (CL4)), implying that a national diet may be a reasonable approximation, many countries belong to multiple clusters indicative of the coexistence of dietary types. For example, Australia appears in CL3 and CL5, the UK in CL1 and CL2.

Before we attempt to map the clusters to specific diets, Figure 2 shows the evolution of (weighted average) per

Figure 1: Clusters, representative countries and membership degrees



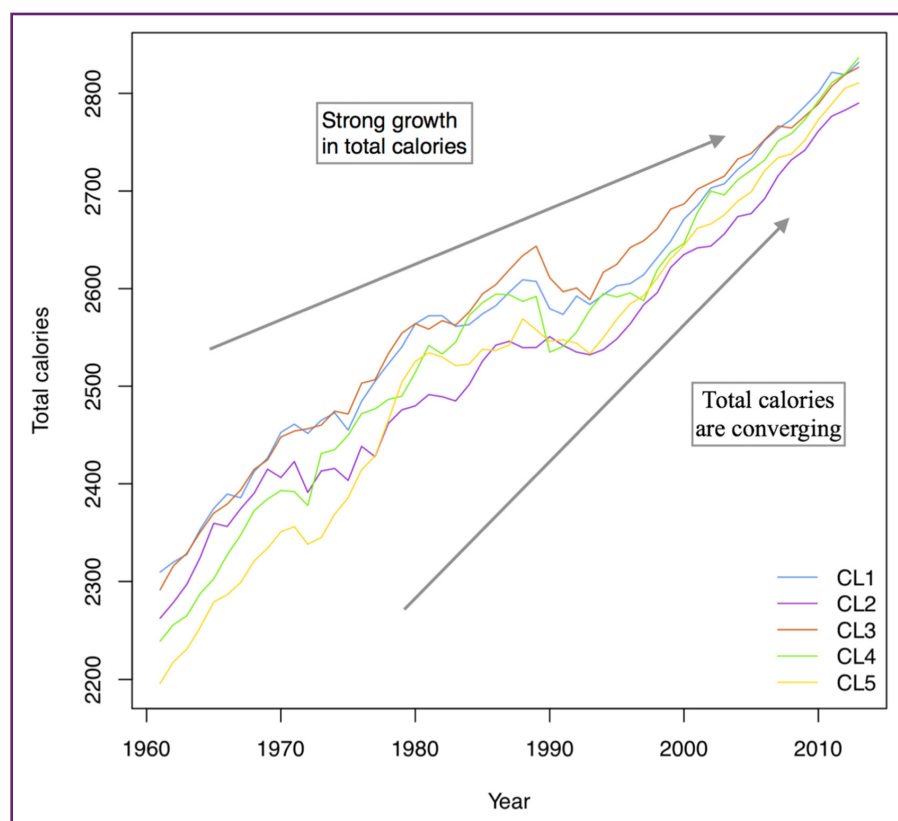
capita apparent food consumption for each cluster over the last five decades. A number of features seem noteworthy. Foremost is the positive trend, a feature that is common to all clusters. Broadly speaking, per capita calorie consumption has risen from around 2,250 to some 2,800 kcal/person/day, an increase of nearly 25 per cent. Second, the gap between clusters has narrowed, giving rise to a convergence in the calories consumed globally. This reduction in the dispersion of the series, what economists term 'sigma convergence' arises since countries with lower initial total calories have tended to exhibit higher rates of growth over the period as whole. Take for example the diet given by CL5 and represented by Saudi Arabia in the fuzzy clustering, which began the period as the least calorific yet by 2013 had a calorific content very close to most calorific diets. This concept of 'catch-up', what economists term 'beta convergence', is highest in CL5 (Saudi Arabia) and CL4 (Nicaragua). With CL1 (Switzerland) exhibiting the highest initial calorie content and the slowest rate of growth over the period, the evidence points to a convergence on the diet of this cluster. The dietary composition of the clusters identified can illustrate whether this corresponds to the Western Diet.

“ Il faut redoubler d'effort pour changer le comportement en matière de consommation alimentaire, non seulement dans les pays riches mais aussi à l'échelle mondiale. ”

Clusters and their dietary characteristics

Identifying clusters (and their representative countries) solely on the behaviour of total calorie consumption over time begs the question of whether it is possible to attach a meaningful dietary type based on dietary composition to each cluster. Figure 3 presents a

Figure 2: The evolution of daily per capita calories over time in each cluster



heat map of the importance, relative to global averages, of 11 food categories (meat (including eggs), animal fat, milk, sugar, fish, vegetable oil, pulses, cereals, starchy roots, fruits and vegetables) to each of five clusters. With red (blue) indicating food groups consumed more (less) than the global average, this provides an indication of the dietary composition of each cluster that has been identified. Specifically, with high intakes of meat and animal fat, fairly high intakes of dairy products but low intakes of cereals and pulses, CL1 (Switzerland) appears to describe the typical 'Western' diet. In contrast, CL2 (Gambia), which comprises mostly staples such as cereals and relatively few fruits or vegetables, is more suggestive of a basic or 'Traditional' diet. Being rich in fish, vegetable oils and vegetables CL3 (Japan) resembles what is often referred to as the 'Mediterranean' diet whereas the relatively high consumption of milk, sugar, pulses and fruits suggests CL4 (Nicaragua) is typical of a more or less 'Tropical' diet. CL5 (Saudi Arabia) is characterised by a low consumption of animal-sourced foods and high consumption of roots and fruits and therefore resembles a 'Vegetarian' diet.

So, while the labels used here are merely convenient descriptors, the fact that clusters map quite neatly into broad dietary types provides a convenient way to categorise the diets that underlie national food consumption statistics. It also provides a basis to assess the health implications of these major dietary types.



Obesity has 'gone global' with over-nutrition more common than under-nutrition.

Diets and health

In order to better quantify the 'healthiness' of the global diet we calculate the Mediterranean Adequacy Index (MAI) developed by Fidanza *et al.* (2004) for each of the five dietary types that have been identified. In simple terms, the MAI is calculated as the ratio of 'good' to 'bad' calories in the diet. Being intuitive and easily computed, the MAI is a widely used metric of dietary quality. Here, the MAI is calculated as the calories consumed from:

$$MAI = \frac{(\text{cereals} + \text{starchy roots} + \text{vegetables} + \text{fruits} + \text{fish} + \text{vegetable oils})}{(\text{milk} + \text{meat} + \text{eggs} + \text{animal fats} + \text{sugars})}$$

so that the higher the MAI, the healthier is the diet.

“Die Anstrengungen zur Änderung des Ernährungsverhaltens müssen verdoppelt und nicht nur in den reichen Ländern, sondern auch weltweit umgesetzt werden.”

Figure 4 illustrates the MAI for each of the five clusters over the period 1961–2013, with a strong downward trend in dietary quality evident in all cases. Interestingly, from a historical perspective the deterioration of dietary quality was most marked in the 1960s. In the 1970s diets actually improved, consistent with the substitution of plant for animal-sourced foods in the wake of the commodity crisis. In the last two decades, the deterioration has been most rapid for the seemingly least healthy diets (the animal-based 'Western' diet and most markedly the sugar-based 'Tropical' diet).

What is clear from Figure 4 is that all of the five dietary types are becoming less healthy and Figure 5 indicates why: each diet has replaced carbohydrates with fat

Figure 3: Heat map of dietary composition of the five clusters (relative to the world average)

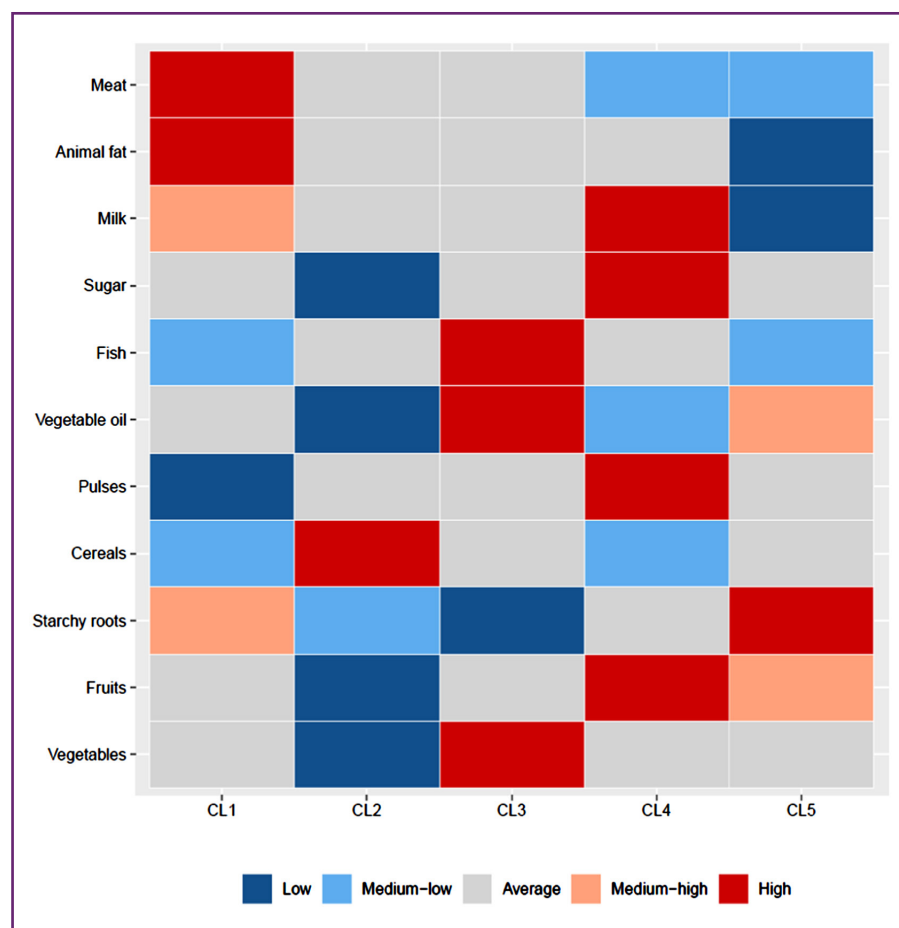
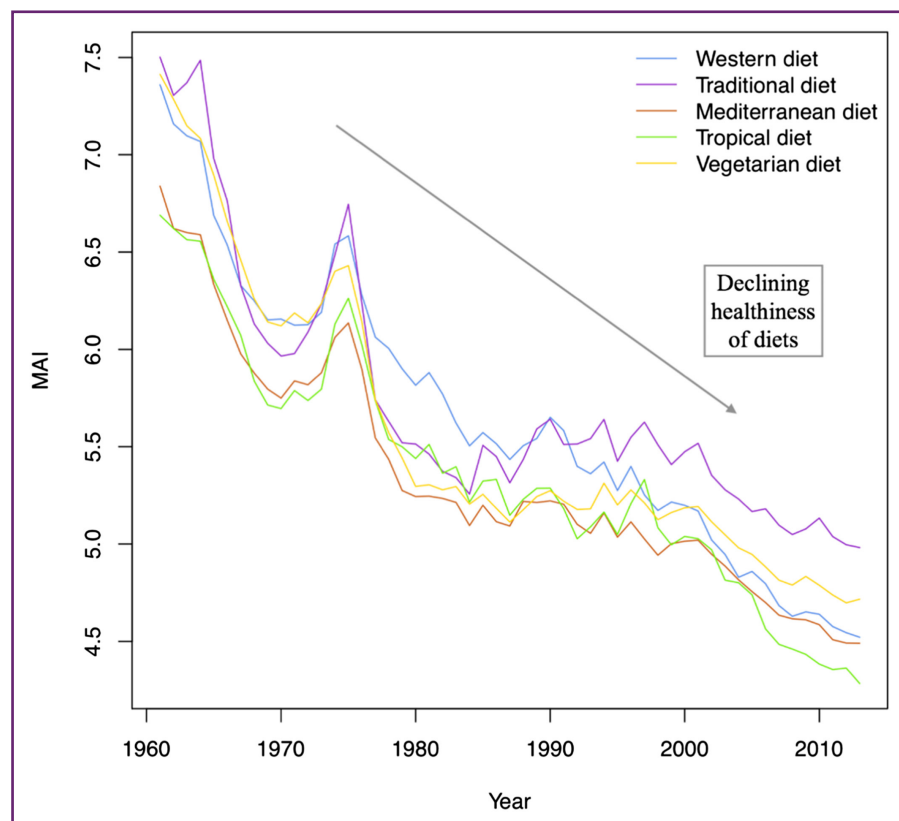


Figure 4: Dietary quality over time: The MAI for five dietary types

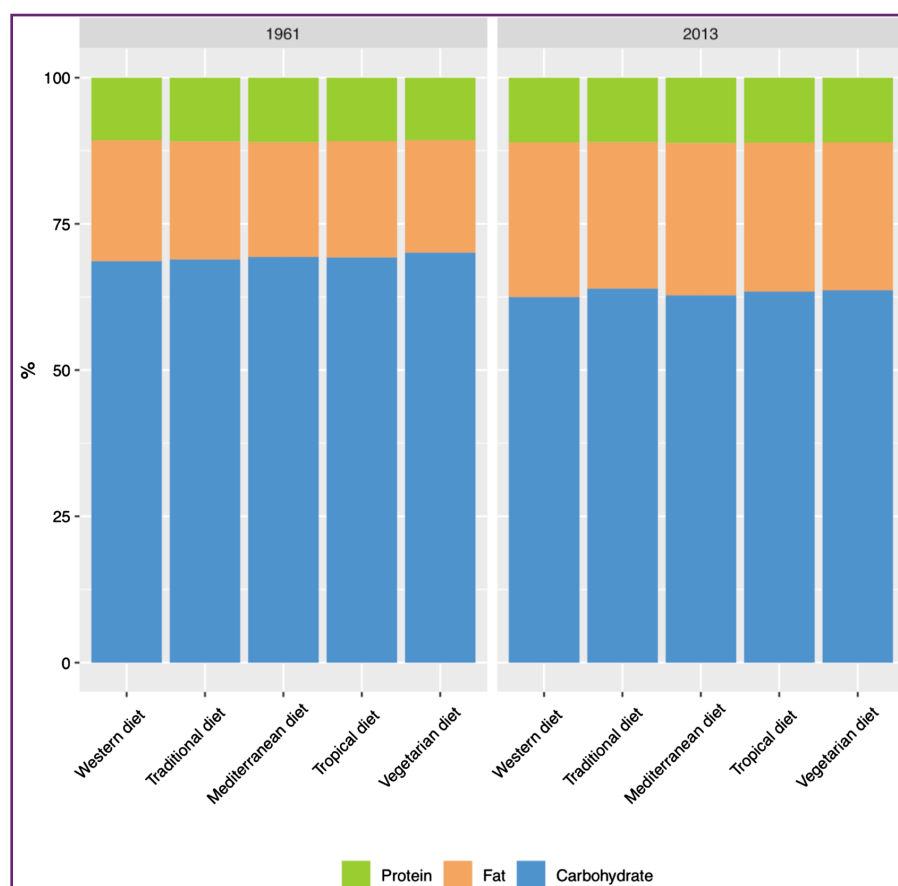


reflecting a transition from plant-based to animal-based foods. Globally, diets have become increasingly unhealthy owing to the confluence of two related facts: not only are we eating more calories, typically in processed forms but that these calories are increasingly from animal-sourced foods. Further, the decline in energy expenditure over time due to sedentary lifestyles allows the effect of these dietary changes to become apparent. The obesity problem has both quantity and quality dimensions.

“Efforts to change food consumption behaviour need to be redoubled and applied not just in rich countries but also globally.”

So what of the implications for mortality and morbidity? As discussed by Bleich *et al.* (2015), the relationship between food and health is complex, and one part of a much richer picture in which economics, lifestyle choices, genetics and medical advances play important roles (see, for example, *BMJ* 2020). However, a quick glance at Table 1 offers some food for thought. While life expectancy is expected to rise among the consumers in all dietary clusters, the figures for health-adjusted life expectancy (HALE) tell a different story. Specifically, while life expectancy at birth is expected to increase by some five years compared with babies born at the start of the millennium, almost all of these longer lives are predicted to be spent in

Figure 5: Changes in macronutrient composition between 1961 and 2013



poor health. While diet is clearly not the only culprit, there is mounting evidence from global studies of its increasingly influential role, with over one-fifth of all adult mortality being linked to dietary factors (*The Lancet*, 2019a).

Converging dietary trends

Historically a disease afflicting a small minority of consumers in the richest echelons of society, obesity is now commonplace almost everywhere, even in countries where malnutrition is endemic in some parts of the population. Against this backdrop we use an innovative time series clustering technique to evaluate whether it is possible to identify the dietary

patterns that are central to the obesity problem. The application of fuzzy clustering algorithms to half a century of annual per capita calorie intake in 118 countries detects five distinct clusters, corresponding to food consumption patterns, that we label Western, Traditional, Mediterranean, Tropical and Vegetarian diets. All share two common themes: rising calorie content and declining healthiness, both of which are probably due to the substitution of plant-based foods with food derived from animals. As a result, there appears to be a growing similarity in the dietary groups with the evidence pointing to a convergence on that which most closely resembles the ‘Western diet’. High in meat and animal fat and low

Table 1: Changes in Life Expectancy (LE) and Health Adjusted Life Expectancy (HALE) in years since 2000 (weighted averages by country)

	Western diet	Traditional diet	Mediterranean diet	Tropical diet	Vegetarian diet
Change in LE ^a	5.2	5.0	5.0	4.7	4.8
[LE at birth]	[66.0–71.2]	[65.0–70.0]	[66.1–71.1]	[67.1–71.8]	[65.3–70.1]
Change in HALE ^b	–5.0	–4.9	–4.9	–4.5	–4.8
[HALE at birth]	[63.0–58.0]	[62.1–57.2]	[62.9–58.0]	[63.6–59.1]	[62.1–57.3]

Figures inside brackets represent life expectancy in years for the beginning and ending period; ^achange between 2000–2013; ^bchange between 2000–2015.

in cereals and pulses, this dietary group is not only the most calorific but also the least healthy. Moreover, in recent decades the dietary quality of the Western diet has deteriorated more rapidly than other diets.

Some caveats are clearly in order. Foremost, is that data on apparent food consumption used in this study are no substitute for in-depth surveys of the food that is actually eaten. Second, as national averages, they mask issues, most notably malnutrition and the inequity of food availability, which afflict sub-groups of the population such as the rural poor. Our aim here is not to crowd-out the emergency that hunger represents, but to highlight an issue that often coexists with it. The key message is that in a future where people are predicted to live longer but not necessarily healthier lives, efforts to change food consumption behaviour need to be redoubled and



Globally there has been an increased intake of energy-dense, high-fat foods.

applied not just in rich countries but also globally. While public health education and other factors such as climate change, disease pandemics and the environmental costs of food production may arrest the worrisome

trends that are clear in the historical data, the sobering fact remains that after 30 years of trying, no country has been able to significantly reduce its obesity level. Clearly, there is much work to be done.

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Summary


National Food Consumption Patterns: Converging Trends and the Implications for Health

 Worldwide, obesity almost tripled between 1975 and 2016 and is now prevalent in both rich and poor countries. Using annual food availability data produced by the Food and Agriculture Organisation of the United Nations (FAO) covering half a century in 118 countries, this article explores the diets that are central to the problem of obesity, identifying groups of countries with similar consumption patterns. Applying algorithms from the fuzzy clustering literature, five distinct consumption patterns are revealed whose dietary composition broadly corresponds to diets that we label 'Western', 'Traditional', 'Mediterranean', 'Tropical' and 'Vegetarian'. Despite differences in dietary characteristics, all five share two common themes: rising total calories and declining healthiness, both of which are linked to the substitution of plant-based foods with food derived from animals. That the evidence points to a convergence on the 'Western' diet, the most obesogenic and least healthy of all the diets we consider, is a cause for concern. The key message is that in a future where people are predicted to live longer – but not necessarily healthier – lives, recent efforts to address the challenge are prescient, and as the results in the article imply, need to be heeded globally.

Modes de consommation alimentaire nationaux : tendances convergentes et incidences sur la santé

 L'obésité a presque triplé dans le monde entre 1975 et 2016 et elle est désormais répandue dans les pays riches comme dans les pays pauvres. À l'aide de données annuelles sur la disponibilité alimentaire couvrant un demi-siècle dans 118 pays, produites par l'Organisation des Nations Unies pour l'alimentation et l'agriculture (FAO), cet article explore les régimes alimentaires qui sont au cœur du problème de l'obésité, en identifiant des groupes de pays ayant des modes de consommation similaires. En appliquant des algorithmes tirés de la littérature sur les grappes floues, apparaissent cinq modes de consommation distincts dont la composition alimentaire correspond largement aux régimes que nous appelons 'occidentaux', 'traditionnels', 'méditerranéens', 'tropicaux' et 'végétariens'. Malgré des différences dans les caractéristiques alimentaires, les cinq partagent deux thèmes communs: l'augmentation des calories totales et la baisse du caractère bénéfique à la santé, tous deux liés à la substitution des aliments d'origine végétale par des aliments d'origine animale. Le fait que les résultats indiquent une convergence sur le régime 'occidental', le plus générateur d'obésité et le moins sain de tous les régimes que nous considérons, est préoccupant. Le message clé est que dans un avenir où les gens devraient vivre plus longtemps - mais pas nécessairement en meilleure santé -, les efforts récents pour relever le défi sont visionnaires et, comme les résultats de l'article le sous-entendent, doivent être pris en compte à l'échelle mondiale.

Nationale Muster des Lebensmittelkonsums: Konvergierende Entwicklungen und die Auswirkungen auf die Gesundheit

 Zwischen 1975 und 2016 hat sich die Anzahl an Übergewichtigen weltweit verdreifacht. Übergewicht ist heute in reichen wie auch in armen Ländern weit verbreitet. In diesem Artikel werden Ernährungsweisen betrachtet, die für das Problem des Übergewichts von zentraler Bedeutung sind und Gruppen von Ländern identifiziert, die ähnliche Ernährungsgewohnheiten aufweisen. Hierfür wurden jährliche Daten zur Lebensmittelverfügbarkeit verwendet, welche die Ernährungs- und Landwirtschaftsorganisation der Vereinten Nationen (FAO) über ein halbes Jahrhundert lang in 118 Ländern gesammelt hat. Unter Anwendung von Algorithmen aus der Fuzzy-Clustering-Literatur wurden fünf verschiedene Ernährungsmuster herausgearbeitet, deren Nahrungszusammensetzung allgemein der von uns als 'westlich', 'traditionell', 'mediterran', 'tropisch' und 'vegetarisch' bezeichneten Ernährungsformen entspricht. Trotz Unterschieden in ihren Merkmalen haben alle fünf Ernährungsformen zwei Themen gemeinsam: steigende Gesamtkalorienmenge und abnehmende Gesundheit, die beide in Verbindung mit dem Ersatz pflanzlicher Lebensmittel durch Lebensmittel auf Basis von Tierprodukten stehen. Dass die Erkenntnisse auf eine Annäherung an die „westliche“ Ernährung hindeuten, welche die am stärksten Übergewicht verursachende und ungesündeste Ernährungsform unter allen betrachteten ist, gibt Anlass zur Sorge. Die Schlüsselbotschaft ist, dass in einer Zukunft, in der die Menschen voraussichtlich länger - aber nicht unbedingt gesünder - leben werden, die jüngsten Bemühungen zur Bewältigung dieser Herausforderung vielversprechend sind und, wie die Ergebnisse des Artikels andeuten, weltweit Beachtung finden müssen.

Summary