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Fast Food consumption and Body Mass Index in children and adolescents: an international cross-sectional study

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ABSTRACT:

Objective: To investigate whether reported fast food consumption over the previous year is associated with higher childhood or adolescent body mass index (BMI).

Design: Secondary analysis from a multi-centre, multi-country, cross-sectional study (International Study of Asthma and Allergies in Children (ISAAC) Phase Three).

Subjects and Methods: Parents / guardians of children aged 6-7 completed questionnaires which included questions about their children's asthma and allergies, fast food consumption, height and weight. Adolescents aged 13-14 completed the same questionnaire. The questionnaire asked "In the past 12 months, how often on average did you (your child) eat fast food/burgers?" Responses were; infrequent (never / only occasionally), frequent (once / twice a week), or very frequent (three or more times per week). A general linear mixed model was used to determine the association between BMI and fast food consumption, adjusting for Gross National Income per capita by country, reported or measured height and weight, age, and sex.

Results: 72,900 children from 17 countries and 199,135 adolescents from 36 countries provided data. Frequent and very frequent fast food consumption was reported in 23% and 4% of children, and 39% and 13% of adolescents. Children in the frequent and very frequent groups had a BMI 0.15 kg/m^2 and 0.22 kg/m^2 higher than the infrequent group ($P<0.001$). Adolescent males in the frequent and very frequent groups had a BMI 0.14 kg/m^2 and 0.28kg/m^2 lower than the infrequent group ($P<0.001$). Adolescent females in the frequent and very frequent groups had a BMI 0.19kg/m^2 lower than the infrequent group ($P<0.001$).

Conclusion: Reported fast food consumption is high in childhood and increases in adolescence. Frequent and very frequent consumption is associated with a higher BMI in children. In contrast, this is associated with a lower BMI in adolescents.

Strengths and limitations of this study:

- 199,135 adolescents from 36 countries and 72,900 children from 17 countries provided information on their height, weight and fast food consumption.
- Many of the countries were middle and low income from which previous data on the association of fast food consumption and BMI had not been reported.
- There is an association between increasing frequency of fast food consumption and higher BMIs in 6-7 year old children, but this association was reversed in adolescents.
- As this is a cross sectional study, causality cannot be proven, but it provides evidence that among children from many different nations, fast food consumption may contribute to weight gain.
- The reverse association observed in adolescents should be interpreted with caution, as the results may be affected by bias, particularly under-reporting of fast food consumption and reverse causation.

INTRODUCTION:

The rising prevalence of childhood obesity is marked (1, 2), and there are well documented concerns about the future health implications of obesity in childhood (3-7). This problem has been identified in low and middle income countries as well as affluent countries (8, 9).

While potential contributors to the problem of childhood obesity are considered to be multiple and complex, the increasing availability of fast food in many countries has been implicated due to its energy dense and low nutritional nature, large portion sizes and increasing availability (10-13). Studies investigating associations between fast food consumption in children and Body Mass Index (BMI) have produced mixed results, some demonstrating small but significant associations between fast food consumption and increased BMI (12, 14-17), while others have failed to demonstrate a significant association (18-20). Many of these have been single centre studies and involved small populations.

The International Study of Asthma and Allergies in Childhood (ISAAC) Phase Three programme was designed to measure time trends in the prevalence and severity of asthma, rhinoconjunctivitis and eczema and to explore the relationship between lifestyle, other putative risk factors and the development of asthma and allergies (21). It also provided the opportunity to explore the relationship between lifestyle factors such as fast food consumption and BMI, as heights, weights and information on the frequency of fast food consumption of participants were gathered in many centres through an optional environmental questionnaire that was answered by parents of children and by the adolescents themselves.

We hypothesised that there would be an association between greater fast food consumption and higher BMI in both children and adolescents, and that this association would be observed worldwide.

SUBJECTS AND METHODS:

ISAAC is a multicentre, multi-country, multiphase, cross-sectional study investigating the prevalence of the symptoms of asthma, rhinoconjunctivitis and eczema, and the role of risk factors, as previously described (21). ISAAC Phase Three used the Phase One standardised core questionnaire on symptoms of asthma, rhinoconjunctivitis and eczema, and included an optional environmental questionnaire to collect potential risk factor data including height, weight, and fast food consumption. Adolescents self-completed their questionnaires and parents or guardians completed questionnaires for the children. The questionnaires are on the ISAAC website: isaac.auckland.ac.nz.

Main outcome variable - Body Mass Index:

Height and weight were reported by the parents of the children, and were self-reported by adolescents. In some centres, each subject's height and weight were measured objectively; there were no standardised or specific instructions for doing this. BMI was calculated as weight (kg)/height $(m)^2$.

Explanatory variables:

Fast food consumption was established by asking participants to answer the following question: "In the past 12 months, how often, on average, did you [your child] eat the following?"

'Fast Food / Burgers' were listed as one option along with 14 other foodstuffs including meat, seafood, fruit and vegetables. The participants were asked to categorise their intake of each listed food as "Never or only occasionally"; "once or twice per week"; or "Three or more times a week". These responses were categorised as 'infrequent', 'frequent' and 'very frequent'. Each variable was examined separately for both age groups.

Country Gross National Index (GNI) was based on the 2006 World Bank of Gross National Income by country. The World Bank categories of high income, high middle income, low middle income and low

income countries were dichotomised into 'high income' (high and high middle income) and 'low income' (low middle and low income) categories.

Participants:

For children aged 6-7 years, data were submitted from 73 centres in 32 countries (214,706 subjects). For adolescents aged 13-14 years data were submitted from 125 centres in 54 countries (369,881 subjects).

Centres that provided data on height, weight and fast food consumption for at least 70% of participants were included in our analyses. Individuals without complete age, sex, fast food consumption, height or weight data were excluded.

Data cleaning:

To eliminate likely erroneous BMI data, we applied the following thresholds:

- For children in each centre, those in the top and bottom 0.5% of weights and heights, and those with heights less than 1.0 metre were excluded. Children with BMI less than 9kg/m^2 and greater than 40kg/m^2 were excluded.

- For adolescents in each centre, those in the top and bottom 0.5% of weights and heights, and those with heights less than 1.25 metres were excluded. Adolescents with BMI less than 10kg/m^2 and greater than 45kg/m^2 were excluded.

Following sequential application of the exclusion and data cleaning criteria described above, 72,900 children (30 centres / 17 countries) and 199,135 adolescents (74 centres / 36 countries) were included in the final analysis (Figure 1). Parents provided heights and weights for 60,027 children, while 12,873 children had their heights and weights measured. 154,624 adolescents provided self-reported height and weight while 44,511 adolescents had measured heights and weights.

Figure 1: Flow of subjects through study.

STATISTICAL ANALYSIS:

BMI was assessed separately for each age group using a general linear mixed model with centre as a random effect and GNI for each country (low and high), the individual's age, sex, measurement type (reported or measured), and fast food consumption('infrequent', 'frequent' 'very frequent') as fixed effects. The BMI values reported are the modelled means for those who reported infrequent fast food consumption in the children and adolescent groups respectively.

In the adolescent group statistically significant interactions were found between sex and fast food consumption, and measurement type and fast food consumption. There was also an interaction found between country GNI and fast food consumption. Consequently, analyses were done separately for each sex, measured height and weight data only, and GNI categories. No similar interactions were found in the children's group, but there were sufficient numbers to analyse each sex separately, which we elected to do.

RESULTS:

Fast food consumption:

22.6% of children reported frequent fast food consumption and 4.2% reported very frequent fast food consumption. Combined frequent and very frequent fast food consumption in each country ranged from 10% in Poland to 63% in South Korea (Figure 2a).

38.7% of adolescents reported frequent fast food consumption and 12.6% reported very frequent consumption. Frequent and very frequent fast food consumption ranged from 15% in Indonesia to 79% in South Africa (Figure 2b).

Figure 2: Reported fast food consumption of study participants by country.

Fast food consumption and BMI:

Children:

Figure 3a shows the difference in BMI between children with infrequent fast food consumption and those with frequent and very frequent fast food consumption in each centre.

Figure 3a: The association between reported fast food consumption and BMI of children.

The estimated mean BMIs in children reporting infrequent fast food consumption were 16.20 and 16.51 kg/m^2 for ages 6 and 7 respectively. After controlling for country GNI, centre, age and measurement type, there was a statistically significant association between frequent and very frequent fast food consumption and higher BMI with an apparent dose response effect (+0.15 and +0.22kg/m^2 for frequent and very frequent fast food consumption respectively), (Table 1). There was no statistically significant interaction between GNI and fast food consumption in this age group (P=0.06).

Table 1 – Association between fast food consumption and BMI (SE) of study participants after adjustment for GNI

		Difference in BMI (Kg/m^2) compared with infrequent fast food consumption		
	Estimated mean BMI* (Kg/m^2) infrequent fast food consumption	Frequent fast food consumption mean (SE)	Very frequent fast food consumption mean (SE)	P value[i]
Children (N=72,900)	16.51	+ 0.15 (0.02)	+ 0.22 (0.05)	P<0.001
Male Children (N=36,778)	16.53	+0.16 (0.03)	+0.24 (0.06)	P<0.001
Female Children (N=36,122)	16.39	+0.14 (0.03)	+0.20 (0.07)	P<0.001
Adolescent Males (N=98,794)	20.02	-0.14 (0.02)	- 0.28 (0.03)	P<0.001
Adolescent Females (N=100,341)	19.98	-0.19 (0.02)	- 0.19 (0.03)	P<0.001
Participants with measured height and weight data				
Children (N=12,873)	15.88	+0.14 (0.05)	+0.13 (0.08)	P=0.02
Adolescent Males (N= 20,384)	19.67	-0.03 (0.05)	-0.11(0.07)	P=0.24

Adolescent Females (N=24,127)	20.15	-0.15 (0.05)	-0.09 (0.06)	P=0.004

[*] **Estimated BMIs for children aged 7 years and adolescents aged 14 years.**
[i] **P value is a test of whether the estimated mean BMIs for frequent and very frequent fast food consumption are zero.**

When boys and girls were analysed separately, both sexes had a significant positive association between frequent and very frequent fast food consumption (Table 1).

Adolescents:

Figure 3b shows the difference in BMI between adolescents with infrequent fast food consumption and those with frequent and very frequent fast food consumption in each centre.

Figure 3b: The association between fast food consumption and BMI of adolescents

In male adolescents, the estimated mean BMIs for those reporting infrequent fast food consumption were 19.74 and 20.02 kg/m^2 for ages 13 and 14 respectively. After controlling for country GNI, centre, age and measurement type, lower BMI's were significantly associated with greater fast food consumption (Table 1). There was a statistically significant interaction between fast food consumption and GNI. In low GNI countries the frequency of fast food consumption had no association with BMI (+0.01 and -0.03kg/m^2 in the frequent and very frequent groups respectively (P=0.89 and 0.56)). In high GNI countries, lower BMI's were associated with greater fast food consumption (-0.21 and -0.42kg/m^2 in the frequent and very frequent groups respectively (P<0.001 in both groups)).

When analyses were restricted to the 20,384 male adolescents who had measured height and weight data there was a tendency towards a lower BMI with higher fast food consumption, but this was not statistically significant (-0.03kg/m2 and -0.11kg/m2 in the frequent and very frequent group respectively, (p=0.24)).

In female adolescents, the estimated mean BMI's for those reporting infrequent fast food consumption were 19.56 and 19.98 kg/m^2 for ages 13 and 14 respectively. Lower BMIs were

associated with greater fast food consumption and this was statistically significant. There was a statistically significant interaction between fast food consumption and GNI. Both low and high GNI countries had an association between increasing fast food consumption and BMI (low GNI countries -0.10kg/m^2 and -0.11kg/m^2 in the frequent and very frequent groups respectively (P=0.03 and 0.01), and high GNI countries -0.24kg/m^2 and -0.22kg/m^2 in the frequent and very frequent groups respectively (P<0.0001 in both cases)).

When analyses were restricted to the 24,127 female adolescents who had measured height and weight data, those who ate fast food frequently or very frequently had lower BMIs and this was statistically significant (Table 1).

DISCUSSION:

This international study has identified that 6-7 year old children whose parents reported frequent consumption of fast food had higher BMIs than those whose parents reported infrequent fast food consumption. This association was independent of the affluence of the country and of similar magnitude in boys and girls. By contrast, adolescents who self-reported that they frequently ate fast foods tended to have lower BMIs, with the exception of male adolescents from low GNI countries, where there was no association between fast food consumption and BMI.

Children

Our results in children are consistent with those of Shan et al who found that 'Western fast food' and 'snack food' were associated with overweight and obesity among children aged 2 to 18 years in Beijing(22). However, In New Zealand, Duncan et al found that low levels of physical activity, skipping breakfast and insufficient sleep on weekdays were associated with increased adiposity in 5 to 11 year olds, but that fast food consumption was not (20). The magnitude of the association between fast food consumption and BMI in children was small (mean BMI values 0.15 kg/m^2 and 0.22kg/m^2 higher in frequent and very frequent consumers compared to infrequent consumers), and

the clinical significance of this is uncertain. Given the long term consequences of overweight and obesity in childhood, even a small change in mean BMI in a population could be of major public health significance.

An observational study such as this cannot attribute causality. The association we have found between fast food consumption and BMI in children could be due to other specific dietary factors that have been shown to be associated with fast food consumption, such as higher fat intake, greater consumption of sugary drinks, fewer fruits and non-starchy vegetables(11). Alternatively fast food consumption may be a marker of other factors that influence BMI such as parental BMI, individual socioeconomic circumstances or patterns of activity and inactivity.

Adolescents

In our analysis self-reported frequent fast food consumption was associated with a lower BMI in adolescents, with stronger association in higher GNI countries. As far as we are aware, no other studies have demonstrated a lower BMI with higher fast food consumption in adolescence and our findings appear to be in stark contrast to other research findings from high GNI countries. One study showed that increasing fast food consumption in American adolescents was associated with increased weight gain from adolescence to adulthood (12). Another study found that American adolescents who consumed greater quantities of fried food away from home were heavier (23), and, in a further American study, increasing frequency of eating quick-service food was associated with an increasing z-BMI in adolescent females (17). A United Kingdom study found that increased visits to fast food outlets was associated with higher BMI standard deviation scores in teenagers (24). In three of these studies heights and weights were measured to pre-set standards by trained investigators (12, 17, 24), whereas heights and weights of our adolescent participants were mostly self-reported. It is possible that in our study some of the larger participants, particularly from body-image conscious countries or cultures may have under-reported their weights. If this were the case, we might expect that the association between fast food consumption and lower BMI would not be

observed when we restricted our analysis to measured height and weight data. Although this was the case in male adolescents, surprisingly the association between higher rates of fast food consumption and lower BMI persisted in female adolescents. We need to consider the possibility that because of the perception of the negative effects of fast food consumption, adolescents who are overweight or obese are likely to have under-reported their actual fast food consumption. Finally, it is possible that our results are influenced by a degree of reverse-causation where those participants who are already overweight or obese are avoiding fast foods in order to reduce their body weight.

Fast food consumption

This study has shown that up to 25% of children worldwide consume fast food frequently or very frequently, and this increases to over 50% in the adolescent age group. This is consistent with results of previous studies, particularly those based in the United States and the United Kingdom (11, 25, 26). This study has highlighted is the unexpectedly high proportion of fast food consumption in both age groups in many developing countries, for which data have not previously been available. In particular, high prevalence of fast food consumption was observed in centres in Latin America and Asia similar in magnitude to that observed in the United States and Western Europe. Importantly, we have also shown that the association between fast food consumption and higher BMI in children persists among those from both affluent and less affluent countries.

Cohort studies have demonstrated that high consumption of fast food at first assessment is associated with higher BMIs later in childhood or adult life (12, 24). If this is the case, despite an apparently lower BMI with higher reported fast food consumption in the adolescent group, the high proportions of adolescents already reporting fast food consumption is of concern, as fast food consumption has been directly linked with insulin resistance, hypertension and other health sequelae (27).

Strengths and limitations:

The major strengths of this study were its size and multicentre structure, with 199,135 adolescents from 36 countries and 72,900 children from 17 countries surveyed. Many of the centres were from middle and low income countries from which previous data on the association between fast food consumption and BMI had not been reported.

The main limitation to this study is the cross-sectional design which allows identification of associations, but not of temporal sequence or causality. The assessment of subject heights and weights and their fast food consumption was primarily undertaken by questionnaire which raises the possibility of misclassification error, particularly with respect to the parent-reported weights of their children and self-reported weights of the adolescents, thereby influencing the calculated BMI. It is also possible that parents and adolescents may have misreported fast food consumption.

A further consideration is the interpretation of the question about the consumption of burgers / fast foods. While 'burger' is almost universally understood,' fast food' can be interpreted in a number of ways, including foodstuffs from global restaurant chains, smaller non-franchised food stores, street vendors and even frozen meals heated and served at home. Without knowing the exact kind of fast food consumed, we can make no assessment of the nutritional content or energy density of the food in question. Additionally, while the questionnaire asked about the frequency of burgers / fast food consumption, we have no indication of portion sizes, or if it was accompanied by other items such as sugar sweetened beverages.

Finally, centres that objectively measured heights and weights received no standardised instructions for doing this. We have controlled for GNI, centre, measurement type, and sex in our analysis. We have no data available on individual socioeconomic status or parental BMI which could potentially affect young peoples' BMI, nor did we control for physical activity / inactivity of the participants.

CONCLUSIONS:

There is an association between a high frequency of fast food consumption and higher BMIs in 6-7 year old children, but this association is reversed in adolescents. As this is a cross sectional study, causality cannot be proven, however it provides evidence that among children from many different nations, fast food consumption may contribute to weight gain. This reverse association observed in adolescents should be interpreted with caution, as the results may be affected by bias, particularly under-reporting of fast food consumption and reverse causation.

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Data Sharing Statement: Information with respect to all ISAAC studies, including methods, data gathering and results is available on the ISAAC website: isaac.auckland.ac.nz/

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FIGURE LEGENDS

Figure 1: Flow of participants through study. Children are represented in panel (a) and adolescents in panel (b)

Figure 2: Reported frequency of fast food consumption by study participants. Children are represented in panel (a) and adolescents in panel (b)

Figure 3: Association between BMI of study participants and frequent and very frequent fast food consumption compared to infrequent fast food consumption. Children are represented in panel (a) and adolescents in panel (b)

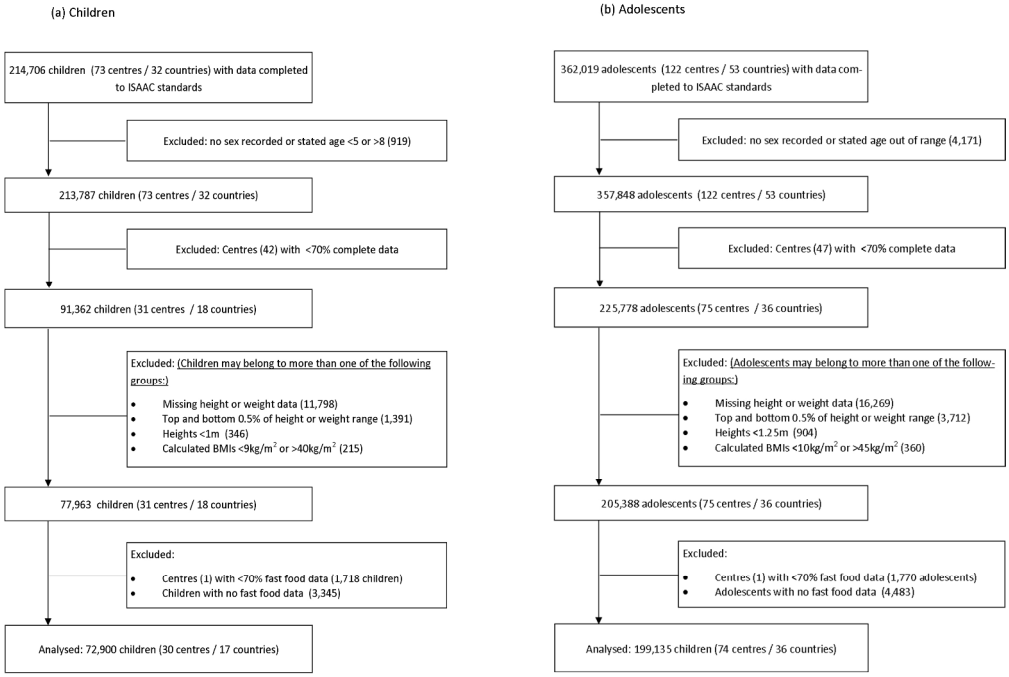

Figure 1: Flow of participants through study. Children are represented in panel (a) and adolescents in panel (b)

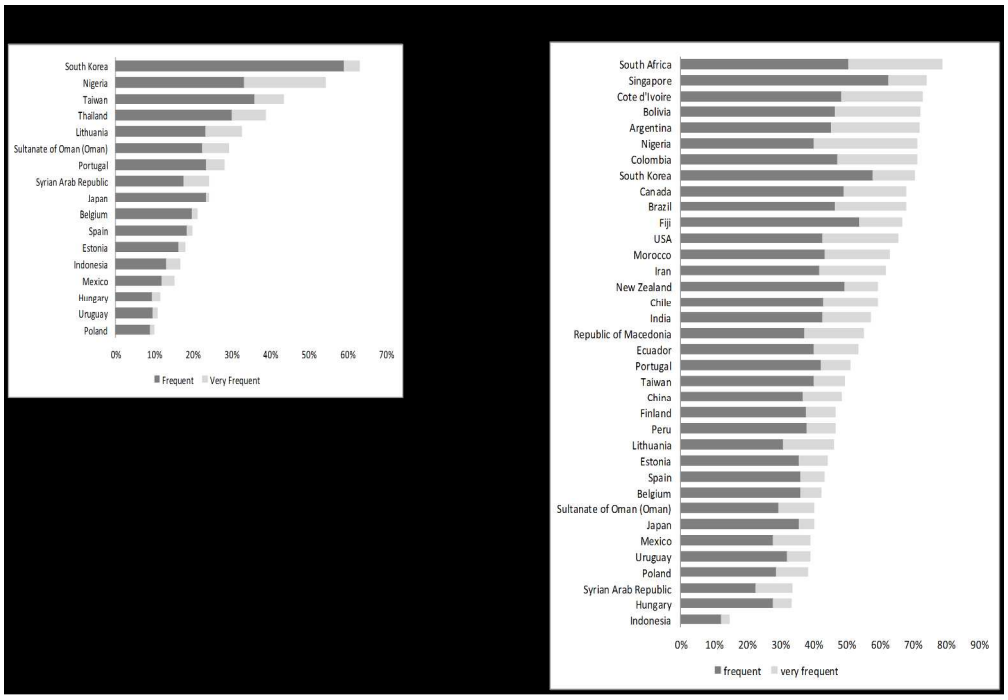

Figure 2: Reported frequency of fast food consumption by study participants. Children are represented in panel (a) and adolescents in panel (b)
261x179mm (300 x 300 DPI)

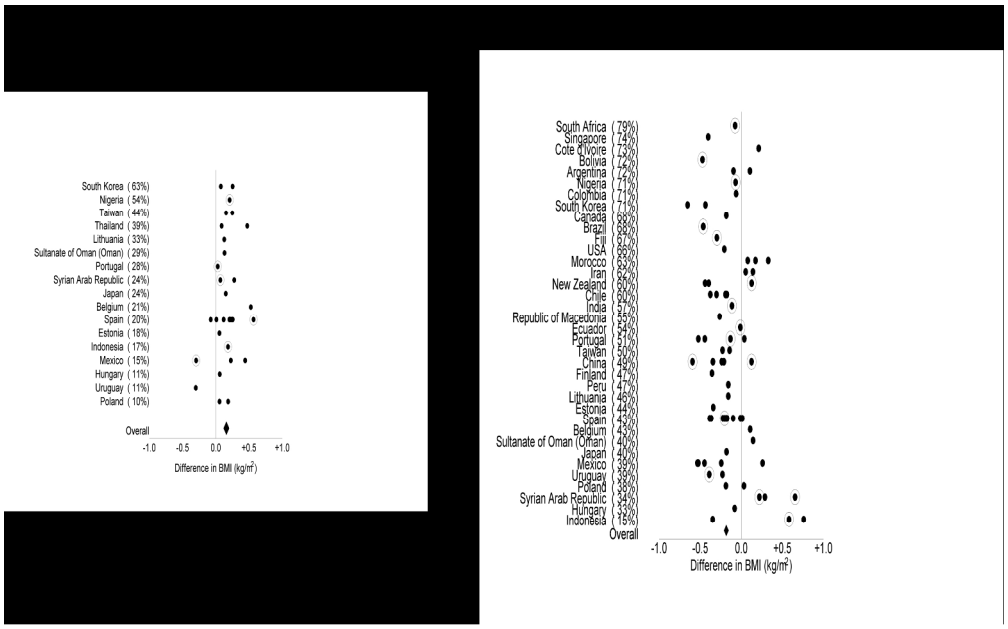

Figure 3: Association between BMI of study participants and frequent and very frequent fast food consumption compared to infrequent fast food consumption. Children are represented in panel (a) and adolescents in panel (b)
261x161mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Title page
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figures 1a and 1b
		(b) Give reasons for non-participation at each stage	Figures 1a and 1b
		(c) Consider use of a flow diagram	Done
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	Figures 1a and 1b
Outcome data	15*	Report numbers of outcome events or summary measures	9-11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-11, including Table 1
		(*b*) Report category boundaries when continuous variables were categorized	6-7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Fast Food consumption and Body Mass Index in children and adolescents: an international cross-sectional study

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Fast Food consumption and Body Mass Index in children and adolescents: an international cross-sectional study

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ABSTRACT:

Objective: To investigate whether reported fast food consumption over the previous year is associated with higher childhood or adolescent body mass index (BMI).

Design: Secondary analysis from a multi-centre, multi-country, cross-sectional study (International Study of Asthma and Allergies in Children (ISAAC) Phase Three).

Subjects and Methods: Parents / guardians of children aged 6-7 completed questionnaires which included questions about their children's asthma and allergies, fast food consumption, height and weight. Adolescents aged 13-14 completed the same questionnaire. The questionnaire asked "In the past 12 months, how often on average did you (your child) eat fast food/burgers?" Responses were; infrequent (never / only occasionally), frequent (once / twice a week), or very frequent (three or more times per week). A general linear mixed model was used to determine the association between BMI and fast food consumption, adjusting for Gross National Income per capita by country, measurement type (whether height and weight were reported or measured), age, and sex.

Results: 72,900 children from 17 countries and 199,135 adolescents from 36 countries provided data. Frequent and very frequent fast food consumption was reported in 23% and 4% of children, and 39% and 13% of adolescents. Children in the frequent and very frequent groups had a BMI 0.15 kg/m^2 and 0.22 kg/m^2 higher than the infrequent group (P<0.001). Adolescent males in the frequent and very frequent groups had a BMI 0.14 kg/m^2 and 0.28kg/m^2 lower than the infrequent group (P<0.001). Adolescent females in the frequent and very frequent groups had a BMI 0.19kg/m^2 lower than the infrequent group (P<0.001).

Conclusion: Reported fast food consumption is high in childhood and increases in adolescence. Compared with infrequent fast food consumption, frequent and very frequent consumption is associated with a higher BMI in children and a lower BMI in adolescents.

Strengths and limitations of this study:

- 199,135 adolescents from 36 countries and 72,900 children from 17 countries provided information on their height, weight and fast food consumption.
- Many of the countries were middle and low income from which previous data on the association of fast food consumption and BMI had not been reported.
- There is an association between increasing frequency of fast food consumption and higher BMIs in 6-7 year old children, but this association was reversed in adolescents.
- As this is a cross sectional study, causality cannot be proven, but it provides evidence that among children from many different nations, fast food consumption may contribute to weight gain.
- The reverse association observed in adolescents should be interpreted with caution, as the results may be affected by bias, particularly under-reporting of fast food consumption and reverse causation.

INTRODUCTION:

The rising prevalence of childhood obesity is marked (1, 2), and there are well documented concerns about the future health implications of obesity in childhood (3-7). This problem has been identified in low and middle income countries as well as affluent countries (8, 9).

While potential contributors to the problem of childhood obesity are considered to be multiple and complex, in many countries fast food has been implicated due to its increasing availability, energy density, and large portion sizes. (10-13). Studies investigating associations between fast food consumption in children and Body Mass Index (BMI) have produced mixed results, some demonstrating small but significant associations between fast food consumption and increased BMI (12, 14-17), while others have failed to demonstrate a significant association (18-20). In a systematic review of studies assessing the association between fast food and obesity in 2008, Rosenheck noted that 'it is difficult to ascertain the true relationship between fast food consumption and weight gain or obesity, as many confounding factors such as physical inactivity and less inhibited food consumption are independently associated with both fast food consumption and weight gain or obesity' and that '… residual confounding from immeasurable lifestyle choices will always distort results garnered from observational study designs.'(14).

Additionally Rosenheck commented on the sample sizes of the cross-sectional studies, where only one study enrolled more than 5,000 participants, and in general enrolment was closer to the 1,000 mark, potentially negatively impacting the power of the studies to effectively assess the association between fast food consumption and weight / obesity. A cross-sectional study large enough to achieve sufficient power to determine an association between fast food consumption and obesity AND adequately address issues of multiple confounding factors is likely to be logistically demanding and prohibitively costly. A secondary analysis of the data from the International Study of Asthma and Allergies in Childhood (ISAAC) Phase Three programme allows an international 'snapshot' of fast food consumption and an assessment of the association between fast food consumption and BMI in

72,900 children from 17 countries and 199,135 adolescents from 36 countries at a single point in time, using a simple universal question. While few confounding variables are taken into account, the large numbers involved give power to this analysis.

We hypothesised that there would be an association between greater fast food consumption and higher BMI in both children and adolescents, and that this association would be observed worldwide.

SUBJECTS AND METHODS:

The International Study of Asthma and Allergies in Childhood (ISAAC) Phase Three programme was designed to measure time trends in the prevalence and severity of asthma, rhinoconjunctivitis and eczema and to explore the relationship between lifestyle, other putative risk factors and the development of asthma and allergies (21). ISAAC Phase Three used the ISAAC Phase One standardised core questionnaire on symptoms of asthma, rhinoconjunctivitis and eczema. ISAAC Phase Three provided the additional opportunity to explore the relationship between lifestyle factors such as fast food consumption and BMI, as heights, weights and information on the frequency of fast food consumption of participants were gathered in many centres through an optional environmental questionnaire that was answered by parents of children and by the adolescents themselves.

The ISAAC Phase One standardised core questionnaire and ISAAC Phase Three environmental questionnaire are on the ISAAC website: isaac.auckland.ac.nz.

Ethical approval was obtained for the original ISAAC Phase Three study, and permission was gained to use the data from ISAAC Phase Three through agreement with the ISAAC Phase Three Steering Committee.

Main outcome variable - Body Mass Index:

Height and weight were reported by the parents of the children, and were self-reported by adolescents. In some centres, each subject's height and weight were measured objectively; there were no standardised or specific instructions for doing this. BMI was calculated as weight (kg)/height $(m)^2$.

Explanatory variables:

Fast food consumption was established by asking participants to answer the following question: "In the past 12 months, how often, on average, did you [your child] eat the following?"

'Fast Food / Burgers' were listed as one option along with 14 other foodstuffs including meat, seafood, fruit and vegetables. The participants were asked to categorise their intake of each listed food as "Never or only occasionally"; "once or twice per week"; or "Three or more times a week". These responses were categorised as 'infrequent', 'frequent' and 'very frequent'. Each variable was examined separately for both age groups.

Country Gross National Index (GNI) was based on the 2006 World Bank of Gross National Income by country. The World Bank categories of high income, high middle income, low middle income and low income countries were dichotomised into 'high income' (high and high middle income) and 'low income' (low middle and low income) categories.

Participants:

For children aged 6-7 years, data were submitted from 73 centres in 32 countries (214,706 subjects). For adolescents aged 13-14 years data were submitted from 125 centres in 54 countries (369,881 subjects).

Centres that provided data on height, weight and fast food consumption for at least 70% of participants were included in our analyses. Individuals without complete age, sex, fast food consumption, height or weight data were excluded.

Data cleaning:

To eliminate likely erroneous BMI data, we applied the following thresholds:

- For children in each centre, those in the top and bottom 0.5% of weights and heights, and those with heights less than 1.0 metre were excluded. Children with BMI less than 9kg/m^2 and greater than 40kg/m^2 were excluded.

- For adolescents in each centre, those in the top and bottom 0.5% of weights and heights, and those with heights less than 1.25 metres were excluded. Adolescents with BMI less than 10kg/m^2 and greater than 45kg/m^2 were excluded.

Following sequential application of the exclusion and data cleaning criteria described above, 72,900 children (30 centres / 17 countries) and 199,135 adolescents (74 centres / 36 countries) were included in the final analysis (Figure 1). Parents provided heights and weights for 60,027 children, while 12,873 children had their heights and weights measured. 154,624 adolescents provided self-reported height and weight while 44,511 adolescents had measured heights and weights.

Figure 1: Flow of subjects through study.

STATISTICAL ANALYSIS:

BMI was assessed separately for each age group using a general linear mixed model with centre as a random effect and GNI for each country (low and high), the individual's age, sex, measurement type (reported or measured), and fast food consumption('infrequent', 'frequent' 'very frequent') as fixed effects. The BMI values reported are the modelled means for those who reported infrequent fast food consumption in the children and adolescent groups respectively.

In the adolescent group statistically significant interactions were found between sex and fast food consumption, and measurement type and fast food consumption. There was also an interaction found between country GNI and fast food consumption. Consequently, analyses were done separately for each sex, measured height and weight data only, and GNI categories. No similar

interactions were found in the children's group, but there were sufficient numbers to analyse each sex separately, which we elected to do.

RESULTS:

Fast food consumption:

22.6% of children reported frequent fast food consumption and 4.2% reported very frequent fast food consumption. Combined frequent and very frequent fast food consumption in each country ranged from 10% in Poland to 63% in South Korea (Figure 2a).

38.7% of adolescents reported frequent fast food consumption and 12.6% reported very frequent consumption. Frequent and very frequent fast food consumption ranged from 15% in Indonesia to 79% in South Africa (Figure 2b).

Figure 2: Reported fast food consumption of study participants by country.

Fast food consumption and BMI:

Children:

Figure 3a shows the difference in BMI between children with infrequent fast food consumption and those with frequent and very frequent fast food consumption in each centre.

Figure 3a: The association between reported fast food consumption and BMI of children.

The estimated mean BMIs in children reporting infrequent fast food consumption were 16.20 and 16.51 kg/m^2 for ages 6 and 7 respectively. After controlling for country GNI, centre, age and measurement type, there was a statistically significant association between frequent and very frequent fast food consumption and higher BMI with an apparent dose response effect (+0.15 and +0.22kg/m^2 for frequent and very frequent fast food consumption respectively), (Table 1). There was no statistically significant interaction between GNI and fast food consumption in this age group (P=0.06).

Table 1 – Association between fast food consumption and BMI (SE) of study participants after adjustment for GNI

		Difference in mean BMI (Kg/m^2) compared with infrequent fast food consumption		
	Estimated mean BMI* (Kg/m^2) infrequent fast food consumption	Frequent fast food consumption: mean (SE)	Very frequent fast food consumption: mean (SE)	P value[i]
Children (N=72,900)	16.51	+ 0.15 (0.02)	+ 0.22 (0.05)	P<0.001
Male Children (N=36,778)	16.53	+0.16 (0.03)	+0.24 (0.06)	P<0.001
Female Children (N=36,122)	16.39	+0.14 (0.03)	+0.20 (0.07)	P<0.001
Adolescent Males (N=98,794)	20.02	-0.14 (0.02)	- 0.28 (0.03)	P<0.001
Adolescent Females (N=100,341)	19.98	-0.19 (0.02)	- 0.19 (0.03)	P<0.001
Participants with measured height and weight data				
Children (N=12,873)	15.88	+0.14 (0.05)	+0.13 (0.08)	P=0.02
Adolescent Males (N= 20,384)	19.67	-0.03 (0.05)	-0.11(0.07)	P=0.24
Adolescent Females (N=24,127)	20.15	-0.15 (0.05)	-0.09 (0.06)	P=0.004

*Estimated BMIs for children aged 7 years and adolescents aged 14 years.

[i] P value is a joint test of whether the differences in BMIs for frequent and very frequent fast food consumption relative to infrequent fast food consumption are zero.

When boys and girls were analysed separately, both sexes had a significant positive association between frequent and very frequent fast food consumption (Table 1).

Adolescents:

Figure 3b shows the difference in BMI between adolescents with infrequent fast food consumption and those with frequent and very frequent fast food consumption in each centre.

Figure 3b: The association between fast food consumption and BMI of adolescents

In male adolescents, the estimated mean BMIs for those reporting infrequent fast food consumption were 19.74 and 20.02 kg/m^2 for ages 13 and 14 respectively. After controlling for country GNI,

centre, age and measurement type, lower BMI's were significantly associated with greater fast food consumption (Table 1). There was a statistically significant interaction between fast food consumption and GNI. In low GNI countries the frequency of fast food consumption had no association with BMI (+0.01 and -0.03kg/m^2 in the frequent and very frequent groups respectively (P=0.89 and 0.56)). In high GNI countries, lower BMI's were associated with greater fast food consumption (-0.21 and -0.42kg/m^2 in the frequent and very frequent groups respectively (P<0.001 in both groups)).

When analyses were restricted to the 20,384 male adolescents who had measured height and weight data there was a tendency towards a lower BMI with higher fast food consumption, but this was not statistically significant (-0.03kg/m2 and -0.11kg/m2 in the frequent and very frequent group respectively, (p=0.24)).

In female adolescents, the estimated mean BMI's for those reporting infrequent fast food consumption were 19.56 and 19.98 kg/m^2 for ages 13 and 14 respectively. Lower BMIs were associated with greater fast food consumption and this was statistically significant. There was a statistically significant interaction between fast food consumption and GNI. Both low and high GNI countries had an association between increasing fast food consumption and BMI (low GNI countries -0.10kg/m^2 and -0.11kg/m^2 in the frequent and very frequent groups respectively (P=0.03 and 0.01), and high GNI countries -0.24kg/m^2 and -0.22kg/m^2 in the frequent and very frequent groups respectively (P<0.0001 in both cases)).

When analyses were restricted to the 24,127 female adolescents who had measured height and weight data, those who ate fast food frequently or very frequently had lower BMIs and this was statistically significant (Table 1).

DISCUSSION:

This international study has identified that 6-7 year old children who consumed fast food frequently had higher BMIs than those who consumed fast food infrequently. This association was independent of the affluence of the country and of similar magnitude in boys and girls. By contrast, adolescents who self-reported that they frequently ate fast foods tended to have lower BMIs, with the exception of male adolescents from low GNI countries, where there was no association between fast food consumption and BMI. We have also found that up to 25% of children worldwide consume fast food frequently or very frequently, and this increases to over 50% in the adolescent age group.

Children

Our results in children are consistent with those of Shan et al who found that 'Western fast food' and 'snack food' were associated with overweight and obesity among children aged 2 to 18 years in Beijing(22). However, In New Zealand, Duncan et al found that low levels of physical activity, skipping breakfast and insufficient sleep on weekdays were associated with increased adiposity in 5 to 11 year olds, but that fast food consumption was not (20). The magnitude of the association between fast food consumption and BMI in children was small (mean BMI values 0.15 kg/m^2 and 0.22kg/m^2 higher in frequent and very frequent consumers compared to infrequent consumers), and the clinical significance of this is uncertain. Given the long term consequences of overweight and obesity in childhood, even a small change in mean BMI in a population could be of major public health significance.

An observational study such as this cannot attribute causality. The association we have found between fast food consumption and BMI in children could be due to other specific dietary factors that have been shown to be associated with fast food consumption, such as higher fat intake, greater consumption of sugary drinks, fewer fruits and non-starchy vegetables(11). Alternatively fast food consumption may be a marker of other factors that influence BMI such as parental BMI, individual socioeconomic circumstances or patterns of activity and inactivity.

Adolescents

In our analysis self-reported frequent fast food consumption was associated with a lower BMI in adolescents, with stronger association in higher GNI countries. As far as we are aware, no other studies have demonstrated a lower BMI with higher fast food consumption in adolescence and our findings appear to be in stark contrast to other research findings from high GNI countries. One study showed that increasing fast food consumption in American adolescents was associated with increased weight gain from adolescence to adulthood (12). Another study found that American adolescents who consumed greater quantities of fried food away from home were heavier (23), and, in a further American study, increasing frequency of eating quick-service food was associated with an increasing z-BMI in adolescent females (17). A United Kingdom study found that increased visits to fast food outlets was associated with higher BMI standard deviation scores in teenagers (24). In three of these studies heights and weights were measured to pre-set standards by trained investigators (12, 17, 24), whereas heights and weights of our adolescent participants were mostly self-reported. It is possible that in our study some of the larger participants, particularly from body-image conscious countries or cultures may have under-reported their weights. In a study evaluating the correlation of measured versus self-reported heights and weights in adolescents, Brener at al found that their study subjects tended to over-report their height by 2.7 inches (6.9cm) on average, and to under-report their weight by 3.5 pounds (1.6kg) on average, resulting in a BMI understated by 2.6kg/m^2 when compared to measured values. White adolescents were most likely to over-report their height and female adolescents were more likely to under-report their weight(25). Similarly Danubio et al found that height was over-estimated in males and females (2.1 and 2.8cm respectively), and that weight was understated (1.5kg in males and 1.9kg in females)(26). Rasmussen et al reported that in the COMPASS study, boys and girls who wished to be leaner under-reported their weight and BMI more than subjects who were satisfied with their body size(27). When we restricted our analysis to measured height and weight data only, the association between higher fast food intake and lower BMI was no longer observed in male adolescents, but the association between

higher rates of fast food consumption and lower BMI persisted in female adolescents. We need to consider the likelihood that because of the perception of the negative effects of fast food consumption, adolescents who are overweight or obese are likely to have under-reported their actual fast food consumption. In a review of validation studies on energy-intake reporting in children and adolescents, Livingstone and Robson describe an increasing in under-reporting of energy intake reporting as age and BMI increases in childhood and adolescence, with 14%, 25% and 40% of energy intake under-reported in obese 6 year olds, 10 year olds and adolescents respectively (28). Finally, it is possible that our results are influenced by a degree of reverse-causation where those participants who are already overweight or obese are avoiding fast foods in order to reduce their body weight.

Fast food consumption

This study has shown that up to 25% of children worldwide consume fast food frequently or very frequently, and this increases to over 50% in the adolescent age group. This is consistent with results of previous studies, particularly those based in the United States and the United Kingdom (11, 29, 30). This study has also highlighted the unexpectedly high proportion of fast food consumption in both age groups in many developing countries, for which data have not previously been available. In particular, high prevalence of fast food consumption was observed in centres in Latin America and Asia similar in magnitude to that observed in the United States and Western Europe. Importantly, we have also shown that the association between fast food consumption and higher BMI in children persists among those from both affluent and less affluent countries.

Cohort studies have demonstrated that high consumption of fast food at first assessment is associated with higher BMIs later in childhood or adult life (12, 24). If this is the case, despite an apparently lower BMI with higher reported fast food consumption in the adolescent group, the high proportions of adolescents already reporting fast food consumption is of concern, as fast food

consumption has been directly linked with insulin resistance, hypertension and other health sequelae (31).

Strengths and limitations:

The major strengths of this study were its size and multicentre structure, with 199,135 adolescents from 36 countries and 72,900 children from 17 countries surveyed. Many of the centres were from middle and low income countries from which previous data on the association between fast food consumption and BMI had not been reported.

The main limitation to this study is the cross-sectional design which allows identification of associations, but not of temporal sequence or causality. The assessment of subject heights and weights and their fast food consumption was primarily undertaken by questionnaire which raises the possibility of misclassification error, particularly with respect to the parent-reported weights of their children and self-reported weights of the adolescents, thereby influencing the calculated BMI. It is also possible that parents and adolescents may have misreported fast food consumption.

A further consideration is the interpretation of the question about the consumption of burgers / fast foods. While 'burger' is almost universally understood,' fast food' can be interpreted in a number of ways, including foodstuffs from global restaurant chains, smaller non-franchised food stores, street vendors and even frozen meals heated and served at home. Without knowing the exact kind of fast food consumed, we can make no assessment of the nutritional content or energy density of the food in question. Additionally, while the questionnaire asked about the frequency of burgers / fast food consumption, we have no indication of portion sizes, or if it was accompanied by other items such as sugar sweetened beverages.

Finally, centres that objectively measured heights and weights received no standardised instructions for doing this. We have controlled for GNI, centre, measurement type, and sex in our analysis. We

have no data available on individual socioeconomic status or parental BMI which could potentially affect young peoples' BMI, nor did we control for physical activity / inactivity of the participants.

CONCLUSIONS:

This cross-sectional study has found that one quarter of children and half of adolescents consume fast food frequently or very frequently. Additionally there was an association between a high frequency of fast food consumption and higher BMIs in 6-7 year old children, but this association was reversed in adolescents. As this is an observational study, causality cannot be proven, however it provides evidence that among children from many different nations, fast food consumption may contribute to weight gain. This reverse association observed in adolescents should be interpreted with caution, as the results may be affected by bias, particularly under-reporting of fast food consumption and reverse causation.

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Author Contributions: Mr A Stewart had access to all the data on the study and takes responsibility for the integrity of the data and accuracy of the data analysis. *Study concept and design:* All authors. *Acquisition of Data:* ISAAC steering committee. *Drafting of the manuscript:* Braithwaite. *Critical revision of the manuscript for important intellectual content:* all authors. *Statistical analysis:* Stewart. *Obtained Funding:* Mitchell. *Administrative, technical and material support:* All authors. *Study supervision:* Mitchell.

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FIGURE LEGENDS

Figure 1: Flow of participants through study. Children are represented in panel (a) and adolescents in panel (b)

Figure 2: Reported frequency of fast food consumption by study participants. Children are represented in panel (a) and adolescents in panel (b)

Figure 3: The difference in BMI of study participants that consumed fast food consumption frequently and very frequently compared to infrequent fast food consumption. Children are represented in panel (a) and adolescents in panel (b). For each country the proportion of participants who consume fast food frequently or very frequently is shown in parentheses. Those centres with reported height and weights are shown with filled in circles, and those centres that measured heights and weights are shown with hollowed circles.

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Fast Food consumption and Body Mass Index in children and adolescents: an international cross-sectional study

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ABSTRACT:

Objective: To investigate whether reported fast food consumption over the previous year is associated with higher childhood or adolescent body mass index (BMI).

Design: Secondary analysis from a multi-centre, multi-country, cross-sectional study (International Study of Asthma and Allergies in Children (ISAAC) Phase Three).

Subjects and Methods: Parents / guardians of children aged 6-7 completed questionnaires which included questions about their children's asthma and allergies, fast food consumption, height and weight. Adolescents aged 13-14 completed the same questionnaire. The questionnaire asked "In the past 12 months, how often on average did you (your child) eat fast food/burgers?" Responses were; infrequent (never / only occasionally), frequent (once / twice a week), or very frequent (three or more times per week). A general linear mixed model was used to determine the association between BMI and fast food consumption, adjusting for Gross National ~~Income per~~Income per capita by country, measurement type (whether~~reported or measured~~ height and weight were reported or measured), age, and sex.

Results: 72,900 children from 17 countries and 199,135 adolescents from 36 countries provided data. Frequent and very frequent fast food consumption was reported in 23% and 4% of children, and 39% and 13% of adolescents. Children in the frequent and very frequent groups had a BMI 0.15 kg/m^2 and 0.22 kg/m^2 higher than the infrequent group (P<0.001). Adolescent males in the frequent and very frequent groups had a BMI 0.14 kg/m^2 and 0.28kg/m^2 lower than the infrequent group (P<0.001). Adolescent females in the frequent and very frequent groups had a BMI 0.19kg/m^2 lower than the infrequent group (P<0.001).

Conclusion: Reported fast food consumption is high in childhood and increases in adolescence. Compared with infrequent fast food consumption, f~~F~~requent and very frequent consumption is associated with a higher BMI in children and ~~. In contrast, this is associated with~~ a lower BMI in adolescents.

Strengths and limitations of this study:

- 199,135 adolescents from 36 countries and 72,900 children from 17 countries provided information on their height, weight and fast food consumption.
- Many of the countries were middle and low income from which previous data on the association of fast food consumption and BMI had not been reported.
- There is an association between increasing frequency of fast food consumption and higher BMIs in 6-7 year old children, but this association was reversed in adolescents.
- As this is a cross sectional study, causality cannot be proven, but it provides evidence that among children from many different nations, fast food consumption may contribute to weight gain.
- The reverse association observed in adolescents should be interpreted with caution, as the results may be affected by bias, particularly under-reporting of fast food consumption and reverse causation.

INTRODUCTION:

The rising prevalence of childhood obesity is marked (1, 2), and there are well documented concerns about the future health implications of obesity in childhood (3-7). This problem has been identified in low and middle income countries as well as affluent countries (8, 9).

While potential contributors to the problem of childhood obesity are considered to be multiple and complex, ~~the increasing availability of fast food~~ in many countries fast food has been implicated due to its increasing availability, energy ~~dense and low nutritional nature~~density, and large portion sizes~~ and increasing availability~~ (10-13). Studies investigating associations between fast food consumption in children and Body Mass Index (BMI) have produced mixed results, some demonstrating small but significant associations between fast food consumption and increased BMI (12, 14-17), while others have failed to demonstrate a significant association (18-20). ~~Many of these have been single centre studies and involved small populations.~~ In a systematic review of studies assessing the association between fast food and obesity in 2008, Rosenheck noted that 'it is difficult to ascertain the true relationship between fast food consumption and weight gain or obesity, as many confounding factors such as physical inactivity and less inhibited food consumption are independently associated with both fast food consumption and weight gain or obesity' and that '… residual confounding from immeasurable lifestyle choices will always distort results garnered from observational study designs.'(14).

Additionally Rosenheck commented on the sample sizes of the cross-sectional studies, where only one study enrolled more than 5,000 participants, and in general enrolment was closer to the 1,000 mark, potentially negatively impacting the power of the studies to effectively assess the association between fast food consumption and weight / obesity. A cross-sectional study large enough to achieve sufficient power to determine an association between fast food consumption and obesity AND adequately address issues of multiple confounding factors is likely to be logistically demanding and prohibitively costly.

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A secondary analysis of the data from the International Study of Asthma and Allergies in Childhood (ISAAC) Phase Three programme allows an international 'snapshot' of fast food consumption and an assessment of the association between fast food consumption and BMI in ~~across~~ 72,900 children from 17 countries and 199,135 adolescents from 36 countries at a single point in time, using a simple universal question. While few confounding variables are taken into account, the large numbers involved ~~do bring a degree of~~give power to ~~the~~this analysis.

~~The International Study of Asthma and Allergies in Childhood (ISAAC) Phase Three programme was designed to measure time trends in the prevalence and severity of asthma, rhinoconjunctivitis and eczema and to explore the relationship between lifestyle, other putative risk factors and the development of asthma and allergies (21). It also provided the opportunity to explore the relationship between lifestyle factors such as fast food consumption and BMI, as heights, weights and information on the frequency of fast food consumption of participants were gathered in many centres through an optional environmental questionnaire that was answered by parents of children and by the adolescents themselves.~~

We hypothesised that there would be an association between greater fast food consumption and higher BMI in both children and adolescents, and that this association would be observed worldwide.

SUBJECTS AND METHODS:

The International Study of Asthma and Allergies in Childhood (ISAAC) Phase Three programme was designed to measure time trends in the prevalence and severity of asthma, rhinoconjunctivitis and eczema and to explore the relationship between lifestyle, other putative risk factors and the development of asthma and allergies (21).~~ISAAC is a multicentre, multi-country, multiphase, cross-sectional study investigating the prevalence of the symptoms of asthma, rhinoconjunctivitis and~~

~~eczema, and the role of risk factors, as previously described (21).~~ ISAAC Phase Three used the ISAAC Phase One standardised core questionnaire on symptoms of asthma, rhinoconjunctivitis and eczema. ~~, and included an optional environmental questionnaire to collect potential risk factor data including height, weight, and fast food consumption.~~ ISAAC Phase Three provided the ~~and~~ additional opportunity to explore the relationship between lifestyle factors such as fast food consumption and BMI, as heights, weights and information on the frequency of fast food consumption of participants were gathered in many centres through an optional environmental questionnaire that was answered by parents of children and by the adolescents themselves.

~~Adolescents self-completed their questionnaires and parents or guardians completed questionnaires for the children.~~ The ISAAC Phase One standardised core questionnaire and ISAAC Phase Three environmental questionnaire~~s~~ are on the ISAAC website: isaac.auckland.ac.nz.

Ethical approval was obtained for the original ISAAC Phase Three study, and permission was gained to use the data from ISAAC Phase Three through agreement with the ISAAC Phase Three Steering Committee.

Main outcome variable - Body Mass Index:

Height and weight were reported by the parents of the children, and were self-reported by adolescents. In some centres, each subject's height and weight were measured objectively; there were no standardised or specific instructions for doing this. BMI was calculated as weight (kg)/height $(m)^2$.

Explanatory variables:

Fast food consumption was established by asking participants to answer the following question: "In the past 12 months, how often, on average, did you [your child] eat the following?"

'Fast Food / Burgers' were listed as one option along with 14 other foodstuffs including meat, seafood, fruit and vegetables. The participants were asked to categorise their intake of each listed

food as “Never or only occasionally”; “once or twice per week”; or “Three or more times a week”. These responses were categorised as ‘infrequent’, ‘frequent’ and ‘very frequent’. Each variable was examined separately for both age groups.

Country Gross National Index (GNI) was based on the 2006 World Bank of Gross National Income by country. The World Bank categories of high income, high middle income, low middle income and low income countries were dichotomised into ‘high income’ (high and high middle income) and ‘low income’ (low middle and low income) categories.

Participants:

For children aged 6-7 years, data were submitted from 73 centres in 32 countries (214,706 subjects). For adolescents aged 13-14 years data were submitted from 125 centres in 54 countries (369,881 subjects).

Centres that provided data on height, weight and fast food consumption for at least 70% of participants were included in our analyses. Individuals without complete age, sex, fast food consumption, height or weight data were excluded.

Data cleaning:

To eliminate likely erroneous BMI data, we applied the following thresholds:

- For children in each centre, those in the top and bottom 0.5% of weights and heights, and those with heights less than 1.0 metre were excluded. Children with BMI less than 9kg/m^2 and greater than 40kg/m^2 were excluded.
- For adolescents in each centre, those in the top and bottom 0.5% of weights and heights, and those with heights less than 1.25 metres were excluded. Adolescents with BMI less than 10kg/m^2 and greater than 45kg/m^2 were excluded.

Following sequential application of the exclusion and data cleaning criteria described above, 72,900 children (30 centres / 17 countries) and 199,135 adolescents (74 centres / 36 countries) were included in the final analysis (Figure 1). Parents provided heights and weights for 60,027 children, while 12,873 children had their heights and weights measured. 154,624 adolescents provided self-reported height and weight while 44,511 adolescents had measured heights and weights.

Figure 1: Flow of subjects through study.

STATISTICAL ANALYSIS:

BMI was assessed separately for each age group using a general linear mixed model with centre as a random effect and GNI for each country (low and high), the individual's age, sex, measurement type (reported or measured), and fast food consumption('infrequent', 'frequent' 'very frequent') as fixed effects. The BMI values reported are the modelled means for those who reported infrequent fast food consumption in the children and adolescent groups respectively.

In the adolescent group statistically significant interactions were found between sex and fast food consumption, and measurement type and fast food consumption. There was also an interaction found between country GNI and fast food consumption. Consequently, analyses were done separately for each sex, measured height and weight data only, and GNI categories. No similar interactions were found in the children's group, but there were sufficient numbers to analyse each sex separately, which we elected to do.

RESULTS:

Fast food consumption:

22.6% of children reported frequent fast food consumption and 4.2% reported very frequent fast food consumption. Combined frequent and very frequent fast food consumption in each country ranged from 10% in Poland to 63% in South Korea (Figure 2a).

38.7% of adolescents reported frequent fast food consumption and 12.6% reported very frequent consumption. Frequent and very frequent fast food consumption ranged from 15% in Indonesia to 79% in South Africa (Figure 2b).

Figure 2: Reported fast food consumption of study participants by country.

Fast food consumption and BMI:

Children:

Figure 3a shows the difference in BMI between children with infrequent fast food consumption and those with frequent and very frequent fast food consumption in each centre.

Figure 3a: The association between reported fast food consumption and BMI of children.

The estimated mean BMIs in children reporting infrequent fast food consumption were 16.20 and 16.51 kg/m^2 for ages 6 and 7 respectively. After controlling for country GNI, centre, age and measurement type, there was a statistically significant association between frequent and very frequent fast food consumption and higher BMI with an apparent dose response effect (+0.15 and +0.22kg/m^2 for frequent and very frequent fast food consumption respectively), (Table 1). There was no statistically significant interaction between GNI and fast food consumption in this age group (P=0.06).

Table 1 – Association between fast food consumption and BMI (SE) of study participants after adjustment for GNI

		Difference in mean BMI (Kg/m^2) compared with infrequent fast food consumption		
	Estimated mean BMI* (Kg/m^2) infrequent fast food consumption	**Frequent fast food consumption: mean (SE)**	**Very frequent fast food consumption: mean (SE)**	**P value[i]**
Children (N=72,900)	16.51	+ 0.15 (0.02)	+ 0.22 (0.05)	P<0.001
Male Children (N=36,778)	16.53	+0.16 (0.03)	+0.24 (0.06)	P<0.001

Female Children (N=36,122)	16.39	+0.14 (0.03)	+0.20 (0.07)	P<0.001
Adolescent Males (N=98,794)	20.02	-0.14 (0.02)	- 0.28 (0.03)	P<0.001
Adolescent Females (N=100,341)	19.98	-0.19 (0.02)	- 0.19 (0.03)	P<0.001
Participants with measured height and weight data				
Children (N=12,873)	15.88	+0.14 (0.05)	+0.13 (0.08)	P=0.02
Adolescent Males (N= 20,384)	19.67	-0.03 (0.05)	-0.11(0.07)	P=0.24
Adolescent Females (N=24,127)	20.15	-0.15 (0.05)	-0.09 (0.06)	P=0.004

[*] **Estimated BMIs for children aged 7 years and adolescents aged 14 years.**

[i] **P value is a joint test of whether the ~~estimated mean~~differences in BMIs for frequent and very frequent fast food consumption relative to infrequent fast food consumption are zero.**

When boys and girls were analysed separately, both sexes had a significant positive association between frequent and very frequent fast food consumption (Table 1).

Adolescents:

Figure 3b shows the difference in BMI between adolescents with infrequent fast food consumption and those with frequent and very frequent fast food consumption in each centre.

Figure 3b: The association between fast food consumption and BMI of adolescents

In male adolescents, the estimated mean BMIs for those reporting infrequent fast food consumption were 19.74 and 20.02 kg/m^2 for ages 13 and 14 respectively. After controlling for country GNI, centre, age and measurement type, lower BMI's were significantly associated with greater fast food consumption (Table 1). There was a statistically significant interaction between fast food consumption and GNI. In low GNI countries the frequency of fast food consumption had no association with BMI (+0.01 and -0.03kg/m^2 in the frequent and very frequent groups respectively (P=0.89 and 0.56)). In high GNI countries, lower BMI's were associated with greater fast food consumption (-0.21 and -0.42kg/m^2 in the frequent and very frequent groups respectively (P<0.001 in both groups)).

When analyses were restricted to the 20,384 male adolescents who had measured height and weight data there was a tendency towards a lower BMI with higher fast food consumption, but this was not statistically significant (-0.03kg/m2 and -0.11kg/m2 in the frequent and very frequent group respectively, (p=0.24)).

In female adolescents, the estimated mean BMI's for those reporting infrequent fast food consumption were 19.56 and 19.98 kg/m^2 for ages 13 and 14 respectively. Lower BMIs were associated with greater fast food consumption and this was statistically significant. There was a statistically significant interaction between fast food consumption and GNI. Both low and high GNI countries had an association between increasing fast food consumption and BMI (low GNI countries -0.10kg/m^2 and -0.11kg/m^2 in the frequent and very frequent groups respectively (P=0.03 and 0.01), and high GNI countries -0.24kg/m^2 and -0.22kg/m^2 in the frequent and very frequent groups respectively (P<0.0001 in both cases)).

When analyses were restricted to the 24,127 female adolescents who had measured height and weight data, those who ate fast food frequently or very frequently had lower BMIs and this was statistically significant (Table 1).

DISCUSSION:

This international study has identified that 6-7 year old children ~~whose parents reported frequent consumption of~~who consumed fast food frequently had higher BMIs than those ~~whose parents reported infrequent~~who consumed ~~-~~fast food ~~consumption~~infrequently. This association was independent of the affluence of the country and of similar magnitude in boys and girls. By contrast, adolescents who self-reported that they frequently ate fast foods tended to have lower BMIs, with the exception of male adolescents from low GNI countries, where there was no association between fast food consumption and BMI. We have also found that up to 25% of children worldwide consume fast food frequently or very frequently, and this increases to over 50% in the adolescent age group.

Children

Our results in children are consistent with those of Shan et al who found that 'Western fast food' and 'snack food' were associated with overweight and obesity among children aged 2 to 18 years in Beijing(22). However, In New Zealand, Duncan et al found that low levels of physical activity, skipping breakfast and insufficient sleep on weekdays were associated with increased adiposity in 5 to 11 year olds, but that fast food consumption was not (20). The magnitude of the association between fast food consumption and BMI in children was small (mean BMI values 0.15 kg/m^2 and 0.22kg/m^2 higher in frequent and very frequent consumers compared to infrequent consumers), and the clinical significance of this is uncertain. Given the long term consequences of overweight and obesity in childhood, even a small change in mean BMI in a population could be of major public health significance.

An observational study such as this cannot attribute causality. The association we have found between fast food consumption and BMI in children could be due to other specific dietary factors that have been shown to be associated with fast food consumption, such as higher fat intake, greater consumption of sugary drinks, fewer fruits and non-starchy vegetables(11). Alternatively fast food consumption may be a marker of other factors that influence BMI such as parental BMI, individual socioeconomic circumstances or patterns of activity and inactivity.

Adolescents

In our analysis self-reported frequent fast food consumption was associated with a lower BMI in adolescents, with stronger association in higher GNI countries. As far as we are aware, no other studies have demonstrated a lower BMI with higher fast food consumption in adolescence and our findings appear to be in stark contrast to other research findings from high GNI countries. One study showed that increasing fast food consumption in American adolescents was associated with increased weight gain from adolescence to adulthood (12). Another study found that American adolescents who consumed greater quantities of fried food away from home were heavier (23), and,

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in a further American study, increasing frequency of eating quick-service food was associated with an increasing z-BMI in adolescent females (17). A United Kingdom study found that increased visits to fast food outlets was associated with higher BMI standard deviation scores in teenagers (24). In three of these studies heights and weights were measured to pre-set standards by trained investigators (12, 17, 24), whereas heights and weights of our adolescent participants were mostly self-reported. It is possible that in our study some of the larger participants, particularly from body-image conscious countries or cultures may have under-reported their weights. In a study evaluating the correlation of measured versus self-reported heights and weights in adolescents, Brenner at al found that their study subjects tended to over-report their height by 2.7 inches (6.9cm) on average, and to under-report their weight by 3.5 pounds (1.6kg) on average, resulting in a BMI understated by 2.6kg/m^2 when compared to measured values. White adolescents were most likely to over-report their height and female adolescents were more likely to under-report their weight(25) [REF: Brenner – Reliability and validity of self-reported height and weight among high school students]. Similarly Danubio et al found that height was over-estimated in males and females (2.1 and 2.8cm respectively), and that weight was understated (1.5kg in males and 1.9kg in females) (26).[Danubio – comparison of self-reported and measured height and weight: implications of obesity research among young adults]. Rasmussen et al reported that in the COMPASS study, boys and girls who wished to be leaner under-reported their weight and BMI more than subjects who were satisfied with their body size(27). [Rasmussen: Bias and height and weight reported by Swedish adolescents and relations to body dissatisfaction]. If this were the case, we might expect that the association between fast food consumption and lower BMI would not be observed wWhen we restricted our analysis to measured height and weight data only, the association between higher fast food intake and lower BMI was no longer observed in male adolescents, but . Although this was the case in male adolescents, surprisingly the association between higher rates of fast food consumption and lower BMI persisted in female adolescents. We need to consider the possibility likelihood that because of

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the perception of the negative effects of fast food consumption, adolescents who are overweight or obese are likely to have under-reported their actual fast food consumption. In a ~~meta-analysis~~review of validation studies on energy-intake reporting in children and adolescents, Livingstone and Robson describe an increasing in under-reporting of energy intake reporting as age and BMI increases in childhood and adolescence, with 14%, 25% and 40% of energy intake under-reported in obese 6 year olds, 10 year olds and adolescents respectively (28)~~[Liningstone / Robson: Measurement of Dietary Intake in Children]~~. Finally, it is possible that our results are influenced by a degree of reverse-causation where those participants who are already overweight or obese are avoiding fast foods in order to reduce their body weight.

Fast food consumption

This study has shown that up to 25% of children worldwide consume fast food frequently or very frequently, and this increases to over 50% in the adolescent age group. This is consistent with results of previous studies, particularly those based in the United States and the United Kingdom (11, 29, 30)~~(11, 25, 26)~~. This study has also highlighted ~~is~~ the unexpectedly high proportion of fast food consumption in both age groups in many developing countries, for which data have not previously been available. In particular, high prevalence of fast food consumption was observed in centres in Latin America and Asia similar in magnitude to that observed in the United States and Western Europe. Importantly, we have also shown that the association between fast food consumption and higher BMI in children persists among those from both affluent and less affluent countries.

Cohort studies have demonstrated that high consumption of fast food at first assessment is associated with higher BMIs later in childhood or adult life (12, 24). If this is the case, despite an apparently lower BMI with higher reported fast food consumption in the adolescent group, the high proportions of adolescents already reporting fast food consumption is of concern, as fast food consumption has been directly linked with insulin resistance, hypertension and other health sequelae (31)~~(27)~~.

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Strengths and limitations:

The major strengths of this study were its size and multicentre structure, with 199,135 adolescents from 36 countries and 72,900 children from 17 countries surveyed. Many of the centres were from middle and low income countries from which previous data on the association between fast food consumption and BMI had not been reported.

The main limitation to this study is the cross-sectional design which allows identification of associations, but not of temporal sequence or causality. The assessment of subject heights and weights and their fast food consumption was primarily undertaken by questionnaire which raises the possibility of misclassification error, particularly with respect to the parent-reported weights of their children and self-reported weights of the adolescents, thereby influencing the calculated BMI. It is also possible that parents and adolescents may have misreported fast food consumption.

A further consideration is the interpretation of the question about the consumption of burgers / fast foods. While 'burger' is almost universally understood,' fast food' can be interpreted in a number of ways, including foodstuffs from global restaurant chains, smaller non-franchised food stores, street vendors and even frozen meals heated and served at home. Without knowing the exact kind of fast food consumed, we can make no assessment of the nutritional content or energy density of the food in question. Additionally, while the questionnaire asked about the frequency of burgers / fast food consumption, we have no indication of portion sizes, or if it was accompanied by other items such as sugar sweetened beverages.

Finally, centres that objectively measured heights and weights received no standardised instructions for doing this. We have controlled for GNI, centre, measurement type, and sex in our analysis. We have no data available on individual socioeconomic status or parental BMI which could potentially affect young peoples' BMI, nor did we control for physical activity / inactivity of the participants.

CONCLUSIONS:

~~There is~~This cross-sectional study has found that one quarter of children and half of adolescents consume fast food frequently or very frequently. Additionally there was an association between a high frequency of fast food consumption and higher BMIs in 6-7 year old children, but this association ~~is~~ was reversed in adolescents. As this is ~~a cross sectional~~an observational study, causality cannot be proven, however it provides evidence that among children from many different nations, fast food consumption may contribute to weight gain. This reverse association observed in adolescents should be interpreted with caution, as the results may be affected by bias, particularly under-reporting of fast food consumption and reverse causation.

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Author Contributions: Mr A Stewart had access to all the data on the study and takes responsibility for the integrity of the data and accuracy of the data analysis. *Study concept and design:* All authors. *Acquisition of Data:* ISAAC steering committee. *Drafting of the manuscript:* Braithwaite. *Critical revision of the manuscript for important intellectual content:* all authors. *Statistical analysis:* Stewart. *Obtained Funding:* Mitchell. *Administrative, technical and material support:* All authors. *Study supervision:* Mitchell.

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FIGURE LEGENDS

Figure 1: Flow of participants through study. Children are represented in panel (a) and adolescents in panel (b)

Figure 2: Reported frequency of fast food consumption by study participants. Children are represented in panel (a) and adolescents in panel (b)

Figure 3: ~~Association between~~The difference in -BMI of study participants ~~and frequent and very frequent~~that consumed -fast food consumption frequently and very frequently compared to infrequent fast food consumption. Children are represented in panel (a) and adolescents in panel (b). For each country the proportion of participants who consume fast food frequently or very frequently is shown in parentheses. Those centres with reported height and weights are shown with filled in circles, and those centres that measured heights and weights are shown with hollowed circles.

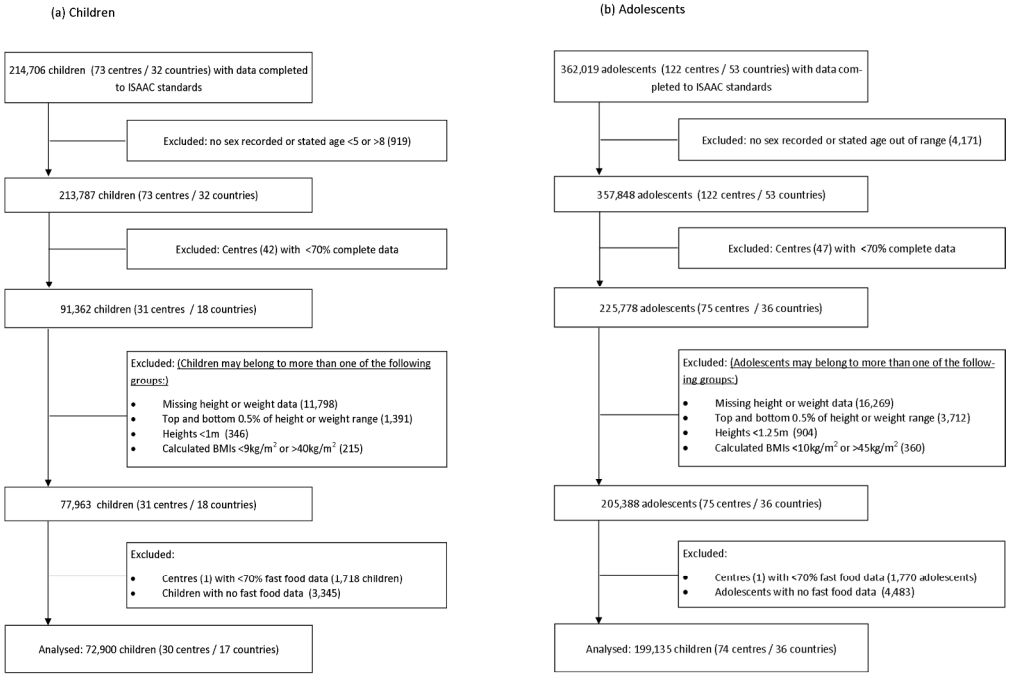

Figure 1: Flow of participants through study. Children are represented in panel (a) and adolescents in panel (b)

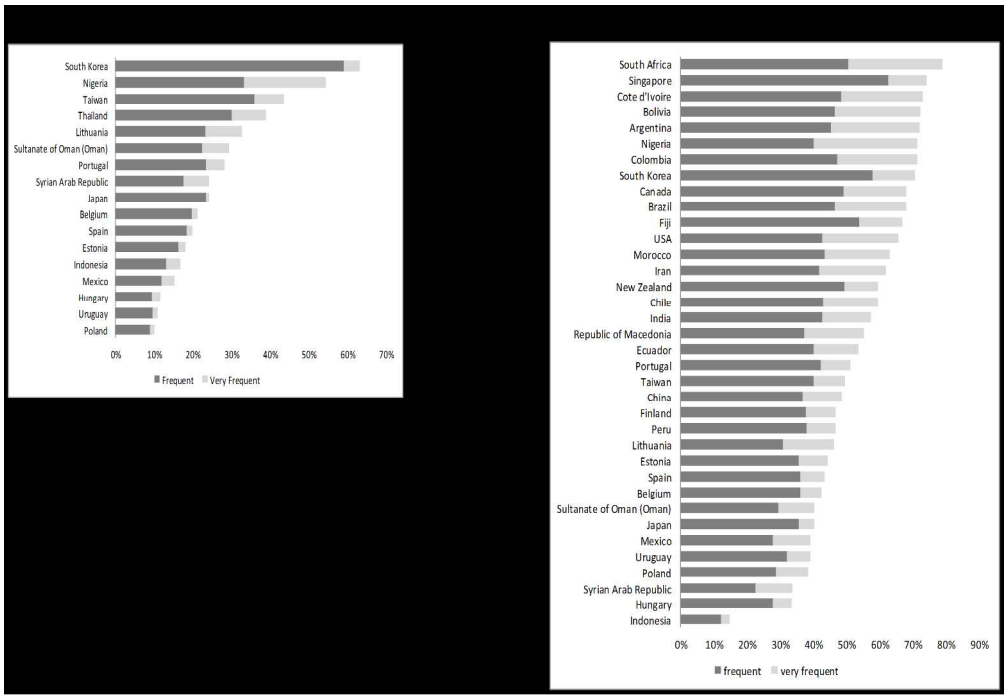

Figure 2: Reported frequency of fast food consumption by study participants. Children are represented in panel (a) and adolescents in panel (b)
261x179mm (300 x 300 DPI)

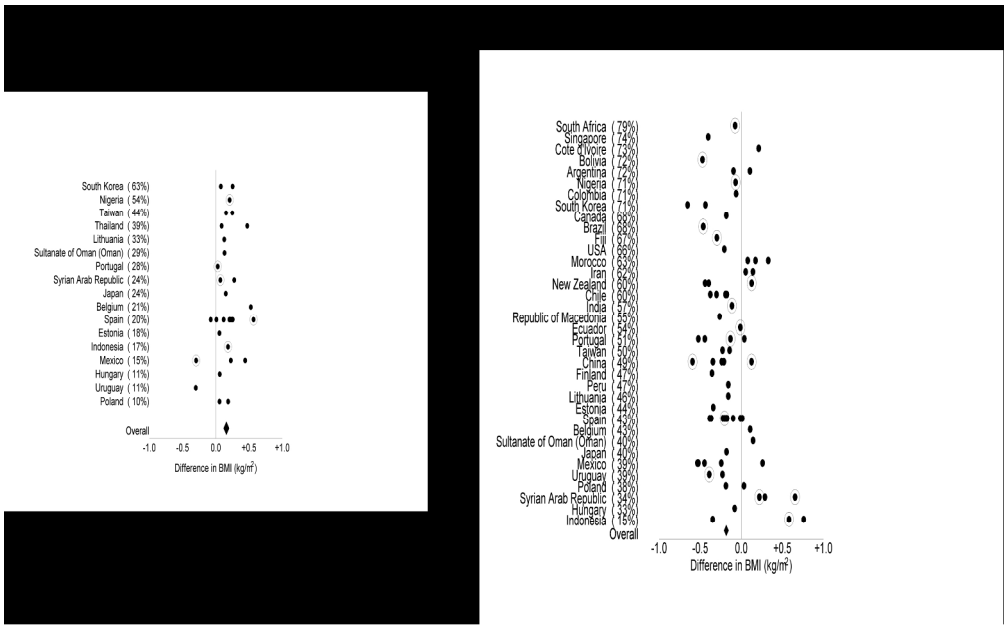

Figure 3: Association between BMI of study participants and frequent and very frequent fast food consumption compared to infrequent fast food consumption. Children are represented in panel (a) and adolescents in panel (b)
261x161mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Title page
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figures 1a and 1b
		(b) Give reasons for non-participation at each stage	Figures 1a and 1b
		(c) Consider use of a flow diagram	Done
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	Figures 1a and 1b
Outcome data	15*	Report numbers of outcome events or summary measures	9-11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-11, including Table 1
		(*b*) Report category boundaries when continuous variables were categorized	6-7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Fast Food consumption and Body Mass Index in children and adolescents: an international cross-sectional study

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Fast Food consumption and Body Mass Index in children and adolescents: an international cross-sectional study

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Word Count: **Abstract:** 297, Article: 3229

ABSTRACT:

Objective: To investigate whether reported fast food consumption over the previous year is associated with higher childhood or adolescent body mass index (BMI).

Design: Secondary analysis from multi-centre, multi-country, cross-sectional study (International Study of Asthma and Allergies in Children (ISAAC) Phase Three).

Subjects and Methods: Parents/guardians of children aged 6-7 completed questionnaires which included questions about their children's asthma and allergies, fast food consumption, height and weight. Adolescents aged 13-14 completed the same questionnaire. The questionnaire asked "In the past 12 months, how often on average did you (your child) eat fast food/burgers?" Responses were; infrequent (never/only occasionally), frequent (once/twice a week), or very frequent (three or more times per week). A general linear mixed model was used to determine the association between BMI and fast food consumption, adjusting for Gross National Income per capita by country, measurement type (whether heights/weights were reported or measured), age, and sex.

Results: 72,900 children (17 countries) and 199,135 adolescents (36 countries) provided data. Frequent and very frequent fast food consumption was reported in 23% and 4% of children, and 39% and 13% of adolescents. Children in the frequent and very frequent groups had a BMI 0.15 kg/m^2 and 0.22 kg/m^2 higher than the infrequent group ($P<0.001$). Adolescent males in the frequent and very frequent groups had a BMI 0.14 kg/m^2 and 0.28kg/m^2 lower than the infrequent group ($P<0.001$). Adolescent females in the frequent and very frequent groups had a BMI 0.19kg/m^2 lower than the infrequent group ($P<0.001$).

Conclusion: Reported fast food consumption is high in childhood and increases in adolescence. Compared with infrequent fast food consumption, frequent and very frequent consumption is

associated with a higher BMI in children. Because of residual confounding, reverse causation and likely misreporting, the reverse association observed in adolescents should be interpreted with caution.

Strengths and limitations of this study:

- 199,135 adolescents from 36 countries and 72,900 children from 17 countries provided information on their height, weight and fast food consumption.
- Many of the countries were middle and low income from which previous data on the association of fast food consumption and BMI had not been reported.
- There is an association between increasing frequency of fast food consumption and higher BMIs in 6-7 year old children, but this association was reversed in adolescents.
- As this is a cross sectional study, causality cannot be proven, but it provides evidence that among children from many different nations, fast food consumption may contribute to weight gain.
- The reverse association observed in adolescents should be interpreted with caution, as the results may be affected by bias, particularly under-reporting of fast food consumption and reverse causation.

INTRODUCTION:

The rising prevalence of childhood obesity is marked (1, 2), and there are well documented concerns about the future health implications of obesity in childhood (3-7). This problem has been identified in low and middle income countries as well as affluent countries (8, 9).

While potential contributors to the problem of childhood obesity are considered to be multiple and complex, in many countries fast food has been implicated due to its increasing availability, energy density, and large portion sizes. (10-13). Studies investigating associations between fast food consumption in children and Body Mass Index (BMI) have produced mixed results, some demonstrating small but significant associations between fast food consumption and increased BMI (12, 14-17), while others have failed to demonstrate a significant association (18-20). In a systematic review of studies assessing the association between fast food and obesity in 2008, Rosenheck noted that 'it is difficult to ascertain the true relationship between fast food consumption and weight gain or obesity, as many confounding factors such as physical inactivity and less inhibited food consumption are independently associated with both fast food consumption and weight gain or obesity' and that '… residual confounding from immeasurable lifestyle choices will always distort results garnered from observational study designs.'(14).

Additionally Rosenheck commented on the sample sizes of the cross-sectional studies, where only one study enrolled more than 5,000 participants, and in general enrolment was closer to the 1,000 mark, potentially negatively impacting the power of the studies to effectively assess the association between fast food consumption and weight / obesity. A cross-sectional study large enough to achieve sufficient power to determine an association between fast food consumption and obesity AND adequately address issues of multiple confounding factors is likely to be logistically demanding and prohibitively costly. A secondary analysis of the data from the International Study of Asthma and Allergies in Childhood (ISAAC) Phase Three programme allows an international 'snapshot' of fast food consumption and an assessment of the association between fast food consumption and BMI in

72,900 children from 17 countries and 199,135 adolescents from 36 countries at a single point in time, using a simple universal question. While few confounding variables are taken into account, the large numbers involved give power to this analysis.

We hypothesised that there would be an association between greater fast food consumption and higher BMI in both children and adolescents, and that this association would be observed worldwide.

SUBJECTS AND METHODS:

The International Study of Asthma and Allergies in Childhood (ISAAC) Phase Three programme was designed to measure time trends in the prevalence and severity of asthma, rhinoconjunctivitis and eczema and to explore the relationship between lifestyle, other putative risk factors and the development of asthma and allergies (21). ISAAC Phase Three used the ISAAC Phase One standardised core questionnaire on symptoms of asthma, rhinoconjunctivitis and eczema. ISAAC Phase Three provided the additional opportunity to explore the relationship between lifestyle factors such as fast food consumption and BMI, as heights, weights and information on the frequency of fast food consumption of participants were gathered in many centres through an optional environmental questionnaire that was answered by parents of children and by the adolescents themselves.

The ISAAC Phase One standardised core questionnaire and ISAAC Phase Three environmental questionnaire are on the ISAAC website: isaac.auckland.ac.nz.

Ethical approval was obtained for the original ISAAC Phase Three study, and permission was gained to use the data from ISAAC Phase Three through agreement with the ISAAC Phase Three Steering Committee.

Main outcome variable - Body Mass Index:

Height and weight were reported by the parents of the children, and were self-reported by adolescents. In some centres, each subject's height and weight were measured objectively; there were no standardised or specific instructions for doing this. BMI was calculated as weight (kg)/height $(m)^2$.

Explanatory variables:

Fast food consumption was established by asking participants to answer the following question: "In the past 12 months, how often, on average, did you [your child] eat the following?"

'Fast Food / Burgers' were listed as one option along with 14 other foodstuffs including meat, seafood, fruit and vegetables. The participants were asked to categorise their intake of each listed food as "Never or only occasionally"; "once or twice per week"; or "Three or more times a week". These responses were categorised as 'infrequent', 'frequent' and 'very frequent'. Each variable was examined separately for both age groups.

Country Gross National Index (GNI) was based on the 2006 World Bank of Gross National Income by country. The World Bank categories of high income, high middle income, low middle income and low income countries were dichotomised into 'high income' (high and high middle income) and 'low income' (low middle and low income) categories.

Participants:

For children aged 6-7 years, data were submitted from 73 centres in 32 countries (214,706 subjects). For adolescents aged 13-14 years data were submitted from 125 centres in 54 countries (369,881 subjects).

Centres that provided data on height, weight and fast food consumption for at least 70% of participants were included in our analyses. Individuals without complete age, sex, fast food consumption, height or weight data were excluded.

Data cleaning:

To eliminate likely erroneous BMI data, we applied the following thresholds:

- For children in each centre, those in the top and bottom 0.5% of weights and heights, and those with heights less than 1.0 metre were excluded. Children with BMI less than 9kg/m^2 and greater than 40kg/m^2 were excluded.

- For adolescents in each centre, those in the top and bottom 0.5% of weights and heights, and those with heights less than 1.25 metres were excluded. Adolescents with BMI less than 10kg/m^2 and greater than 45kg/m^2 were excluded.

Following sequential application of the exclusion and data cleaning criteria described above, 72,900 children (30 centres / 17 countries) and 199,135 adolescents (74 centres / 36 countries) were included in the final analysis (Figure 1). Parents provided heights and weights for 60,027 children, while 12,873 children had their heights and weights measured. 154,624 adolescents provided self-reported height and weight while 44,511 adolescents had measured heights and weights.

Figure 1: Flow of subjects through study.

STATISTICAL ANALYSIS:

BMI was assessed separately for each age group using a general linear mixed model with centre as a random effect and GNI for each country (low and high), the individual's age, sex, measurement type (reported or measured), and fast food consumption('infrequent', 'frequent' 'very frequent') as fixed effects. The BMI values reported are the modelled means for those who reported infrequent fast food consumption in the children and adolescent groups respectively.

In the adolescent group statistically significant interactions were found between sex and fast food consumption, and measurement type and fast food consumption. There was also an interaction found between country GNI and fast food consumption. Consequently, analyses were done separately for each sex, measured height and weight data only, and GNI categories. No similar

interactions were found in the children's group, but there were sufficient numbers to analyse each sex separately, which we elected to do.

RESULTS:

Fast food consumption:

22.6% of children reported frequent fast food consumption and 4.2% reported very frequent fast food consumption. Combined frequent and very frequent fast food consumption in each country ranged from 10% in Poland to 63% in South Korea (Figure 2a).

38.7% of adolescents reported frequent fast food consumption and 12.6% reported very frequent consumption. Frequent and very frequent fast food consumption ranged from 15% in Indonesia to 79% in South Africa (Figure 2b).

Figure 2: Reported fast food consumption of study participants by country.

Fast food consumption and BMI:

Children:

Figure 3a shows the difference in BMI between children with infrequent fast food consumption and those with frequent and very frequent fast food consumption in each centre.

Figure 3a: The association between reported fast food consumption and BMI of children.

The estimated mean BMIs in children reporting infrequent fast food consumption were 16.20 and 16.51 kg/m^2 for ages 6 and 7 respectively. After controlling for country GNI, centre, age and measurement type, there was a statistically significant association between frequent and very frequent fast food consumption and higher BMI with an apparent dose response effect (+0.15 and +0.22kg/m^2 for frequent and very frequent fast food consumption respectively), (Table 1). There was no statistically significant interaction between GNI and fast food consumption in this age group (P=0.06).

Table 1 – Association between fast food consumption and BMI (SE) of study participants after adjustment for GNI

		Difference in mean BMI (Kg/m^2) compared with infrequent fast food consumption		
	Estimated mean BMI* (Kg/m^2) infrequent fast food consumption	Frequent fast food consumption: mean (SE)	Very frequent fast food consumption: mean (SE)	P value[i]
Children (N=72,900)	16.51	+ 0.15 (0.02)	+ 0.22 (0.05)	P<0.001
Male Children (N=36,778)	16.53	+0.16 (0.03)	+0.24 (0.06)	P<0.001
Female Children (N=36,122)	16.39	+0.14 (0.03)	+0.20 (0.07)	P<0.001
Adolescent Males (N=98,794)	20.02	-0.14 (0.02)	- 0.28 (0.03)	P<0.001
Adolescent Females (N=100,341)	19.98	-0.19 (0.02)	- 0.19 (0.03)	P<0.001
Participants with measured height and weight data				
Children (N=12,873)	15.88	+0.14 (0.05)	+0.13 (0.08)	P=0.02
Adolescent Males (N= 20,384)	19.67	-0.03 (0.05)	-0.11(0.07)	P=0.24
Adolescent Females (N=24,127)	20.15	-0.15 (0.05)	-0.09 (0.06)	P=0.004

*Estimated BMIs for children aged 7 years and adolescents aged 14 years.

[i] P value is a joint test of whether the differences in BMIs for frequent and very frequent fast food consumption relative to infrequent fast food consumption are zero.

When boys and girls were analysed separately, both sexes had a significant positive association between frequent and very frequent fast food consumption (Table 1).

Adolescents:

Figure 3b shows the difference in BMI between adolescents with infrequent fast food consumption and those with frequent and very frequent fast food consumption in each centre.

Figure 3b: The association between fast food consumption and BMI of adolescents

In male adolescents, the estimated mean BMIs for those reporting infrequent fast food consumption were 19.74 and 20.02 kg/m^2 for ages 13 and 14 respectively. After controlling for country GNI,

centre, age and measurement type, lower BMI's were significantly associated with greater fast food consumption (Table 1). There was a statistically significant interaction between fast food consumption and GNI. In low GNI countries the frequency of fast food consumption had no association with BMI (+0.01 and -0.03kg/m^2 in the frequent and very frequent groups respectively (P=0.89 and 0.56)). In high GNI countries, lower BMI's were associated with greater fast food consumption (-0.21 and -0.42kg/m^2 in the frequent and very frequent groups respectively (P<0.001 in both groups)).

When analyses were restricted to the 20,384 male adolescents who had measured height and weight data there was a tendency towards a lower BMI with higher fast food consumption, but this was not statistically significant (-0.03kg/m2 and -0.11kg/m2 in the frequent and very frequent group respectively, (p=0.24)).

In female adolescents, the estimated mean BMI's for those reporting infrequent fast food consumption were 19.56 and 19.98 kg/m^2 for ages 13 and 14 respectively. Lower BMIs were associated with greater fast food consumption and this was statistically significant. There was a statistically significant interaction between fast food consumption and GNI. Both low and high GNI countries had an association between increasing fast food consumption and BMI (low GNI countries -0.10kg/m^2 and -0.11kg/m^2 in the frequent and very frequent groups respectively (P=0.03 and 0.01), and high GNI countries -0.24kg/m^2 and -0.22kg/m^2 in the frequent and very frequent groups respectively (P<0.0001 in both cases)).

When analyses were restricted to the 24,127 female adolescents who had measured height and weight data, those who ate fast food frequently or very frequently had lower BMIs and this was statistically significant (Table 1).

DISCUSSION:

This international study has identified that 6-7 year old children who consumed fast food frequently had higher BMIs than those who consumed fast food infrequently. This association was independent of the affluence of the country and of similar magnitude in boys and girls. By contrast, adolescents who self-reported that they frequently ate fast foods tended to have lower BMIs, with the exception of male adolescents from low GNI countries, where there was no association between fast food consumption and BMI. We have also found that up to 25% of children worldwide consume fast food frequently or very frequently, and this increases to over 50% in the adolescent age group.

Children

Our results in children are consistent with those of Shan et al who found that 'Western fast food' and 'snack food' were associated with overweight and obesity among children aged 2 to 18 years in Beijing(22). However, In New Zealand, Duncan et al found that low levels of physical activity, skipping breakfast and insufficient sleep on weekdays were associated with increased adiposity in 5 to 11 year olds, but that fast food consumption was not (20). The magnitude of the association between fast food consumption and BMI in children was small (mean BMI values 0.15 kg/m^2 and 0.22kg/m^2 higher in frequent and very frequent consumers compared to infrequent consumers), and the clinical significance of this is uncertain. Given the long term consequences of overweight and obesity in childhood, even a small change in mean BMI in a population could be of major public health significance.

An observational study such as this cannot attribute causality. The association we have found between fast food consumption and BMI in children could be due to other specific dietary factors that have been shown to be associated with fast food consumption, such as higher fat intake, greater consumption of sugary drinks, fewer fruits and non-starchy vegetables(11). Alternatively fast food consumption may be a marker of other factors that influence BMI such as parental BMI, individual socioeconomic circumstances or patterns of activity and inactivity.

Adolescents

In our analysis self-reported frequent fast food consumption was associated with a lower BMI in adolescents, with stronger association in higher GNI countries. As far as we are aware, no other studies have demonstrated a lower BMI with higher fast food consumption in adolescence and our findings appear to be in stark contrast to other research findings from high GNI countries. One study showed that increasing fast food consumption in American adolescents was associated with increased weight gain from adolescence to adulthood (12). Another study found that American adolescents who consumed greater quantities of fried food away from home were heavier (23), and, in a further American study, increasing frequency of eating quick-service food was associated with an increasing z-BMI in adolescent females (17). A United Kingdom study found that increased visits to fast food outlets was associated with higher BMI standard deviation scores in teenagers (24). In three of these studies heights and weights were measured to pre-set standards by trained investigators (12, 17, 24), whereas heights and weights of our adolescent participants were mostly self-reported. It is possible that in our study some of the larger participants, particularly from body-image conscious countries or cultures may have under-reported their weights. In a study evaluating the correlation of measured versus self-reported heights and weights in adolescents, Brener at al found that their study subjects tended to over-report their height by 2.7 inches (6.9cm) on average, and to under-report their weight by 3.5 pounds (1.6kg) on average, resulting in a BMI understated by 2.6kg/m^2 when compared to measured values. White adolescents were most likely to over-report their height and female adolescents were more likely to under-report their weight(25). Similarly Danubio et al found that height was over-estimated in males and females (2.1 and 2.8cm respectively), and that weight was understated (1.5kg in males and 1.9kg in females)(26). Rasmussen et al reported that in the COMPASS study, boys and girls who wished to be leaner under-reported their weight and BMI more than subjects who were satisfied with their body size(27). When we restricted our analysis to measured height and weight data only, the association between higher fast food intake and lower BMI was no longer observed in male adolescents, but the association between

higher rates of fast food consumption and lower BMI persisted in female adolescents. We need to consider the likelihood that because of the perception of the negative effects of fast food consumption, adolescents who are overweight or obese are likely to have under-reported their actual fast food consumption. In a review of validation studies on energy-intake reporting in children and adolescents, Livingstone and Robson describe an increasing in under-reporting of energy intake reporting as age and BMI increases in childhood and adolescence, with 14%, 25% and 40% of energy intake under-reported in obese 6 year olds, 10 year olds and adolescents respectively (28). Finally, it is possible that our results are influenced by a degree of reverse-causation where those participants who are already overweight or obese are avoiding fast foods in order to reduce their body weight.

Fast food consumption

This study has shown that up to 25% of children worldwide consume fast food frequently or very frequently, and this increases to over 50% in the adolescent age group. This is consistent with results of previous studies, particularly those based in the United States and the United Kingdom (11, 29, 30). This study has also highlighted the unexpectedly high proportion of fast food consumption in both age groups in many developing countries, for which data have not previously been available. In particular, high prevalence of fast food consumption was observed in centres in Latin America and Asia similar in magnitude to that observed in the United States and Western Europe. Importantly, we have also shown that the association between fast food consumption and higher BMI in children persists among those from both affluent and less affluent countries.

Cohort studies have demonstrated that high consumption of fast food at first assessment is associated with higher BMIs later in childhood or adult life (12, 24). If this is the case, despite an apparently lower BMI with higher reported fast food consumption in the adolescent group, the high proportions of adolescents already reporting fast food consumption is of concern, as fast food

consumption has been directly linked with insulin resistance, hypertension and other health sequelae (31).

Strengths and limitations:

The major strengths of this study were its size and multicentre structure, with 199,135 adolescents from 36 countries and 72,900 children from 17 countries surveyed. Many of the centres were from middle and low income countries from which previous data on the association between fast food consumption and BMI had not been reported.

The main limitation to this study is the cross-sectional design which allows identification of associations, but not of temporal sequence or causality. The assessment of subject heights and weights and their fast food consumption was primarily undertaken by questionnaire which raises the possibility of misclassification error, particularly with respect to the parent-reported weights of their children and self-reported weights of the adolescents, thereby influencing the calculated BMI. It is also possible that parents and adolescents may have misreported fast food consumption.

A further consideration is the interpretation of the question about the consumption of burgers / fast foods. While 'burger' is almost universally understood,' fast food' can be interpreted in a number of ways, including foodstuffs from global restaurant chains, smaller non-franchised food stores, street vendors and even frozen meals heated and served at home. Without knowing the exact kind of fast food consumed, we can make no assessment of the nutritional content or energy density of the food in question. Additionally, while the questionnaire asked about the frequency of burgers / fast food consumption, we have no indication of portion sizes, or if it was accompanied by other items such as sugar sweetened beverages.

Finally, centres that objectively measured heights and weights received no standardised instructions for doing this. We have controlled for GNI, centre, measurement type, and sex in our analysis. We

have no data available on individual socioeconomic status or parental BMI which could potentially affect young peoples' BMI, nor did we control for physical activity / inactivity of the participants.

CONCLUSIONS:

This cross-sectional study has found that one quarter of children and half of adolescents consume fast food frequently or very frequently. Additionally there was an association between a high frequency of fast food consumption and higher BMIs in 6-7 year old children, but this association was reversed in adolescents. As this is an observational study, causality cannot be proven, however it provides evidence that among children from many different nations, fast food consumption may contribute to weight gain. This reverse association observed in adolescents should be interpreted with caution, as the results may be affected by bias, particularly under-reporting of fast food consumption and reverse causation.

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Data Sharing Statement: Information with respect to all ISAAC studies, including methods, data gathering and results is available on the ISAAC website: isaac.auckland.ac.nz/

FIGURE LEGENDS

Figure 1: Flow of participants through study. Children are represented in panel (a) and adolescents in panel (b)

Figure 2: Reported frequency of fast food consumption by study participants. Children are represented in panel (a) and adolescents in panel (b)

Figure 3: The difference in BMI of study participants that consumed fast food consumption frequently and very frequently compared to infrequent fast food consumption. Children are represented in panel (a) and adolescents in panel (b). For each country the proportion of participants who consume fast food frequently or very frequently is shown in parentheses. Those centres with reported height and weights are shown with filled in circles, and those centres that measured heights and weights are shown with hollowed circles.

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Fast Food consumption and Body Mass Index in children and adolescents: an international cross-sectional study

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ABSTRACT:

Objective: To investigate whether reported fast food consumption over the previous year is associated with higher childhood or adolescent body mass index (BMI).

Design: Secondary analysis from a multi-centre, multi-country, cross-sectional study (International Study of Asthma and Allergies in Children (ISAAC) Phase Three).

Subjects and Methods: Parents / guardians of children aged 6-7 completed questionnaires which included questions about their children's asthma and allergies, fast food consumption, height and weight. Adolescents aged 13-14 completed the same questionnaire. The questionnaire asked "In the past 12 months, how often on average did you (your child) eat fast food/burgers?" Responses were; infrequent (never / only occasionally), frequent (once / twice a week), or very frequent (three or more times per week). A general linear mixed model was used to determine the association between BMI and fast food consumption, adjusting for Gross National Income per capita by country, measurement type (whether height and weight were reported or measured), age, and sex.

Results: 72,900 children from 17 countries and 199,135 adolescents from 36 countries provided data. Frequent and very frequent fast food consumption was reported in 23% and 4% of children, and 39% and 13% of adolescents. Children in the frequent and very frequent groups had a BMI 0.15 kg/m^2 and 0.22 kg/m^2 higher than the infrequent group (P<0.001). Adolescent males in the frequent and very frequent groups had a BMI 0.14 kg/m^2 and 0.28kg/m^2 lower than the infrequent group (P<0.001). Adolescent females in the frequent and very frequent groups had a BMI 0.19kg/m^2 lower than the infrequent group (P<0.001).

- **Conclusion:** Reported fast food consumption is high in childhood and increases in adolescence. Compared with infrequent fast food consumption, frequent and very frequent consumption is associated with a higher BMI in children. Because of residual confounding, reverse causation and likely misreporting, the reverse association observed in adolescents should be interpreted with caution.

~~and a lower BMI in adolescents.~~

Strengths and limitations of this study:

- 199,135 adolescents from 36 countries and 72,900 children from 17 countries provided information on their height, weight and fast food consumption.
- Many of the countries were middle and low income from which previous data on the association of fast food consumption and BMI had not been reported.
- There is an association between increasing frequency of fast food consumption and higher BMIs in 6-7 year old children, but this association was reversed in adolescents.
- As this is a cross sectional study, causality cannot be proven, but it provides evidence that among children from many different nations, fast food consumption may contribute to weight gain.
- The reverse association observed in adolescents should be interpreted with caution, as the results may be affected by bias, particularly under-reporting of fast food consumption and reverse causation.

INTRODUCTION:

The rising prevalence of childhood obesity is marked (1, 2), and there are well documented concerns about the future health implications of obesity in childhood (3-7). This problem has been identified in low and middle income countries as well as affluent countries (8, 9).

While potential contributors to the problem of childhood obesity are considered to be multiple and complex, in many countries fast food has been implicated due to its increasing availability, energy density, and large portion sizes. (10-13). Studies investigating associations between fast food consumption in children and Body Mass Index (BMI) have produced mixed results, some demonstrating small but significant associations between fast food consumption and increased BMI (12, 14-17), while others have failed to demonstrate a significant association (18-20). In a systematic review of studies assessing the association between fast food and obesity in 2008, Rosenheck noted that 'it is difficult to ascertain the true relationship between fast food consumption and weight gain or obesity, as many confounding factors such as physical inactivity and less inhibited food consumption are independently associated with both fast food consumption and weight gain or obesity' and that '… residual confounding from immeasurable lifestyle choices will always distort results garnered from observational study designs.'(14).

Additionally Rosenheck commented on the sample sizes of the cross-sectional studies, where only one study enrolled more than 5,000 participants, and in general enrolment was closer to the 1,000 mark, potentially negatively impacting the power of the studies to effectively assess the association between fast food consumption and weight / obesity. A cross-sectional study large enough to achieve sufficient power to determine an association between fast food consumption and obesity AND adequately address issues of multiple confounding factors is likely to be logistically demanding and prohibitively costly. A secondary analysis of the data from the International Study of Asthma and Allergies in Childhood (ISAAC) Phase Three programme allows an international 'snapshot' of fast food consumption and an assessment of the association between fast food consumption and BMI in

72,900 children from 17 countries and 199,135 adolescents from 36 countries at a single point in time, using a simple universal question. While few confounding variables are taken into account, the large numbers involved give power to this analysis.

We hypothesised that there would be an association between greater fast food consumption and higher BMI in both children and adolescents, and that this association would be observed worldwide.

SUBJECTS AND METHODS:

The International Study of Asthma and Allergies in Childhood (ISAAC) Phase Three programme was designed to measure time trends in the prevalence and severity of asthma, rhinoconjunctivitis and eczema and to explore the relationship between lifestyle, other putative risk factors and the development of asthma and allergies (21). ISAAC Phase Three used the ISAAC Phase One standardised core questionnaire on symptoms of asthma, rhinoconjunctivitis and eczema. ISAAC Phase Three provided the additional opportunity to explore the relationship between lifestyle factors such as fast food consumption and BMI, as heights, weights and information on the frequency of fast food consumption of participants were gathered in many centres through an optional environmental questionnaire that was answered by parents of children and by the adolescents themselves.

The ISAAC Phase One standardised core questionnaire and ISAAC Phase Three environmental questionnaire are on the ISAAC website: isaac.auckland.ac.nz.

Ethical approval was obtained for the original ISAAC Phase Three study, and permission was gained to use the data from ISAAC Phase Three through agreement with the ISAAC Phase Three Steering Committee.

Main outcome variable - Body Mass Index:

Height and weight were reported by the parents of the children, and were self-reported by adolescents. In some centres, each subject's height and weight were measured objectively; there were no standardised or specific instructions for doing this. BMI was calculated as weight (kg)/height $(m)^2$.

Explanatory variables:

Fast food consumption was established by asking participants to answer the following question: "In the past 12 months, how often, on average, did you [your child] eat the following?"

'Fast Food / Burgers' were listed as one option along with 14 other foodstuffs including meat, seafood, fruit and vegetables. The participants were asked to categorise their intake of each listed food as "Never or only occasionally"; "once or twice per week"; or "Three or more times a week". These responses were categorised as 'infrequent', 'frequent' and 'very frequent'. Each variable was examined separately for both age groups.

Country Gross National Index (GNI) was based on the 2006 World Bank of Gross National Income by country. The World Bank categories of high income, high middle income, low middle income and low income countries were dichotomised into 'high income' (high and high middle income) and 'low income' (low middle and low income) categories.

Participants:

For children aged 6-7 years, data were submitted from 73 centres in 32 countries (214,706 subjects). For adolescents aged 13-14 years data were submitted from 125 centres in 54 countries (369,881 subjects).

Centres that provided data on height, weight and fast food consumption for at least 70% of participants were included in our analyses. Individuals without complete age, sex, fast food consumption, height or weight data were excluded.

Data cleaning:

To eliminate likely erroneous BMI data, we applied the following thresholds:

- For children in each centre, those in the top and bottom 0.5% of weights and heights, and those with heights less than 1.0 metre were excluded. Children with BMI less than 9kg/m^2 and greater than 40kg/m^2 were excluded.

- For adolescents in each centre, those in the top and bottom 0.5% of weights and heights, and those with heights less than 1.25 metres were excluded. Adolescents with BMI less than 10kg/m^2 and greater than 45kg/m^2 were excluded.

Following sequential application of the exclusion and data cleaning criteria described above, 72,900 children (30 centres / 17 countries) and 199,135 adolescents (74 centres / 36 countries) were included in the final analysis (Figure 1). Parents provided heights and weights for 60,027 children, while 12,873 children had their heights and weights measured. 154,624 adolescents provided self-reported height and weight while 44,511 adolescents had measured heights and weights.

Figure 1: Flow of subjects through study.

STATISTICAL ANALYSIS:

BMI was assessed separately for each age group using a general linear mixed model with centre as a random effect and GNI for each country (low and high), the individual's age, sex, measurement type (reported or measured), and fast food consumption('infrequent', 'frequent' 'very frequent') as fixed effects. The BMI values reported are the modelled means for those who reported infrequent fast food consumption in the children and adolescent groups respectively.

In the adolescent group statistically significant interactions were found between sex and fast food consumption, and measurement type and fast food consumption. There was also an interaction found between country GNI and fast food consumption. Consequently, analyses were done separately for each sex, measured height and weight data only, and GNI categories. No similar

interactions were found in the children's group, but there were sufficient numbers to analyse each sex separately, which we elected to do.

RESULTS:

Fast food consumption:

22.6% of children reported frequent fast food consumption and 4.2% reported very frequent fast food consumption. Combined frequent and very frequent fast food consumption in each country ranged from 10% in Poland to 63% in South Korea (Figure 2a).

38.7% of adolescents reported frequent fast food consumption and 12.6% reported very frequent consumption. Frequent and very frequent fast food consumption ranged from 15% in Indonesia to 79% in South Africa (Figure 2b).

Figure 2: Reported fast food consumption of study participants by country.

Fast food consumption and BMI:

Children:

Figure 3a shows the difference in BMI between children with infrequent fast food consumption and those with frequent and very frequent fast food consumption in each centre.

Figure 3a: The association between reported fast food consumption and BMI of children.

The estimated mean BMIs in children reporting infrequent fast food consumption were 16.20 and 16.51 kg/m^2 for ages 6 and 7 respectively. After controlling for country GNI, centre, age and measurement type, there was a statistically significant association between frequent and very frequent fast food consumption and higher BMI with an apparent dose response effect (+0.15 and +0.22kg/m^2 for frequent and very frequent fast food consumption respectively), (Table 1). There was no statistically significant interaction between GNI and fast food consumption in this age group (P=0.06).

Table 1 – Association between fast food consumption and BMI (SE) of study participants after adjustment for GNI

		Difference in mean BMI (Kg/m^2) compared with infrequent fast food consumption		
	Estimated mean BMI* (Kg/m^2) infrequent fast food consumption	Frequent fast food consumption: mean (SE)	Very frequent fast food consumption: mean (SE)	P value[i]
Children (N=72,900)	16.51	+ 0.15 (0.02)	+ 0.22 (0.05)	P<0.001
Male Children (N=36,778)	16.53	+0.16 (0.03)	+0.24 (0.06)	P<0.001
Female Children (N=36,122)	16.39	+0.14 (0.03)	+0.20 (0.07)	P<0.001
Adolescent Males (N=98,794)	20.02	-0.14 (0.02)	- 0.28 (0.03)	P<0.001
Adolescent Females (N=100,341)	19.98	-0.19 (0.02)	- 0.19 (0.03)	P<0.001
Participants with measured height and weight data				
Children (N=12,873)	15.88	+0.14 (0.05)	+0.13 (0.08)	P=0.02
Adolescent Males (N= 20,384)	19.67	-0.03 (0.05)	-0.11(0.07)	P=0.24
Adolescent Females (N=24,127)	20.15	-0.15 (0.05)	-0.09 (0.06)	P=0.004

*Estimated BMIs for children aged 7 years and adolescents aged 14 years.

[i] P value is a joint test of whether the differences in BMIs for frequent and very frequent fast food consumption relative to infrequent fast food consumption are zero.

When boys and girls were analysed separately, both sexes had a significant positive association between frequent and very frequent fast food consumption (Table 1).

Adolescents:

Figure 3b shows the difference in BMI between adolescents with infrequent fast food consumption and those with frequent and very frequent fast food consumption in each centre.

Figure 3b: The association between fast food consumption and BMI of adolescents

In male adolescents, the estimated mean BMIs for those reporting infrequent fast food consumption were 19.74 and 20.02 kg/m^2 for ages 13 and 14 respectively. After controlling for country GNI,

centre, age and measurement type, lower BMI's were significantly associated with greater fast food consumption (Table 1). There was a statistically significant interaction between fast food consumption and GNI. In low GNI countries the frequency of fast food consumption had no association with BMI (+0.01 and -0.03kg/m^2 in the frequent and very frequent groups respectively (P=0.89 and 0.56)). In high GNI countries, lower BMI's were associated with greater fast food consumption (-0.21 and -0.42kg/m^2 in the frequent and very frequent groups respectively (P<0.001 in both groups)).

When analyses were restricted to the 20,384 male adolescents who had measured height and weight data there was a tendency towards a lower BMI with higher fast food consumption, but this was not statistically significant (-0.03kg/m2 and -0.11kg/m2 in the frequent and very frequent group respectively, (p=0.24)).

In female adolescents, the estimated mean BMI's for those reporting infrequent fast food consumption were 19.56 and 19.98 kg/m^2 for ages 13 and 14 respectively. Lower BMIs were associated with greater fast food consumption and this was statistically significant. There was a statistically significant interaction between fast food consumption and GNI. Both low and high GNI countries had an association between increasing fast food consumption and BMI (low GNI countries -0.10kg/m^2 and -0.11kg/m^2 in the frequent and very frequent groups respectively (P=0.03 and 0.01), and high GNI countries -0.24kg/m^2 and -0.22kg/m^2 in the frequent and very frequent groups respectively (P<0.0001 in both cases)).

When analyses were restricted to the 24,127 female adolescents who had measured height and weight data, those who ate fast food frequently or very frequently had lower BMIs and this was statistically significant (Table 1).

DISCUSSION:

This international study has identified that 6-7 year old children who consumed fast food frequently had higher BMIs than those who consumed fast food infrequently. This association was independent of the affluence of the country and of similar magnitude in boys and girls. By contrast, adolescents who self-reported that they frequently ate fast foods tended to have lower BMIs, with the exception of male adolescents from low GNI countries, where there was no association between fast food consumption and BMI. We have also found that up to 25% of children worldwide consume fast food frequently or very frequently, and this increases to over 50% in the adolescent age group.

Children

Our results in children are consistent with those of Shan et al who found that 'Western fast food' and 'snack food' were associated with overweight and obesity among children aged 2 to 18 years in Beijing(22). However, In New Zealand, Duncan et al found that low levels of physical activity, skipping breakfast and insufficient sleep on weekdays were associated with increased adiposity in 5 to 11 year olds, but that fast food consumption was not (20). The magnitude of the association between fast food consumption and BMI in children was small (mean BMI values 0.15 kg/m^2 and 0.22kg/m^2 higher in frequent and very frequent consumers compared to infrequent consumers), and the clinical significance of this is uncertain. Given the long term consequences of overweight and obesity in childhood, even a small change in mean BMI in a population could be of major public health significance.

An observational study such as this cannot attribute causality. The association we have found between fast food consumption and BMI in children could be due to other specific dietary factors that have been shown to be associated with fast food consumption, such as higher fat intake, greater consumption of sugary drinks, fewer fruits and non-starchy vegetables(11). Alternatively fast food consumption may be a marker of other factors that influence BMI such as parental BMI, individual socioeconomic circumstances or patterns of activity and inactivity.

Adolescents

In our analysis self-reported frequent fast food consumption was associated with a lower BMI in adolescents, with stronger association in higher GNI countries. As far as we are aware, no other studies have demonstrated a lower BMI with higher fast food consumption in adolescence and our findings appear to be in stark contrast to other research findings from high GNI countries. One study showed that increasing fast food consumption in American adolescents was associated with increased weight gain from adolescence to adulthood (12). Another study found that American adolescents who consumed greater quantities of fried food away from home were heavier (23), and, in a further American study, increasing frequency of eating quick-service food was associated with an increasing z-BMI in adolescent females (17). A United Kingdom study found that increased visits to fast food outlets was associated with higher BMI standard deviation scores in teenagers (24). In three of these studies heights and weights were measured to pre-set standards by trained investigators (12, 17, 24), whereas heights and weights of our adolescent participants were mostly self-reported. It is possible that in our study some of the larger participants, particularly from body-image conscious countries or cultures may have under-reported their weights. In a study evaluating the correlation of measured versus self-reported heights and weights in adolescents, Brener at al found that their study subjects tended to over-report their height by 2.7 inches (6.9cm) on average, and to under-report their weight by 3.5 pounds (1.6kg) on average, resulting in a BMI understated by 2.6kg/m^2 when compared to measured values. White adolescents were most likely to over-report their height and female adolescents were more likely to under-report their weight(25). Similarly Danubio et al found that height was over-estimated in males and females (2.1 and 2.8cm respectively), and that weight was understated (1.5kg in males and 1.9kg in females)(26). Rasmussen et al reported that in the COMPASS study, boys and girls who wished to be leaner under-reported their weight and BMI more than subjects who were satisfied with their body size(27). When we restricted our analysis to measured height and weight data only, the association between higher fast food intake and lower BMI was no longer observed in male adolescents, but the association between

higher rates of fast food consumption and lower BMI persisted in female adolescents. We need to consider the likelihood that because of the perception of the negative effects of fast food consumption, adolescents who are overweight or obese are likely to have under-reported their actual fast food consumption. In a review of validation studies on energy-intake reporting in children and adolescents, Livingstone and Robson describe an increasing in under-reporting of energy intake reporting as age and BMI increases in childhood and adolescence, with 14%, 25% and 40% of energy intake under-reported in obese 6 year olds, 10 year olds and adolescents respectively (28). Finally, it is possible that our results are influenced by a degree of reverse-causation where those participants who are already overweight or obese are avoiding fast foods in order to reduce their body weight.

Fast food consumption

This study has shown that up to 25% of children worldwide consume fast food frequently or very frequently, and this increases to over 50% in the adolescent age group. This is consistent with results of previous studies, particularly those based in the United States and the United Kingdom (11, 29, 30). This study has also highlighted the unexpectedly high proportion of fast food consumption in both age groups in many developing countries, for which data have not previously been available. In particular, high prevalence of fast food consumption was observed in centres in Latin America and Asia similar in magnitude to that observed in the United States and Western Europe. Importantly, we have also shown that the association between fast food consumption and higher BMI in children persists among those from both affluent and less affluent countries.

Cohort studies have demonstrated that high consumption of fast food at first assessment is associated with higher BMIs later in childhood or adult life (12, 24). If this is the case, despite an apparently lower BMI with higher reported fast food consumption in the adolescent group, the high proportions of adolescents already reporting fast food consumption is of concern, as fast food

consumption has been directly linked with insulin resistance, hypertension and other health sequelae (31).

Strengths and limitations:

The major strengths of this study were its size and multicentre structure, with 199,135 adolescents from 36 countries and 72,900 children from 17 countries surveyed. Many of the centres were from middle and low income countries from which previous data on the association between fast food consumption and BMI had not been reported.

The main limitation to this study is the cross-sectional design which allows identification of associations, but not of temporal sequence or causality. The assessment of subject heights and weights and their fast food consumption was primarily undertaken by questionnaire which raises the possibility of misclassification error, particularly with respect to the parent-reported weights of their children and self-reported weights of the adolescents, thereby influencing the calculated BMI. It is also possible that parents and adolescents may have misreported fast food consumption.

A further consideration is the interpretation of the question about the consumption of burgers / fast foods. While 'burger' is almost universally understood,' fast food' can be interpreted in a number of ways, including foodstuffs from global restaurant chains, smaller non-franchised food stores, street vendors and even frozen meals heated and served at home. Without knowing the exact kind of fast food consumed, we can make no assessment of the nutritional content or energy density of the food in question. Additionally, while the questionnaire asked about the frequency of burgers / fast food consumption, we have no indication of portion sizes, or if it was accompanied by other items such as sugar sweetened beverages.

Finally, centres that objectively measured heights and weights received no standardised instructions for doing this. We have controlled for GNI, centre, measurement type, and sex in our analysis. We

have no data available on individual socioeconomic status or parental BMI which could potentially affect young peoples' BMI, nor did we control for physical activity / inactivity of the participants.

CONCLUSIONS:

This cross-sectional study has found that one quarter of children and half of adolescents consume fast food frequently or very frequently. Additionally there was an association between a high frequency of fast food consumption and higher BMIs in 6-7 year old children, but this association was reversed in adolescents. As this is an observational study, causality cannot be proven, however it provides evidence that among children from many different nations, fast food consumption may contribute to weight gain. This reverse association observed in adolescents should be interpreted with caution, as the results may be affected by bias, particularly under-reporting of fast food consumption and reverse causation.

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Author Contributions: Mr A Stewart had access to all the data on the study and takes responsibility for the integrity of the data and accuracy of the data analysis. *Study concept and design:* All authors. *Acquisition of Data:* ISAAC steering committee. *Drafting of the manuscript:* Braithwaite. *Critical revision of the manuscript for important intellectual content:* all authors. *Statistical analysis:* Stewart. *Obtained Funding:* Mitchell. *Administrative, technical and material support:* All authors. *Study supervision:* Mitchell.

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FIGURE LEGENDS

Figure 1: Flow of participants through study. Children are represented in panel (a) and adolescents in panel (b)

Figure 2: Reported frequency of fast food consumption by study participants. Children are represented in panel (a) and adolescents in panel (b)

Figure 3: The difference in BMI of study participants that consumed fast food consumption frequently and very frequently compared to infrequent fast food consumption. Children are represented in panel (a) and adolescents in panel (b). For each country the proportion of participants who consume fast food frequently or very frequently is shown in parentheses. Those centres with reported height and weights are shown with filled in circles, and those centres that measured heights and weights are shown with hollowed circles.

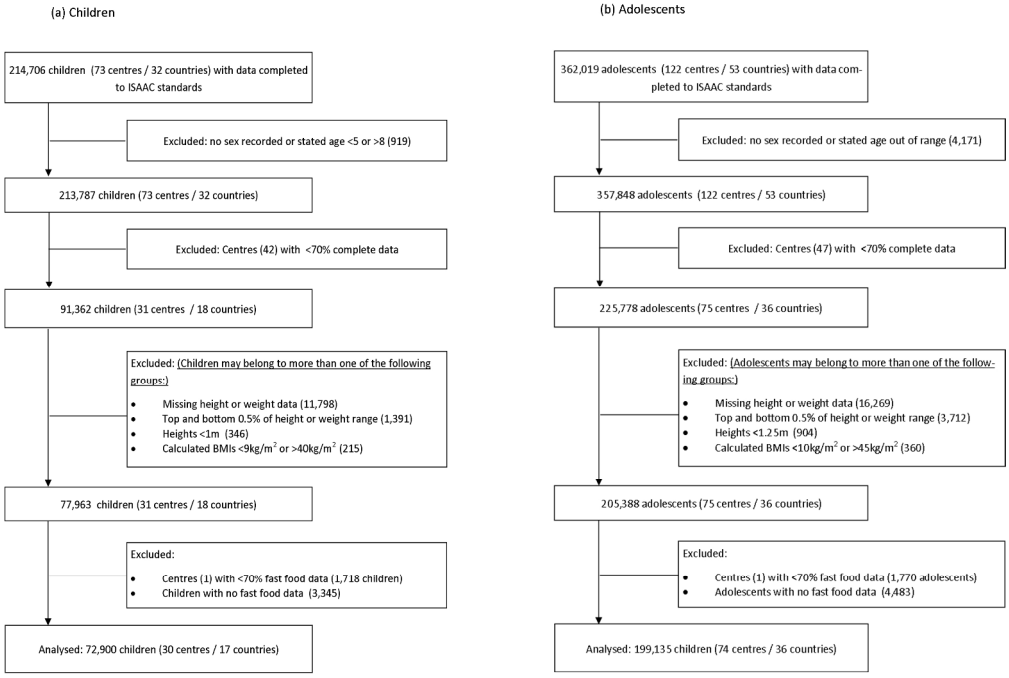

Figure 1: Flow of participants through study. Children are represented in panel (a) and adolescents in panel (b)

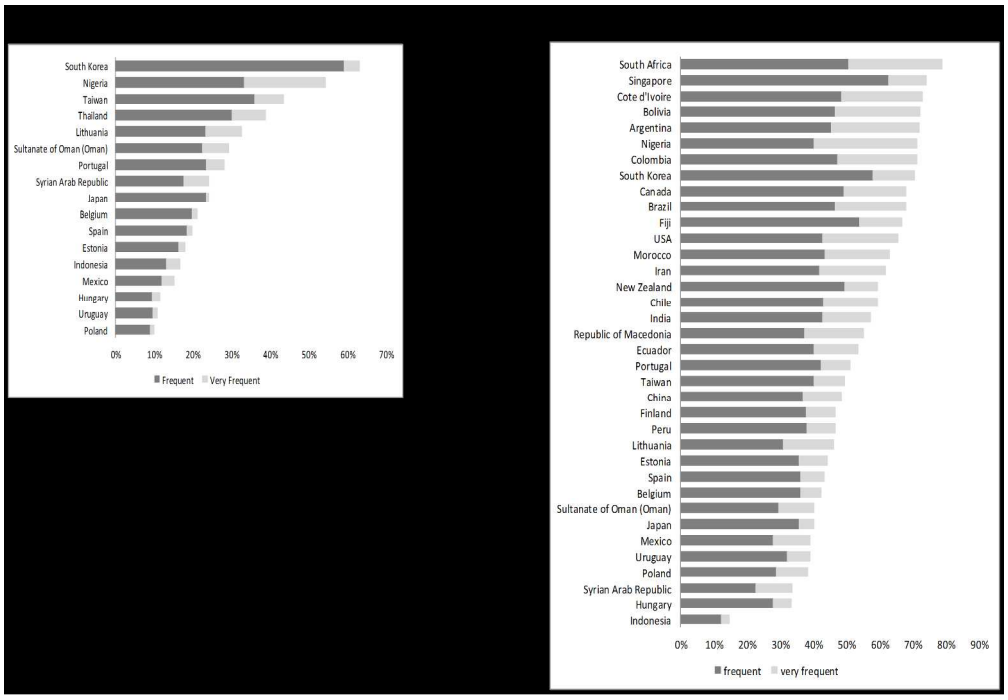

Figure 2: Reported frequency of fast food consumption by study participants. Children are represented in panel (a) and adolescents in panel (b)
261x179mm (300 x 300 DPI)

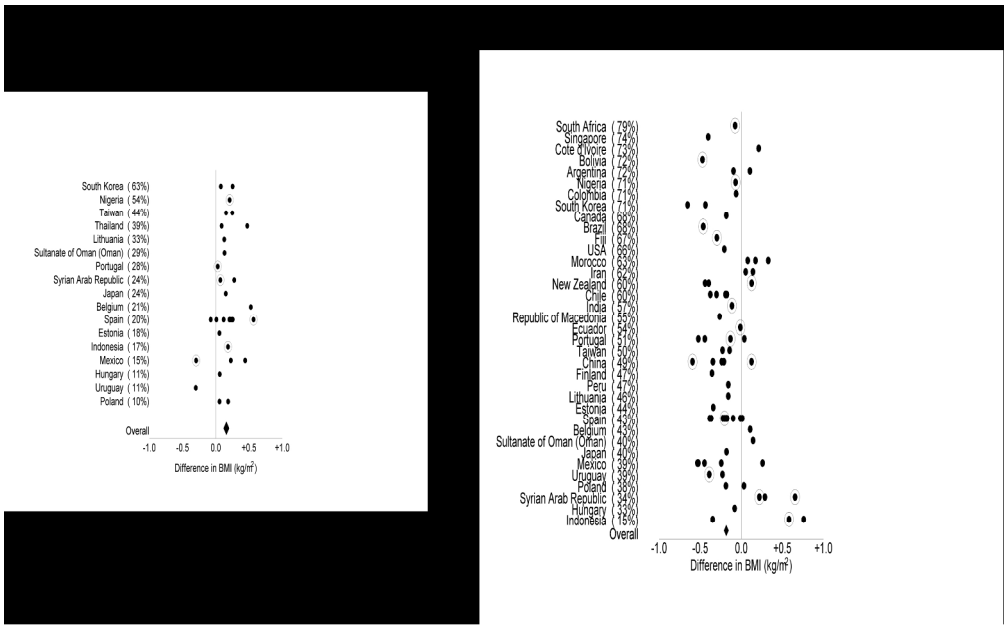

Figure 3: Association between BMI of study participants and frequent and very frequent fast food consumption compared to infrequent fast food consumption. Children are represented in panel (a) and adolescents in panel (b)
261x161mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Title page
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figures 1a and 1b
		(b) Give reasons for non-participation at each stage	Figures 1a and 1b
		(c) Consider use of a flow diagram	Done
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	Figures 1a and 1b
Outcome data	15*	Report numbers of outcome events or summary measures	9-11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-11, including Table 1
		(*b*) Report category boundaries when continuous variables were categorized	6-7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.