Measured energy content of frequently purchased restaurant meals: multi-country cross sectional study

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ABSTRACT

OBJECTIVE
To measure the energy content of frequently ordered meals from full service and fast food restaurants in five countries and compare values with US data.

DESIGN
Cross sectional survey.

SETTING
223 meals from 111 randomly selected full service and fast food restaurants serving popular cuisines in Brazil, China, Finland, Ghana, and India were the primary sampling unit; 10 meals from five worksite canteens were also studied in Finland. The observational unit was frequently ordered meals in selected restaurants.

MAIN OUTCOME MEASURE
Meal energy content, measured by bomb calorimetry.

RESULTS
Compared with the US, weighted mean energy of restaurant meals was lower only in China (719 (95% confidence interval 646 to 799) kcal versus 1088 (1002 to 1181) kcal; P<0.001). In analysis of variance models, fast food contained 33% less energy than full service meals (P<0.001). In Finland, worksite canteens provided 25% less energy than full service and fast food restaurants (mean 880 (SD 156) versus 1166 (298); P=0.009). Country, restaurant type, number of meal components, and meal weight predicted meal energy in a factorial analysis of variance (R^2=0.62, P<0.001). Ninety four per cent of full service meals and 72% of fast food meals contained at least 600 kcal.

Modeling indicated that, except in China, consuming current servings of a full service and a fast food meal daily would supply between 70% and 120% of the daily energy requirements for a sedentary woman, without additional meals, drinks, snacks, appetizers, or desserts.

CONCLUSION
Very high dietary energy content of both full service and fast food restaurant meals is a widespread phenomenon that is probably supporting global obesity and provides a valid intervention target.

Introduction

The prevalence of obesity is at epidemic levels in most countries.[1][2] In additionto being the underlying cause of most non-communicable diseases,[1] obesity is a major risk factor for dementia, Alzheimer's disease, and disability in old age,[3][4] and it challenges national economies through its detrimental effects on workforce productivity, healthcare costs, and rates of disability.[5–9] The World Health Organization and many national governments have issued calls to action to reduce population obesity.[10] However, the prevalence of obesity continues to rise, showing that effective interventions have yet to be identified.

The increase in per capita dietary energy worldwide, especially from refined carbohydrates and fats,[11] identifies increased energy intake as an important facilitator of global obesity. However, the development of effective interventions to reduce overeating requires identification of specific eating practices, environmental factors, or both that are quantitatively important and malleable. Fast food has been widely implicated as one such target on the basis of its high energy content and a variety of research findings including a positive association between number of fast food restaurant transactions and rates of obesity across countries.[12][13] However, studies of the spatial association of the density of fast food outlets and rates of obesity provide conflicting evidence.[14–16] Furthermore, the prevalence of obesity increased to a greater extent in a region of the US with zoning interventions to reduce access to fast food,[17] although this single study finding needs to be replicated. Nevertheless, these data call into question the presumed role of fast food in the obesity epidemic.

A major limitation of previous research on restaurants and obesity is that almost all studies examining the composition of meals have used nutritional

WHAT IS ALREADY KNOWN ON THIS TOPIC

The prevalence of obesity continues to increase in most countries

Fast food has been proposed as an important contributor to global obesity on the basis of nutritional information reported by large chain restaurants

Little is known about other types of restaurant meals owing to a lack of data on measured meal energy content

WHAT THIS STUDY ADDS

Of five countries (Brazil, China, Finland, Ghana, and India), only restaurants in China served meals containing significantly less energy than restaurants in the US

In contrast to widespread assumptions, fast food meals contained 33% less dietary energy on average than meals from full service restaurants

The high energy content of restaurant meals may be an important contributor to the global obesity epidemic and a potentially impactful target for public health interventions

data provided by large chain restaurants.[12] [18] [19] This approach excludes restaurants that do not provide nutritional information, which is the case for most full service and local fast food restaurants. The limited information available on measured energy contents indicates that restaurants in general, rather than fast food restaurants specifically, provide very high energy levels. In some cases, restaurant meals supply a whole day's energy needs in a single entrée.[20–24] Furthermore, the positive relation between frequency of eating out and higher overall energy intake and weight gain is consistent with experimental data suggesting a low ability to compensate for bouts of overeating by equivalent undereating on other occasions.[25–29] However, almost all data have been collected in the US,[20] [21] [23] and very little information is available from other countries,[24] especially the low and middle income countries where rates of obesity are rising very rapidly.

This study measured the energy contents of the most frequently ordered meals in full service and fast food restaurants in five countries (Brazil, China, Finland, Ghana, and India), as well in worksite canteens in Finland. We compared data with the measured energy contents of the most frequently ordered US restaurant meals to test the hypothesis that large restaurant portions are not a phenomenon unique to the US and to identify other countries where portion sizes may be problematic.

Methods

This study measured the energy content of a representative sample of 223 popular meals purchased from 111 randomly selected full service (sit down meal served by waitperson and eaten in premises) and fast food (counter served meal eaten on or off premises) restaurants in a major city in each of six countries (Ribeirao Preto in Brazil, Beijing in China, Kuopio in Finland, Accra in Ghana, Bangalore in India, and Boston in the US). In addition to the restaurant orders, 10 meals were obtained from five worksite canteens in Finland as an exploratory study component to compare data with regular full service and fast food restaurants. We included this last evaluation because worksite canteens in Finland typically offer subsidized lunches to support employees' health and are included in national dietary recommendations.[30] We collected and analyzed meals for Brazil, China, Ghana, Finland, and India between 2014 and 2017. We compared data with comparable information for the most 100 popular meal choices in US restaurants. We analyzed a total of 233 meals including the US sample and the Finland canteens.

We selected countries from diverse regions of the world to provide data, and we chose the specific sites because they had experienced researchers able to implement the local protocol. We chose the US as the comparison site because of existing comparable data on the most popular US menu orders. We extracted the US data from two previous studies that also randomly selected restaurants and measured the most frequently

ordered meals,[20] [23] with three additional randomly selected fast food restaurants for comparability across sites. Full service restaurants in the US data included the most popular ethnic choices (American, Mexican, Chinese, Italian, and Japanese), reflecting the multiethnic nature of popular US cuisines.

For the purpose of this study, we defined a "meal" as the main course with side dishes that were included at no extra charge. We did not include drinks, appetizers, and desserts that required extra payment. We used this approach because the focus of the study was to compare the most commonly ordered meals across countries, recognizing that we likely underestimated total energy content of typical meal orders owing to the non-inclusion of drinks and perhaps additional courses.

Selection of restaurants and meals

The restaurant selection process involved local research teams using internet searches and site visits to identify all full service and fast food establishments in a predefined geographic area of approximately 25 km^2 in the locality of the research center in each country. Buffet restaurants and hot pot restaurants (which are equivalent to buffets in terms of self selected portion sizes) were not included. Each restaurant was then categorized by ethnicity (local, international, specific other national), with the goal of excluding international and specific national restaurants from the selection process unless they were widespread (defined as >15% of total restaurants). As restaurants in Ghana are used for both full service meals and fast food, selected eating establishments at this site were not distinguished by restaurant type.

Full service and fast food restaurants were randomly selected for inclusion in the study by use of a random number generator in SAS 9.4, and back-up sites were also randomly identified for use if initial selections were closed or ineligible or failed to have the meals previously identified for collection at the time the order was placed. Restaurants are not identified by name in the data presentations because they were selected randomly to represent general restaurant categories. The local research staff called each selected restaurant and asked to speak with the restaurant manager to obtain information on the most frequently ordered main course meals. These calls were made before the selected meals were ordered for collection and analysis. We chose this method of selecting the most frequently ordered meals because we found no national or regional statistics to determine the most frequent orders at each site.

Meal collection and energy determination

Local research staff posed as restaurant patrons and ordered the target meals by following a standard procedure. Orders were placed for the identified meals in person at the time of the main meal in that country. Collected foods included all those that came as part of the meal order but did not include any additional items that required further payment. Any drinks that

came with the meal were excluded from analyses. The researcher requested the meal to take away with all items packed separately.

The two most popular meals in each randomly selected restaurant were targeted for collection in Brazil, Ghana, Finland, and India (five full service and five fast food restaurants per country). In addition, the 10 most popular meals from five worksite canteens in Finland were included as an exploratory study component. As the work in China was part of a larger investigation, and restaurant goers in full service restaurants in China routinely share individual items among people dining together, a different method of sample collection was necessary. A single full service meal order was placed for the five (four at one location) most popular items in each restaurant (74 foods items across 15 full service restaurants), and information was divided by the number of items to yield an energy equivalent meal size for a single diner. This method approximates the traditional practice of consuming an average of one item per person, with a greater number of items ordered for variety and so that leftovers can be taken home.

After the purchase, meals were taken to the laboratory and individual components were separated from each other if not previously done by the restaurant. Total meals and meal components were then weighed to within 0.1 g on a calibrated electronic balance before preparation for analysis by bomb calorimetry. Samples from Brazil, Ghana, Finland, and India were shipped to Tufts University for analysis because the sites had no local bomb calorimeter, whereas samples from China were analyzed by the local investigator's team. Samples were prepared as previously described.[22] Briefly, the meals were homogenized to a smooth puree, freeze dried to constant weight, and reground in a food processor to a fine, dry powder. The food powders were then analyzed for gross energy content in duplicate by bomb calorimetry (Parr 1261 at Tufts University and Parr 6100 with a 1109 semi-micro bomb for China samples; Parr Instruments, Moline, IL, USA). Both bomb calorimeters were standardized daily with benzoic acid pellets, and all calibration values were within 1% of the known heat of combustion for benzoic acid. Total energy content was determined for each meal as the product of total dried food weight and the mean heat of combustion of the duplicate dry samples. Energy density was calculated as gross energy per gram of fresh meal weight. In addition, we calculated the percentage of meals containing at least 600 and at least 2000 kcal metabolizable energy, with adjustment for the obligatory approximate 10% energy losses in urinary nitrogenous compounds and fecal energy.[31 32] We did the 600 kcal/meal calculation because this is a benchmark that has recently been adopted as a public health recommendation for a healthy level of meal energy in the UK.[33] We did the 2000 kcal/meal calculation because this is the total daily energy requirement of a typical woman.

Statistical analysis

We compared the mean energy content of meals (primary outcome) for Brazil, China, Ghana, Finland, and India with the US data. A retrospective power calculation indicated that the sample size was sufficient to detect an approximate 180 kcal/meal difference between the US and the international sites with 80% power. We also examined meal weight (g) and energy density (kcal/g). We obtained descriptive statistics for each measurement for each country by restaurant type (full service and fast food). We compared full service and fast food meals within each country by using an independent samples t test. We calculated sample weighted mean energy content, meal weight, and energy density separately for each country on the basis of the number of measured full service and fast food meals. All measurements were natural-log transformed for use in statistical tests to meet model assumptions for normality. We compared weighted mean energy content, meal weight, and energy density for each county with the US by using an analysis of variance model. We used factorial analysis of variance to evaluate the major predictors of meal energy content, including country, restaurant type, and number of individual foods per meal. We assessed effect modification of country by both restaurant type and number of foods. We calculated least squares means and 95% confidence intervals. We compared worksite canteen meals with the combined full service and fast food restaurants by using the Wilcoxon rank sum test. We used SAS 9.4 for all statistical analyses and considered a P value below 0.05 to be statistically significant. In addition to statistical analysis of the measured data, modeling of the impact of the results is given in the supplementary appendix together with a description of how the modeling was conducted, as outlined below.

Patient and public involvement

No patients or members of the public were directly involved in this study, other than as employees of restaurants that were targeted for covert meal collection. There are no plans to involve patients or the public in the dissemination of results.

Results

We found a significant positive association between meal weight and meal energy content (R^2=0.53; P<0.001; fig 1), although the moderate strength of the correlation indicates that meal weight by itself was a very imprecise predictor of meal energy content. In addition, a significant, negative association existed between meal energy density and meal weight (R^2=0.10; P<0.001; fig 1). The descriptions and energy contents of individual meals for each restaurant are given in supplementary table A.

The total energy content of fast food meals was significantly lower than that of meals from full service restaurants in Brazil (34%; P=0.03), China (46%; P<0.001), and the US (29%; P<0.001) (table 1).
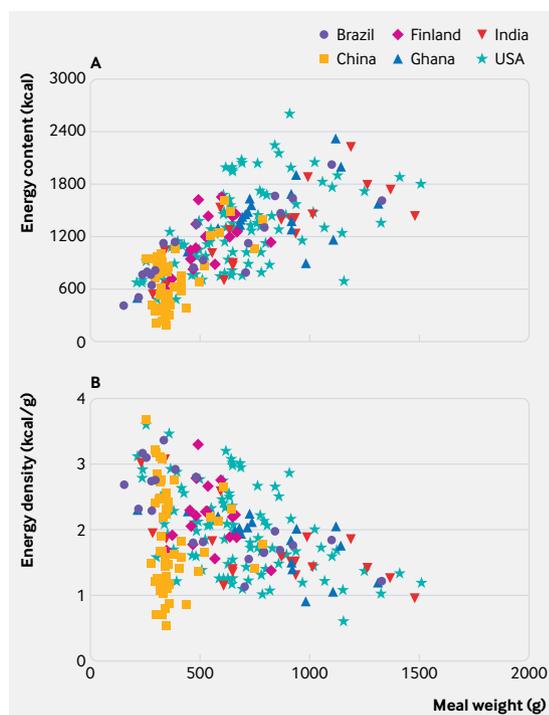
Fig 1 | Scatterplot of associations of meal weight with energy content (R^2=0.53; P<0.001) and energy density (R^2=0.10; P<0.001) for popular meals served in full service and fast food restaurants in six countries

Weights of fast food portions in these countries were also significantly lower than for meals from full service restaurants (P=0.002, P<0.001, and P<0.001 for Brazil, China, and the US, respectively), whereas the energy density (kcal/g) of fast food meals was higher in Brazil (P=0.003) and lower in China (P=0.005) than the energy density of meals from full service restaurants.

Only China had fast food meals that had less energy than US fast food (by 44%; P<0.001), and similarly only China had full service restaurant meals that had less energy than full service meals in the US (by 21%; P=0.009). The unadjusted mean energy content for all countries was 1317 (SD 442) kcal for full service meals and 809 (363) kcal for fast food meals (table 1). In addition, when we used country weighed values, 94% of meals from full service restaurants and 72% of fast food meals across all sites contained at least 600 metabolizable kcal, and 3% of meals from full service restaurants (including meals from Ghana, India, and the US) contained at least 2000 kcal/serving.

Figure 2 shows the mean differences in meal energy content, meal weights, and meal energy density across countries, using weighted mean values that incorporate the sample sizes for different meal types. In the primary study analysis, a comparison of meal energy content from Brazil, China, Ghana, Finland, and India with US data, only China had meal energy contents that were significantly less than the US (719 (95% confidence interval 646 to 799) kcal versus 1088 (1002 to 1181) kcal). In addition, only China had lower meal weights than US values (392 (353 to 435) g versus 562 (518 to 610) g) and also lower meal energy density (1.8 (1.6 to 2.0) kcal/g versus 1.9 (1.8 to 2.1) kcal/g). We did not identify any other significant comparisons.

Table 2 shows the multiple variable predictors of meal energy content. In model I (R^2=0.44; P<0.001), which included country and restaurant type, we observed a strong effect of country on meal energy content, and post hoc testing indicated that China had significantly lower meal energy content compared with US values (39%; P<0.001). Restaurant type also had a significant effect, and meals from fast food restaurants had lower energy contents than meals from full service restaurants, by 33% on average (P<0.001).

Table 1 | Mean energy content, meal weight, and energy density for full service and fast food restaurant meals in six countries. Values are means (SD) unless stated otherwise

Country and restaurant type	No of meals	Energy content (kcal)	P value*	Weight (g)	P value*	Energy density (kcal/g)	P value*
Brazil:							
Full service	10	1301 (453)	0.03	780 (327)	0.002	1.82 (0.56)	0.003
Fast food	10	862 (285)		337 (122)		2.63 (0.52)	
China:							
Full service	15	1045 (289)	<0.001	484 (169)	<0.001	2.32 (0.73)	0.005
Fast food	40	561 (236)		338 (30)		1.67 (0.71)	
Finland:							
Full service	10	1135 (346)	0.48	500 (102)	0.08	2.25 (0.52)	0.45
Fast food	8	1205 (242)		593 (117)		2.06 (0.45)	
Worksite	10	880 (156)	–	668 (93)	–	1.34 (0.27)	–
Ghana:							
Full service/fast food	20	1412 (392)	–	815 (256)	–	1.82 (0.41)	–
India:							
Full service	10	1414 (488)	0.22	855 (416)	0.59	1.86 (0.63)	0.54
Fast food	10	1129 (389)		731 (311)		1.68 (0.53)	
USA:							
Full service	71	1362 (469)	<0.001	741 (266)	<0.001	1.96 (0.65)	0.27
Fast food	19	969 (283)		475 (134)		2.12 (0.66)	
All countries:							
Full service	136	1317 (442)	–	717 (285)	–	1.98 (0.63)	–
Fast food	87	809 (363)	–	436 (188)	–	1.92 (0.71)	–

*P values calculated by independent samples t tests to compare full service with fast food meals within country.
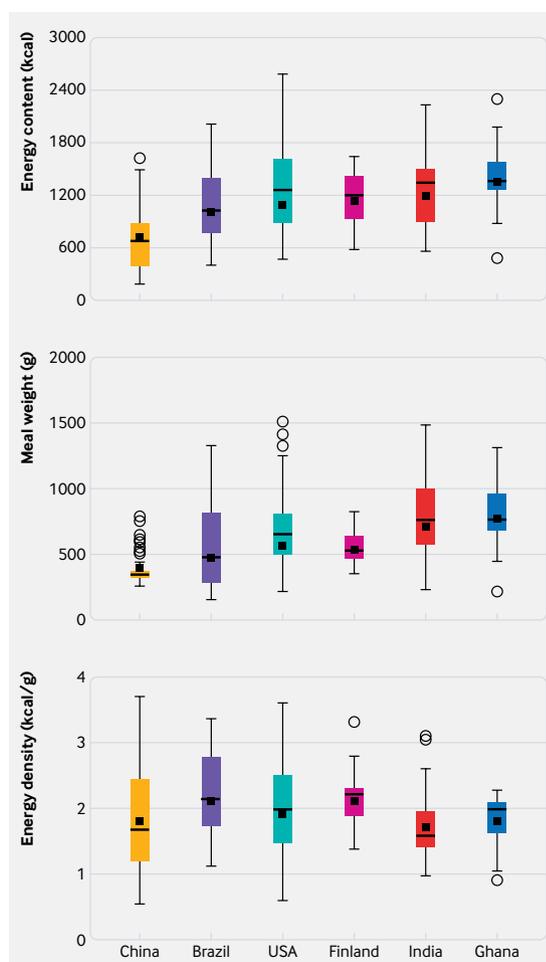
Fig 2 | Energy content, weight, and energy density of restaurant meals in six countries. Boxplots show unweighted fifths (five number summary) and weighted means (indicated by filled square)

within the meal (R^2=0.53; P<0.001). Country of origin (P<0.001), restaurant type (P=0.003), and number of food items per meal (P<0.001) were all significant variables in this model. Model III shows the best fitting model (R^2=0.62; P<0.001), which predicted meal energy content from country, restaurant type, number of foods, and meal weight. The significantly lower energy content of meals from China compared with the US was retained in this model. Number of foods and meal weight were also significant, but type of meal (full service versus fast food) was not. These analyses show that only China had meals that were lower in energy content than the US, that fast food meals had less energy than full service meals, and that the lower energy content of fast food was in part explained by smaller portion sizes in the meal. In addition, the modeling of the impact of meal energy provided in the supplementary appendix (supplementary tables B-H and supplementary figures A-G) indicated that, except in China, consuming current servings of a full service and a fast food meal daily would supply between 70% and 120% of the daily energy requirements of a sedentary woman (depending on the country), without additional meals and snacks and without the drinks, appetizers, and desserts that were excluded from the definition of a meal in this study.

To examine meal energy content and other meal variables in worksite canteens in Finland, we compared values with combined data from full service and fast food restaurants (fig 3). Canteen meals had a significantly lower mean energy content, by 25% on average, compared with the full service and fast food meals (mean 880 (156) v 1166 (298) kcal; P=0.009). In addition, the canteen meals had higher meal weight and lower energy density (P=0.004 and P<0.001, respectively).

Discussion
The increasing global per capita energy intake, especially from refined carbohydrates and fats,[11] as

Model II shows the prediction of meal energy content by country, restaurant type, and an additional independent variable for the number of food items

Table 2 | Regression models predicting restaurant meal energy content in kilocalories						
	Model I		Model II		Model III	
Variable	Coefficient (95% CI)	P value	Coefficient (95% CI)	P value	Coefficient (95% CI)	P value
Country of origin:						
Brazil*	0.93 (0.77 to 1.13)	0.45	0.93 (0.79 to 1.12)	0.44	1.02 (0.87 to 1.20)	0.79
China*	0.61 (0.53 to 0.71)	<0.001	0.70 (0.59 to 0.82)	<0.001	0.81 (0.70 to 0.93)	0.005
Finland*	1.00 (0.81 to 1.23)	0.99	0.91 (0.76 to 1.12)	0.40	1.03 (0.86 to 1.23)	0.72
India*	1.04 (0.82 to 1.32)	0.72	0.95 (0.76 to 1.20)	0.67	0.98 (0.80 to 1.20)	0.84
United States	Referent	–	Referent	–	Referent	–
Restaurant type:						
Fast food	0.66 (0.56 to 0.78)	<0.001	0.78 (0.66 to 0.90)	0.003	0.91 (0.78 to 1.06)	0.22
Full service	Referent	–	Referent	–	Referent	–
No of foods per meal:						
More than one	–	–	1.35 (1.16 to 1.57)	<0.001	1.21 (1.06 to 1.39)	0.006
One	–	–	Referent	–	Referent	–
Meal weight (g)	–	–	–	–	1.58 (1.39 to 1.80)	<0.001
Country × restaurant type	1.03 (0.96 to 1.11)	0.43	1.04 (0.97 to 1.11)	0.30	0.99 (0.93 to 1.05)	0.72
Country × food number	–	–	0.93 (0.85 to 1.02)	0.12	0.97 (0.90 to 1.05)	0.39
Model R^2	0.44	<0.001	0.53	<0.001	0.62	<0.001

Energy content and meal weight measurements were natural-log transformed. Models use 203 meals across five countries (excluding Ghana because all restaurants were considered equivalent providers of fast food and full service meals).
*P values for post hoc tests for comparisons of each country v US using Dunnett's method.
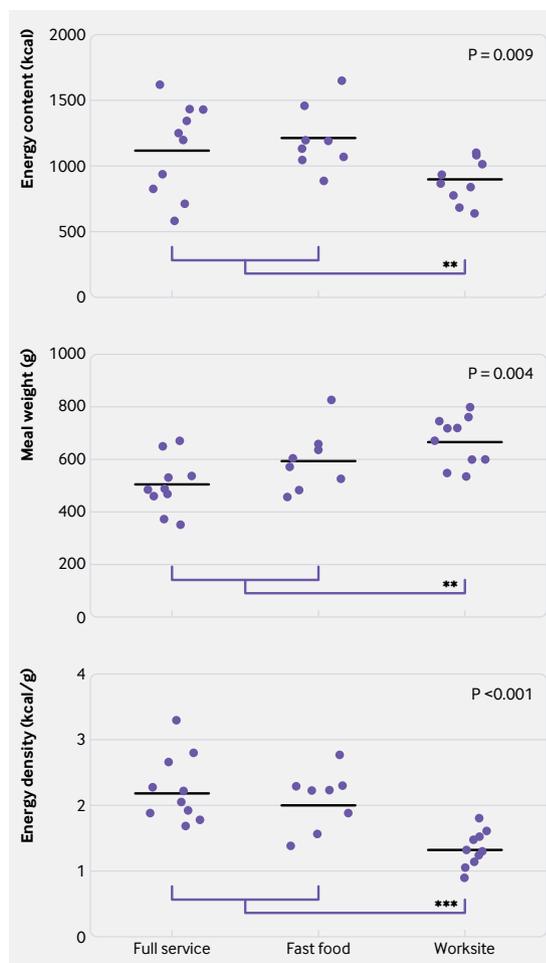
Fig 3 | Individual and mean values for energy content, meal weight, and energy density of meals served in different restaurant types in Finland. Canteen values differed significantly from weighted values for full service and fast food restaurants. **P<0.01. *** P<0.001

well as the positive association between rising rates of obesity and increasing energy intake across different countries,[34] highlights the central role that overeating has played in the global obesity epidemic. However, identifying specific aspects of eating behavior, the food environment, or both that are quantitatively important and can lead to effective public health interventions has been challenging. To our knowledge, this is the first study of measured restaurant meal energy contents across different countries, allowing us to examine meals from full service and local fast food restaurants that do not routinely provide nutritional information. Notably, given the previous focus on high meal energy content as a particular problem in the US, only one country (China) had an average meal energy content that was significantly lower than the US value. In addition, substantial variability existed in meal energy content within countries, and in some cases more than a twofold difference existed in the energy content of the same meals purchased in different restaurants (for example, the same meal in China had 1386 and 657 kcal in restaurants 37 and 39 in supplementary table A), which would make

providing consumers with guidance on how to eat less in restaurants extremely challenging in the absence of uniform menu labeling. Nevertheless, we observed some patterns—for example, single orders of popular meals ordered in fast food restaurants contained 33% less energy than meals in full service restaurants, in direct contrast to previous suggestions that the problem of excessive meal energy contents is specific to fast food. These results are broadly consistent with previous work by our team in the US in identifying restaurant meals in general, rather than fast food specifically, as an important target for interventions to reduce obesity,[20–23] and they show that this is a global rather than a specifically US problem.

Strengths and limitations of study

Implementing comparable protocols across six countries is challenging, and the study has several limitations. Firstly, despite the very large measured energy content of restaurant meals, this study almost certainly underestimates the restaurant meal orders made by consumers, because we analyzed only main course meals (entrées plus side dishes provided with them), whereas people dining out will typically order drinks, and sometimes appetizers and desserts, as well. In addition, although we collected the most popular orders as defined by the restaurants, we had no independent data on the frequency of meal purchases. Some restaurant patrons may also consume multiple meals at the same sitting, which would have resulted in further underestimation of meal energy. Seasonality was also not considered, and sampling was restricted to a specific urban area in each country. Concerning China specifically, because full service meals are consumed communally, the assumptions made in sample collection (an equal number of food items and diners on average) necessarily influenced the accuracy of projected meal energy levels. An additional general limitation was that most of the reference US data were collected about three years earlier than the data for other countries, but this is unlikely to have had a more than a small effect. We also assumed that the size of meals collected for taking away was the same as those supplied to diners inside the restaurants. These limitations notwithstanding, this study provides the first multinational data on measured energy contents of popular meals from full service and fast food restaurants and, as such, provides unique information relevant to the global obesity epidemic.

Interpretation and policy implications

Very high energy content of restaurant meals is problematic for several reasons. In particular, the frequency of consuming meals prepared away from home is increasing worldwide.[35–38] In addition, even the average portion sizes measured in this study are very high relative to human energy requirements, especially for people with lower than average requirements such as sedentary people, older women, and people below average height. Our supplementary modeling data show that two average sized restaurant

meals a day (one from a fast food restaurant and one in a full service restaurant) would provide almost all the daily energy requirement of a person with one standard deviation lower energy requirements than average, without any additional meals, drinks, snacks, appetizers, or desserts.

Large restaurant meals as measured here would not necessarily be a problem if people ate them infrequently, but, as noted above, dining out is now common. In addition, three meals and one or more snacks daily is usual worldwide, including in the countries studied here.[39] In addition, even the average [40-45] Excessively sized restaurant meals may also normalize overeating in other situations,[46] with a resulting further increase in energy intake. Although people eating out frequently may try to compensate by choosing smaller meals, the consistent associations between frequent eating out and body mass index suggest that this strategy is, at the very least, not fully effective.[25-28] Part of the explanation for this phenomenon seems to be that humans have a poor ability to compensate for overeating at one meal by eating less at other meals, especially for higher energy meals and liquid calorie sources,[47] resulting in a net increase in energy intake when eating of restaurant meals is frequent.[25 27] This may be due in part to the cephalic phase initiation of digestion, which is a normal physiologic mechanism whereby the sight and smell of food causes parasympathetic mediated preparations for digestion that include increased hunger, enlarged stomach lumen, and greater gastric motility.[48 49] Effectively, the human body is in equilibration with the immediate food environment via its cephalic phase, with the result that human eating patterns tend to synchronize with the available amount of food, whatever that amount is. Another innate mechanism that may contribute to overeating when portion sizes are very large is an increase in bite size without a compensatory decrease in the rate of bites, which results in a faster rate of energy ingestion.[50]

The results of this study support menu labeling for all restaurant foods, because in studies of large chain fast food restaurants, the introduction of labeling has been associated with reduced energy content of offered menu items over time,[51] and the same benefit could potentially be achieved in all restaurants with uniform labeling requirements. We have previously provided an open access web tool to support recipe calculation by restaurants.[52] In addition, our results suggest that recent public health recommendations to reduce restaurant meal servings to 600 kcal could become an important contributor to reducing the prevalence of obesity worldwide, by helping to prevent weight gain and providing active support for weight loss.[33] Results of our supplementary modeling indicate that if restaurant meals were reduced to 600 kcals, even US adults with low energy requirements could consume up to seven restaurant meals a week without consuming more than 20% of daily requirements on average. However, 94% of meals from full service restaurants and 74% of meals from fast food restaurants contained more than 600 kcal

in this study, indicating that substantial changes would be needed in all countries if the new guidelines were broadly adopted. We have also previously suggested that allowing restaurants to serve any meal size, as long as they additionally offer physiologically reasonable serving sizes of the same meals at a proportionally reduced price, could be a flexible option that would provide consumers with a strong economic incentive to reduce overeating when eating out.[21] This option would also take into account the fact that many but not all people would benefit from meals as small as 600 kcal, allowing for larger orders to be placed by those who want a larger portion. Focus group studies have indicated that restaurant owners see ways to make proportional pricing mechanisms feasible, including by offsetting the lower profit margin on smaller portions by increasing the price of larger portions.[53]

During the past decade, substantial attention has been given to the potential role of fast food in the global spread of obesity, and public health interventions to reduce fast food consumption have been promoted.[13] However, one intervention that reduced the availability of fast food with zoning regulations was associated with an increase in the prevalence of obesity rather than the reverse,[17] and studies of the spatial association of obesity and fast food restaurants provide conflicting results.[14-16] Our study found that single servings of fast food meals contained less—not more—energy on average than full service meals (unweighted means: 809 v 1317 kcal/meal), and significantly lower values were also seen in three countries (Brazil, China, and US). It is also noteworthy that, although most large fast food chains did not meet the predefined criteria for restaurant density to be included in this study, local fast food restaurants are very common worldwide and have been shown to serve meals with energy contents that were broadly comparable.[12 18 54] Overall, the results of this study suggest that the controversy about the importance of fast food in the global obesity epidemic may be due to the fact that international fast food is only one of several types of meals prepared away from home that are served in excessive portion sizes. Our findings further suggest that new public health interventions should consider all types of meals prepared away from home as targets for intervention, not just meals from fast food restaurants providing nutritional information.

Two countries among the ones tested stand out as having potentially positive lessons for future interventions. Although, as noted above, there is greater uncertainty in the accuracy of the data from China than from the other countries in the study, China had 34% lower mean meal energy contents than the US (weighted means: 719 v 1088 kcal/meal) and the lowest mean fast food meal energy content of any country, which is likely to be a far greater difference than can be accounted for by the possible bias in sample collections. The number of countries tested was too small to analyze the relation of the energy content of restaurant meals with the prevalence of obesity, but nevertheless it is noteworthy that China has the

lowest prevalence of obesity of any country in this study.[1] Finland was another notable country because, although the energy contents of commercial full service and fast food restaurants were not different from US values, a finding consistent the high prevalence of obesity nationwide,[55] the worksite canteen meals contained 25% less energy than full service and fast food restaurants (880 *v* 1166 kcal/meal). Worksite canteens in Finland are supported by social policies and included in dietary recommendations, and their widespread use has been linked to improved dietary habits.[56]

In contrast to the positive examples of China and Finland, Ghana and India had restaurant meal energy contents that were not different from the high values observed in the US, even though they are lower-middle income countries with limited financial resources for the treatment of diabetes, cardiovascular disease, and other non-communicable diseases resulting from obesity. Little information is available from these countries on the frequency of consumption of restaurant meals, but high meal energy content is likely to have a particularly negative impact, because smaller body sizes mean that restaurant meals are disproportionately large relative to energy requirements. As in the US, trends in these countries seem to be driven by a combination of consumer demand and the profits being made by food service industries,[57][58] indicating that government led interventions are more likely to be effective than voluntary industry sponsored changes.

Conclusions and future research

This study found that the measured energy content of meals from restaurants in Brazil, Ghana, India, and Finland were not significantly different from the very high values previously reported for the US, and only one country (China) had measured values lower than the US. In addition, and contrary to widespread assumptions, fast food meals contained significantly less energy than did meals from full service restaurants. Further studies are needed to expand testing of restaurants in different countries and locations. Nevertheless, the consistency of results obtained here across very diverse countries suggests that the very high energy content of meals prepared away from home generally, rather than of fast food specifically, may be an important contributor to the global obesity epidemic and a potentially impactful target for public health interventions.

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Supplementary tables and figures