PEER REVIEW HISTORY

ARTICLE DETAILS

TITLE (PROVISIONAL)	Ultra-processed foods and excessive free sugar intake in the United Kingdom: a nationally representative cross-sectional study
AUTHORS	Rauber, Fernanda; Louzada, Maria Laura; Martinez Steele, Euridice; Rezende, Leandro; Millett, Christopher; Monteiro, Carlos; Levy, Renata

VERSION 1 – REVIEW

REVIEWER	Robert H Lustig UCSF San Francisco, CA 94143 USA
REVIEW RETURNED	23-Nov-2018

GENERAL COMMENTS	In this manuscript, Rauber et al. perform a valuable public health exercise. They attempt to: 1) total the added or free sugars (this manuscript chooses the term “free” over “added”) contained in specific types of foods within the UK over a decade; 2) ascribe that total to specific types of foodstuffs based on the degree of processing; 3) determine which age groups are most likely eat which foods; and 4) finally to determine how much added or “free” sugar consumption would change if societal interventions limiting the availability of high sugar items could be enacted. Given the role of added or free sugars in the pathogenesis of various chronic diseases, this exercise can provide guidance to the public and to governments as to how to structure policies to protect public health. Given that the majority of added or free sugars appears in ultra-processed foods, the authors make a strong case for intervention in this particular food class. The authors are to be congratulated for assembling all these data for policy makers. However, there are two major concerns and three minor concerns with the science and its interpretation, which are elaborated below. Major concern 1: The authors express virtually all of their added sugar data as a percent of daily energy intake. I suppose this could be done for a population, making assumptions that: a) all of the food is eaten, and b) using equations like the Harris-Benedict equation of what “total energy intake” for “energy balance” would be. However, given that the authors had individual data on both adults and children, it is surprising and concerning that their body weights did not factor into a calculation of total energy intake, so that the percent of energy intake per person could be more rationally calculated. For instance, in the analysis, a 17-year old weighing 45 kg and one weighing 90 kg are treated equally. If each consumed the same amount of dietary sugar, the 45 kg child would have a much higher percent intake than the 100 kg child.

	As a corollary, it is not obvious to me why the data needs to be expressed as percent of energy intake at all. Why can't the authors as grams of added or free sugars, and then determine how many people consume more than their requisite amounts (12 tsp/d for WHO and USDA, 6 tsp/d (for female) or 9 tsp/d (for male) for AHA, 6 tsp/d for SACN), and through which foods. Major concern 2: The authors conglomerate NDNS rolling programme data from years 1-6, pooling and treating all years equally. But added sugar consumption has no doubt changed over time, in part due to the recognition of the obesity epidemic, and in part due to increased awareness of processed food, and in part reduction in soda consumption. The authors must demonstrate that the baseline of added sugar consumption across the 6 years has not appreciably changed, in order to pool these data. Otherwise each of the years must be treated individually, and the amount of sugar consumed by each person within that year should be expressed. Minor concerns: 1. Page 4, Introduction: The authors refer to an added sugar level below 5% to obtain additional health benefits. My understanding that the only benefits incurred below 5% are for dental caries. This statement should be modified to reflect what health benefits the authors are talking about. 2. The authors should collect BMI data on their populations and demonstrate how specific classes of food processing relate to BMI. 3. Page 17, Discussion: The authors refer to juice as bening unprocessed or minimally processed. But once the fiber is removed, juice is no different in terms of sugar that soft drinks. Since they themselves have decided to call it "free sugars", how can they classify juice, which has large amounts of free sugars, as non-processed or minimally processed? This, in my view, would make juice an "ultra-processed food".

REVIEWER	Anna Rangan The University of Sydney I have co-authored a paper (currently submitted) with 3 of these authors (Monteiro, Levy and Martinez-Steele).
REVIEW RETURNED	11-Dec-2018

GENERAL COMMENTS	This paper describes the dietary sources of free sugars in different age groups of the UK population by NOVA food classification and includes some mathematical modelling to reduce excessive free sugar consumption. Although the concept is of interest to public health nutritionist, the details of the modelling are not well described, and some of the modelling results do not seem that impressive. For example, if all UPF were excluded (and these account for 65% of total free sugar), only 47% of excessive free sugar (ie>10%E from free sugar) is avoided? (so individuals with >10%E from free sugars decreases from 61% to approx 30%?). Could the authors please provide more details on the modelling undertaken (eg what was UPF replaced with?), and describe the results in more detail, perhaps in a table showing the exact substitutions. Other comments include: (and posted on the file) p6, last line: could you provide some examples here? p7, second para: could you provide some examples to illustrate disaggregation? or include the procedure as a supplemental table?

	p8, para 3: using mean intake is not recommended to determine percentage not meeting recommendations. Please re-calculate using adjusted means (adjusted for intra-individual variation). p9, line 11: need more details of modelling procedures. what was used to replace UPF, was energy kept constant? what about fat/sat fat/protein/carbs etc. p9, line 16: what did the home made dishes include? p16 line 44: please show the calculations as 47% seems too low if free sugars contribute 12.4% of EI, and 61% of people exceed 10%, and if UPF were eliminated, this would eliminate 65% of all free sugars. I have attached the file containing some additional minor edits.

REVIEWER	Marilyn Tseng Cal Poly San Luis Obispo USA
REVIEW RETURNED	28-Feb-2019

GENERAL COMMENTS	The primary objective of this study appears to be to describe intake of free sugars by level of intake of ultra-processed foods defined using NOVA categories in the UK, although it is not expressed this way in the abstract. The contribution of ultra-processed foods to intake of free sugars is useful to document in the literature, and in this respect, this paper would be a valuable contribution. Two major strengths of the study are its relatively large and representative sample of the UK population, and its use of 4-day food diaries for dietary data collection. Issues to be addressed include: 1. The objective of the study should be stated more precisely in the Abstract, to make it clear that the 'dietary sources' being investigated are not foods categorized by typical food groups, but foods categorized by level of processing. 2. Some more details in methods would be helpful. a. Can you please include some explanation for why NDNS uses NMES (and includes half of sugars in dried/stewed/canned fruit)? What are implications of using NMES estimates as a proxy for 'free sugars', and for comparisons across NOVA categories? b. The NOVA categories have been defined in detail and applied in previous studies. Are there data availability on intra- and inter-reliability of classification of foods into NOVA categories? c. Additional detail on collection and coding of food diary items would be helpful. You note for example that 4% of composite food codes were still mixed dishes; under what circumstances were these left mixed (not disaggregated)? Are 'ready' meals items that are made and sold at takeaway places, and might some of these include minimally processed components to them? To what extent might some of the ultra-processed food groups (such as ice cream) include less processed foods? A concern underlying these questions is that the findings might be seen as an overestimate of the contribution of ultra-processed foods to free sugar intake. Perhaps a sensitivity analysis would help allay this concern. d. Table S2 is very informative and greatly enhances transparency in your methods; this is much appreciated. It does seem that many food groups were categorized as ultra-processed, and that many of those were composite foods – although you state (p.7 line 9) that 4% of composite food codes were not completely disaggregated. Can you provide information that would give a sense of how frequently the items in Table S2 were reported – for

	example, % reporting each item? I would expect that although many food groups were categorized as ultra-processed, the proportion of people reporting their intake would be low because foods were mostly disaggregated for data entry. e. I question the authors' calculation of population attributable fraction, which is typically based on incidence (incidence in population minus incidence in the unexposed, divided by incidence in the population). In addition, I'm not sure that the relevant counterfactual is elimination of ultra-processed foods, as opposed to replacement of those foods with less processed versions of them. Can you provide a reference and a clearer interpretation of this PAF? This might affect the summary of your findings given in the first paragraph of the Discussion section. f. Please also explain your choice of second counterfactual – was this to make the point that eliminating ultra-processed foods, with potentially hidden sugars, has a greater impact than telling people to cut down on table sugars? 3. It would be helpful to know what food groups were major culprits as ultra-processed sources of free sugars. The large proportion of food energy that comes from ultra-processed foods suggests that many of the foods are eaten as core rather than as discretionary items. Are these the major sources, or are the discretionary items more to blame? Other minor comments: 1. Because the term 'added sugars' is also commonly used, it might be useful to define 'free sugars' in the Introduction, and to distinguish this from 'added sugars'. 2. It would be helpful to edit more carefully to correct grammatical errors throughout.

VERSION 1 – AUTHOR RESPONSE

Reviewer: 1

Reviewer Name: Robert H Lustig

Institution and Country: UCSF - San Francisco, USA

Please state any competing interests or state 'None declared': None

Please leave your comments for the authors below

This work is worthwhile and eminently publishable, but a re-evaluation of the analysis and presentation of the data is warranted.

In this manuscript, Rauber et al. perform a valuable public health exercise. They attempt to: 1) total the added or free sugars (this manuscript chooses the term "free" over "added") contained in specific types of foods within the UK over a decade; 2) ascribe that total to specific types of foodstuffs based on the degree of processing; 3) determine which age groups are most likely eat which foods; and 4) finally to determine how much added or "free" sugar consumption would change if societal interventions limiting the availability of high sugar items could be enacted.

Given the role of added or free sugars in the pathogenesis of various chronic diseases, this exercise can provide guidance to the public and to governments as to how to structure policies to protect public health. Given that the majority of added or free sugars appears in ultra-processed foods, the authors make a strong case for intervention in this particular food class. The authors are to be congratulated for assembling all these data for policy makers.

R: We would like to thank the reviewer for careful and thorough reading of this manuscript and for the comments and constructive suggestions.

However, there are two major concerns and three minor concerns with the science and its interpretation, which are elaborated below.

Major concern 1: The authors express virtually all of their added sugar data as a percent of daily energy intake. I suppose this could be done for a population, making assumptions that: a) all of the food is eaten, and b) using equations like the Harris Benedict equation of what "total energy intake" for "energy balance" would be. However, given that the authors had individual data on both adults and children, it is surprising and concerning that their body weights did not factor into a calculation of total energy intake, so that the percent of energy intake per person could be more rationally calculated. For instance, in the analysis, a 17-year old weighing 45 kg and one weighing 90 kg are treated equally. If each consumed the same amount of dietary sugar, the 45 kg child would have a much higher percent intake than the 100 kg child.

As a corollary, it is not obvious to me why the data needs to be expressed as percent of energy intake at all. Why can't the authors as grams of added or free sugars, and then determine how many people consume more than their requisite amounts (12 tsp/d for WHO and USDA, 6 tsp/d (for female) or 9 tsp/d (for male) for AHA, 6 tsp/d for SACN), and through which foods.

R: Thank you for your comment. We understand that individual requirements vary depending on different characteristics and that the effect of sugar may differ between individuals. We believe that considering body weights when calculating total energy intake is most relevant in analyses involving health outcomes, mainly those related to or dependent on the individual's energy requirements. Here we chose to use the percentage of total energy intake from free sugar because this is the way recommendations of the World Health Organization (WHO) and the Scientific Advisory Committee on Nutrition (UK SACN) on sugar intake are expressed. These recommendations do not differentiate by gender, age or body weight.

1. Scientific Advisory Committee on Nutrition. SACN's Sugars and Health Recommendations: Why 5%. London, UK: Scientific Advisory Committee on Nutrition, Department of Health, 2015.
2. Scientific Advisory Committee on Nutrition. Carbohydrates and Health Report. London, UK: Scientific Advisory Committee on Nutrition, Department of Health, 2015.
3. World Health Organization. Sugars intake for adults and children. Geneva, Switzerland: World Health Organization, 2015.

Major concern 2: The authors conglomerate NDNS rolling programme data from years 1-6, pooling and treating all years equally. But added sugar consumption has no doubt changed over time, in part due to the recognition of the obesity epidemic, and in part due to increased awareness of processed food, and in part reduction in soda consumption. The authors must demonstrate that the baseline of added sugar consumption across the 6 years has not appreciably changed, in order to pool these data. Otherwise each of the years must be treated individually, and the amount of sugar consumed by each person within that year should be expressed.

R: We appreciate your comment. We carried out analyses considering your suggestion. Firstly, we assessed the dietary content in free sugars (% of total energy intake from free sugars and individuals with ≥10% of total energy intake from free sugars) according to survey year. We found that the baseline of free sugar consumption across survey years has not appreciably changed (please, see the table below). In addition, we tested the interaction between survey year with dietary contribution of NOVA food groups (as exposure) on the dietary content in free sugars and the prevalence of excessive intake of free sugars. No interaction was found between the exposure and the survey year for the total energy intake from free sugars (unprocessed or minimally processed foods + processed culinary ingredients: $p = 0.2540$; processed foods: $p = 0.5375$; ultra-processed foods: $p = 0.1369$), nor for the prevalence of excessive intake of free sugars (unprocessed or minimally processed foods + processed culinary ingredients: $p = 0.6093$; processed foods: $p = 0.2615$; ultra-processed foods: $p = 0.2579$). Although the

survey year was not associated with our outcomes, we carried out analyses including this variable in the adjusted model. As expected, the magnitudes of associations did not change. To make it clear, we have included the following information in the method and the result sections, respectively.

Page 9: 'We also evaluated the extent to which the association between the exposure (dietary contribution of NOVA food groups) and the dietary content in free sugars changed according to the survey year, by including a multiplicative interaction term (survey year*dietary contribution of NOVA food groups) in the fully adjusted models.'

Page 12: 'No significant interaction was observed between the exposure and the survey year for the total energy intake from free sugars (unprocessed or minimally processed foods + processed culinary ingredients: p = 0.254; processed foods: p = 0.538; ultra-processed foods: p = 0.137), nor for the prevalence of excessive intake of free sugars (unprocessed or minimally processed foods + processed culinary ingredients: p = 0.609; processed foods: p = 0.262; ultra-processed foods: p = 0.258). Even so, we included variable survey year (1-6) in the adjusted model.'

NDNS, Survey year	% of total energy intake from free sugars		Individuals with ≥10% of total energy intake from free sugars	
	Mean	SE	Mean	SE
Year 1 (2008-2009)	12.3	0.2	61.8	1.8
Year 2 (2009-2010)	12.6	0.2	63.6	1.8
Year 3 (2010-2011)	12.5	0.3	58.5	1.9
Year 4 (2011-2012)	12.5	0.2	60.7	1.8
Year 5 (2012-2013)	12.2	0.3	60.3	2.0
Year 6 (2013-2014)	12.6	0.3	62.6	1.9
P for linear trend across all categories	0.711		0.781	

Minor concerns: 1.

Page 4, Introduction: The authors refer to an added sugar level below 5% to obtain additional health benefits. My understanding that the only benefits incurred below 5% are for dental caries. This statement should be modified to reflect what health benefits the authors are talking about.

R: Thank you for your suggestion. We have revised the sentence to clarify it.

Page 4: 'the World Health Organization (WHO) [5] recommends that free sugars should be reduced to less than 10% of total energy intake and also suggests a level below 5% to obtain additional health benefits, such as reduction of dental caries.'

2. The authors should collect BMI data on their populations and demonstrate how specific classes of food processing relate to BMI.

R: We appreciate this suggestion. Indeed, we are already working on a manuscript that will evaluate the association between ultra-processed foods and obesity in the UK population. We believe that it will be better to capture the complexity of exposures and health outcomes in a separate paper.

3. Page 17, Discussion: The authors refer to juice as bening unprocessed or minimally processed. But once the fiber is removed, juice is no different in terms of sugar that soft drinks. Since they themselves have decided to call it "free sugars", how can they classify juice, which has large amounts of free sugars, as non-processed or minimally processed? This, in my view, would make juice an "ultra-processed food".

R: We understand your concern. In the present study, we have classified all food items into food groups defined by the NOVA food classification system, which considers the physical, biological and chemical methods used during the food manufacturing process, and not the food nutrient profile (Monteiro et al, 2018). According to NOVA, minimally processed foods are unprocessed foods submitted to physical processes that do not include addition of any substance to the original food while ultra-processed foods

are formulations of ingredients, mostly of exclusive industrial use, that result from a series of industrial processes. Because 100% fruit juices result essentially from pressing unprocessed foods and filtering the output, they were classified as minimally processed. We also highlight in the manuscript that the contribution of unprocessed or minimally processed foods to the dietary content of free sugar (around 20%) was mostly provided by freshly squeezed fruit juice.

- Monteiro CA, Cannon G, Moubarac J-C et al. (2018) The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. Public Health Nutr 21, 5–17.

Reviewer: 2

Reviewer Name: Anna Rangan

Institution and Country: The University of Sydney

Please state any competing interests or state 'None declared': I have co-authored a paper (currently submitted) with 3 of these authors (Monteiro, Levy and Martinez-Steele).

Please leave your comments for the authors below

This paper describes the dietary sources of free sugars in different age groups of the UK population by NOVA food classification and includes some mathematical modelling to reduce excessive free sugar consumption. Although the concept is of interest to public health nutritionist, the details of the modelling are not well described, and some of the modelling results do not seem that impressive. For example, if all UPF were excluded (and these account for 65% of total free sugar), only 47% of excessive free sugar (ie>10%E from free sugar) is avoided? (so individuals with >10%E from free sugars decreases from 61% to approx 30%?). Could the authors please provide more details on the modelling undertaken (eg what was UPF replaced with?), and describe the results in more detail, perhaps in a table showing the exact substitutions.

R: Thank you for your comments and constructive suggestions. We are sorry that the modelling procedures were not clear. We have added more details throughout the manuscript to clarify this. We realise that the term 'population attributable fraction' may create confusion, so have decided to remove this term and only describe in detail the procedures used here.

We estimated which dietary changes would be most effective in substantially reducing the proportion of excessive free sugar intake in the UK population. For that, we estimated notional scenarios for the main dietary sources of free sugars that can be clearly divided into 1) ultra-processed foods, which include sugar added to food before it is marketed and sold (potentially hidden sugars) and 2) table sugars, which include the sugar added to beverages and foods/dishes by consumers (individuals are able to determine the amount of sugars they add to their diet). We calculated the proportion of excessive free sugar intake that could be potentially avoided in each scenario considering the prevalence of excessive free sugar intake in the UK population and the predicted prevalence of excessive free sugar intake that would be expected had the consumption of each of these main sources of free sugars been zero. The estimation was obtained by subtracting the predicted prevalence from the observed prevalence in the population divided by the observed prevalence in the population. The text now reads:

Page 9: 'Finally, we estimated the proportion of excessive free sugar intake that could be potentially avoided if exposure to the risk factors were eliminated (theoretical minimum risk exposure level scenarios) [22, 23]. The counterfactual scenarios were defined considering the main dietary sources of free sugars. The first counterfactual scenario assumed no consumption of ultra-processed food (potentially hidden sugars), while in the second scenario table sugar consumption was set to zero. Table sugar included honey, molasses, maple syrup (100%), and sugar added to coffee/juice and homemade dishes (potentially sugar that can be measured by the consumer).'

Page 9: ‘In both scenarios, we first calculated the prevalence of excessive free sugar intake in the UK population ($P_{population}$). We then estimated the predicted prevalence of excessive free sugar intake that would be expected had the consumption of each of these main sources of free sugars being zero ($P_{nonexposed}$). Lastly, we calculated the proportion of excessive free sugar intake that could be potentially avoided in each scenario using the following formula: ($P_{population}$ - $P_{nonexposed}$) / $P_{population}$. Prevalences were adjusted for sex, age, ethnicity, region, survey year, and household income.’

We have also added the limitation of our model to make it clear.

Page 19: ‘Finally, our theoretical minimum risk exposure models estimate the potential impact of eliminating each of the main sources of free sugars on excessive free sugar intake, ignoring substitutions that may occur in the consumption of other foods. Although our findings suggest that greater reduction in excessive free sugar intake could be achieved by eliminating ultra-processed food consumption, guidance to the public about reducing the consumption of table sugar remains an important component of any public health guidance.’

We believe that reducing the proportion of excessive free sugar intake by 50% is important for public health, considering that almost 1/3 of the UK population exceed the maximum recommended intake of free sugar. Furthermore, we highlight that ultra-processed foods are discretionary foods, which are not necessary to provide the nutrients the body needs and could be eliminated from the diet. Since our findings confirm that most free sugar is added to food before it is marketed and sold, changing personal behaviour and choice alone may be not an effective or realistic option to reduce the excessive intake of free sugar in the UK population.

Other comments include: (and posted on the file)

p6, last line: could you provide some examples here?

R: Thank you for your comment. Examples of subsidiary food groups are listed in the Supplementary Table S2. We have included this sentence in the paragraph (page 7): ‘Subsidiary food groups as classified by NOVA are described in the Supplementary Table S2.’

p7, second para: could you provide some examples to illustrate disaggregation? or include the procedure as a supplemental table?

R: We are sorry that it was not clear. The disaggregation of composite dishes was made by NDNS (Public Health England) and details of the recipes were not provided in the same dataset. A project was undertaken during Year 1 of the rolling programme to retrospectively disaggregate all pre-existing food codes in the databank. Several categories for these food types were determined and all foods containing any of these food types were systematically disaggregated into their components. The main food components used were meat, fish, fruit, vegetables and cheese. Following this initial project, the food codes are disaggregated prospectively as they are added to the Nutrient Databank. The method adopted to disaggregate food codes in the NDNS has been described fully in a previous paper (Fitt et al, 2010). We have made changes in the text to clarify it.

Page 7: ‘Although the NDNS database was provided with most food items systematically disaggregated into their individual components, about 4% of composite food codes were still mixed dishes compiled from two or more single-ingredient food code [19]. The method adopted to disaggregate food codes has been described previously [19].’

- Fitt E, Mak TN, Stephen AM, Prynne C, Roberts C, Swan G, Farron-Wilson M. Disaggregating composite food codes in the UK National Diet and Nutrition Survey food composition databank. Eur J Clin Nutr 2010;64 Suppl 3:S32-36.
- Public Health England. Appendix A. Dietary data collection and editing. In: National Diet and Nutrition Survey. Results from Years 1-4 (combined) of the Rolling Programme (2008/2009 – 2011/12).

p8, para 3: using mean intake is not recommended to determine percentage not meeting recommendations. Please re-calculate using adjusted means (adjusted for intra-individual variation).

R: We agree that the average of two dietary recalls/diaries does not represent the entire distribution of usual intake due to the intra-individual variance component. However, we used data from the NDNS that collected four food diary days, which considered the representativity of all days of the week, as well as the seasonal variation.

NDNS uses a high-quality dietary assessment method which provides detailed analysis of different foods consumed, several days of assessment. Field work was conducted throughout the year in order to take into account potential seasonal variations in food consumption; the survey was designed so that all days of the week were evenly represented (weekdays and weekend days); and included only participants with at least three or four completed days of the food diary. In our sample, more than 91% completed the four food diary days.

Considering that, we believe that the mean of all days of the food diary can be used as an estimate of usual intake distribution in the population since the data are collected evenly throughout the year and the days of the week are evenly represented (CDC/NCHS).

Moreover, specific statistical adjustment to estimate usual intake, such as the Multiple Source Method (MSM), is still a relatively new method that is also subject to limitations - as described in the program website: 'MSM is still a relatively new method and we are therefore committed to further investigate the strengths and limitations of the MSM' (https://msm.dife.de/).

Finally, since we used the average of all days of intake in the dietary assessment of the exposure and the outcome (both dietary data), we believed that any error related to diet variability would be mitigated and less likely to affect our conclusion.

- Public Health England. National Diet and Nutrition Survey Years 5-6 2012/13-2013/14. User Guide for UK Data. London, UK: Public Health England.
- Centers for Disease Control and Prevention. National Center for Health Statistics (CDC/NCHS). Key Concepts about estimating mean food intakes. Estimate population mean intakes. In NHANES Dietary Web Tutorial. Basic Dietary Analyses. Available in https://www.cdc.gov/nchs/tutorials/Dietary/Basic/PopulationMeanIntakes/intro.htm

p9, line 11: need more details of modelling procedures. what was used to replace UPF, was energy kept constant? what about fat/sat fat/protein/carbs etc.

R: Thank you for your suggestion. We have added more information about the modelling procedures throughout the manuscript to clarify it (please, see examples of sentences included in the response to your first major comment).

p9, line 16: what did the home made dishes include?

R: Some examples of homemade dishes include: biscuits, homemade (7B); fruit pies, homemade (8C); Buns cakes and pastries, homemade (8E), cereal based milk puddings, homemade (9D), sponge pudding, homemade (9F). The code (number + letter) represent the subsidiary food groups, which is presented in the supplementary table S2. To make it clear, we added some examples and the reference of the supplementary table in this paragraph (page 7): 'Examples of homemade dishes include: biscuits, fruit pies, buns cakes and pastries, cereal based milk puddings, and sponge pudding (see Suppl. Table S2).'

p16 line 44: please show the calculations as 47% seems too low if free sugars contribute 12.4% of EI, and 61% of people exceed 10%, and if UPF were eliminated, this would eliminate 65% of all free sugars.

R: Thank you for your suggestion. We have added more information about the modelling procedures throughout the manuscript to clarify this (please, see examples of sentences included in the response to your first major comment).

Although the average daily intake of free sugars was 12% of total energy intake and ultra-processed foods contributed, on average, 65% of the total free sugar intake, our counterfactual scenarios analyses were based on the proportion of excessive free sugar intake, which considered the categorization of individuals above or below the recommendation of 10% of total energy from free sugars. Thus, the contribution of ultra-processed foods to the dietary content of free sugars can vary between the individuals that are both above and below the recommendation of free sugar intake. We hope that this is now better clarified in the manuscript.

Also, the obtained values are compatible with those from Tables 2 to 5. If we take adults as an example (Table 4) we can say that, in average, for every 10 percent point decrease in ultra-processed food consumption (mean difference between quintiles) the inadequate free sugar consumption decreases 8.7 percent points. Therefore, if ultra-processed food consumption were to be reduced from an average 55% to 0% we would expect a reduction of 44% of inadequate cases of free sugar consumption. This approximate value is not that different from the reported value of 49.3% of avoided cases.

Supp Table S2- why are apples, pears and bananas not coded as 1?

R: Some food within these subsidiary food groups could belong to different NOVA groups. For instance, banana chips. Then we classified each food code individually.

Supp Table S2- why are smoothies coded as 1?

R: The subsidiary food group ‘smoothies’ includes only 100% fruit and/or juice (not smoothies containing dairy). Then, we were able to directly classify these in group 1.

Reviewer: 3

Reviewer Name: Marilyn Tseng

Institution and Country: Cal Poly San Luis Obispo – USA

Please state any competing interests or state ‘None declared’: None declared
Please leave your comments for the authors below

The primary objective of this study appears to be to describe intake of free sugars by level of intake of ultra-processed foods defined using NOVA categories in the UK, although it is not expressed this way in the abstract. The contribution of ultra-processed foods to intake of free sugars is useful to document in the literature, and in this respect, this paper would be a valuable contribution. Two major strengths of the study are its relatively large and representative sample of the UK population, and its use of 4-day food diaries for dietary data collection.

R: We appreciate your careful reading of this manuscript and your comments and constructive suggestions.

Issues to be addressed include:

1. The objective of the study should be stated more precisely in the Abstract, to make it clear that the ‘dietary sources’ being investigated are not foods categorized by typical food groups, but foods categorized by level of processing.

R: Thank you. We have included your suggestion in the abstract: ‘to describe dietary sources of free sugars in different age groups of the UK population considering food groups classified according to the NOVA system and to estimate the proportion of excessive free sugars that could potentially be avoided by reducing consumption of their main sources.’

2. Some more details in methods would be helpful.

a. Can you please include some explanation for why NDNS uses NMES (and includes half of sugars in dried/stewed/canned fruit)? What are implications of using NMES estimates as a proxy for 'free sugars', and for comparisons across NOVA categories?

R: The term 'non-milk extrinsic sugars' (NMES) was used exclusively by the UK for almost 25 years, in particular to report sugars intakes in dietary surveys and to describe dietary targets for sugars. In 2015, the term 'free sugars' was adopted by the UK Scientific Advisory Committee on Nutrition (SACN). However, national data were still expressed as non-milk extrinsic sugars. Acknowledging that the values with be very similar to 'free sugars' in most cases, SACN reports and studies have expressed NMES as proxy for free sugars (SACN, 2015; Gibson et al, 2016; Swan et al., 2018).

Overall, the free sugars values would be slightly lower in some cases than the NMES values, because 'free sugars' does not include sugars contributed by dried and processed fruits. However, we believe that it would not affect the relationship between the dietary share of ultra-processed foods and free sugar since the dried and processed fruits (potentially sugar not considered in the definition of 'free sugar') are usually classified as minimally processed foods and processed foods, respectively. We have included more information in the methods to clarify it.

Page 6: 'Intakes in the UK NDNS years 1-6 were expressed as non-milk extrinsic sugars (NMES). The term NMES captures all sugars defined by the term free sugars while also including half of the sugars present in dried, stewed or canned fruit. The NMES values could be slightly higher in some cases than the free sugar values, mostly in the non-ultra-processed food group since the term free sugar does not include sugars contributed by dried and processed fruits.'

- Scientific Advisory Committee on Nutrition. SACN's Sugars and Health Recommendations: Why 5%. London, UK: Scientific Advisory Committee on Nutrition, Department of Health, 2015.
- Gibson S, Francis L, Newens K, Livingstone B. Associations between free sugars and nutrient intakes among children and adolescents in the UK. Br J Nutr. 2016 Oct;116(7):1265-1274. Epub 2016 Sep 19.
- Swan GE, Powell NA, Knowles BL, Bush MT, Levy LB. A definition of free sugars for the UK. Public Health Nutr. 2018 Jun;21(9):1636-1638.

b. The NOVA categories have been defined in detail and applied in previous studies. Are there data availability on intra- and inter-reliability of classification of foods into NOVA categories?

R: We are not aware of any publication that assessed intra- and inter-reliability of classification of foods into NOVA categories. Nevertheless, our research group is working on the evaluation of the consistency in the application of the NOVA food groups between different countries and settings.

c. Additional detail on collection and coding of food diary items would be helpful. You note for example that 4% of composite food codes were still mixed dishes; under what circumstances were these left mixed (not disaggregated)? Are 'ready' meals items that are made and sold at takeaway places, and might some of these include minimally processed components to them? To what extent might some of the ultra-processed food groups (such as ice cream) include less processed foods? A concern underlying these questions is that the findings might be seen as an overestimate of the contribution of ultra-processed foods to free sugar intake. Perhaps a sensitivity analysis would help allay this concern.

R: Thank you for your observation. Regarding mixed dishes, disaggregation was made by NDNS (Public Health England) and details of the recipes were not provided in the same dataset. A project was undertaken during Year 1 of the rolling programme to retrospectively disaggregate all pre-existing food codes in the databank. Several categories for these food types were determined and all foods containing any of these food types were systematically disaggregated into their components. Following this initial project, the food codes are disaggregated prospectively as they are added to the Nutrient Databank. The main food components used were meat, fish, fruit, vegetables and cheese. The method adopted to disaggregate food codes in the NDNS has been described fully in a previous paper (Fitt et al, 2010). Despite this, a few composite dishes were not disaggregated into constituent ingredients.

However, such dishes are identified as homemade or manufactured in the database; then we were able to classify them according to NOVA groups. Homemade dishes were categorised according to the main constituent ingredient (i.e. 'vegetable soup, homemade' was classified as a 'vegetable') or as a specific subgroup of freshly prepared dishes (i.e. 'chicken and vegetable soup), and 'vegetable soup, manufactured' was coded as ultra-processed. We have included more details about the disaggregation in the methods.

Page 7: 'Although the NDNS database was provided with most food items systematically disaggregated into their individual components, about 4% of composite food codes were still mixed dishes compiled from two or more single-ingredient food code [19]. The method adopted to disaggregate food codes has been described previously [19].

Moreover, NDNS allows identification of some meals classified as takeaway that can be fresh meals prepared in restaurants or cafeterias. In those cases, we were more conservative in classifying them as non-ultra-processed foods. Manufactured packaged ready meals, such as frozen meals or meat pies, were classified as ultra-processed foods. A small number of specific food items such as pizza had insufficient information for classification purposes. In those cases, the most frequently consumed alternative (culinary preparation or manufactured product) was chosen. We believe that potential misclassification of these food items was minimal and not systematically incorrect.

This potential bias is described as a limitation in the discussion section (page 19): 'NDNS collects limited information indicative of food processing (for example, place of meals and product brands), which may lead to misclassification of some food items. This bias is more likely for a small number of specific food items such as pizza where there is insufficient information for classification purposes (see Suppl. Table S2). In those cases, the most frequently consumed alternative (culinary preparation or manufactured product) was chosen.'

- Fitt E, Mak TN, Stephen AM, Prynne C, Roberts C, Swan G, Farron-Wilson M. Disaggregating composite food codes in the UK National Diet and Nutrition Survey food composition databank. Eur J Clin Nutr 2010;64 Suppl 3:S32-36.
- Public Health England. Appendix A. Dietary data collection and editing. In: National Diet and Nutrition Survey. Results from Years 1-4 (combined) of the Rolling Programme (2008/2009 – 2011/12).

d. Table S2 is very informative and greatly enhances transparency in your methods; this is much appreciated. It does seem that many food groups were categorized as ultra-processed, and that many of those were composite foods – although you state (p.7 line 9) that 4% of composite food codes were not completely disaggregated. Can you provide information that would give a sense of how frequently the items in Table S2 were reported – for example, % reporting each item? I would expect that although many food groups were categorized as ultra-processed, the proportion of people reporting their intake would be low because foods were mostly disaggregated for data entry.

R: Thank you for your comments. All foods in NDNS are coded as food number (n = 4494 in our database) and also grouped into subsidiary food groups (n = 155), which is a food group level of greater detail than the main food groups. The subsidiary food groups put together foods into specific categories, but mainly helps to identify categories of manufactured foods and homemade dishes. The same food number could be in more than one subsidiary food group since food items could be consumed in different ways. For instance, apple that was consumed as 'Fruit' and apple that was used as an ingredient of 'Fruit pies (homemade)'.

Subsidiary food group were directly classified according to NOVA when all foods in the subsidiary group belonged to the same NOVA group: 12 categories were directly classified as unprocessed or minimally processed foods and processed culinary ingredients; 12 categories were directly classified as processed foods; 66 categories were directly classified as ultra-processed foods; 15 categories were directly classified as supplements; and 52 categories had all their foods individually coded (by food name). Food numbers are not equally distributed among the subsidiary food groups, and then we

believe that the frequency of each subsidiary food groups would not provide accurate information on the number of food items classified according to NOVA.

Since we do not disaggregate ultra-processed foods, we were able to directly classify most of ultra-processed foods by using the subsidiary food group. For homemade dishes, we classified each food code individually, which allowed each ingredient of homemade dishes to be classified in its corresponding NOVA group. That means that the number of food items within each of this subsidiary food group is probably higher. Examples of main and subsidiary food groups and disaggregation categories has been described in the NDNS reports (Appendix A and Appendix R).

- Appendix A. Dietary data collection and editing. National Diet and Nutrition Survey. Results from Years 1-4 (combined) of the Rolling Programme (2008/2009 – 2011/12).
- Appendix R Main and subsidiary food groups and disaggregation categories. National Diet and Nutrition Survey. Headline results from Years 1-4 (combined) of the Rolling Programme (2008/2009 – 2011/12).

e. I question the authors' calculation of population attributable fraction, which is typically based on incidence (incidence in population minus incidence in the unexposed, divided by incidence in the population). In addition, I'm not sure that the relevant counterfactual is elimination of ultra-processed foods, as opposed to replacement of those foods with less processed versions of them. Can you provide a reference and a clearer interpretation of this PAF? This might affect the summary of your findings given in the first paragraph of the Discussion section.

R: We are sorry that the modelling procedures was not clear. We have added more details throughout the manuscript to clarify it.

In general, the formulas for the attributable fraction can be based on data from any of the 3 common study designs (cohort, case-control, prevalence), although in the case of prevalence (cross-sectional) studies, the attributable fraction will represent the proportion of prevalent rather than incident cases that could be avoided if exposure were absent (Steenland et al, 2006; Rezende et al. 2016). However, we realise that the term 'population attributable fraction' may create confusion, so have decided to remove this term and only describe in detail the procedures used here.

As was explained in the response to the Reviewer#2's first major comment, we estimated which dietary changes would be most effective in substantially reducing the proportion of excessive free sugar intake in the UK population. For that, we estimated notional scenarios for the main dietary sources of free sugars that can be clearly divided into 1) ultra-processed foods, which include sugar added to food before it is marketed and sold (potentially hidden sugars) and 2) table sugars, which include the sugar added to beverages and foods/dishes by consumers (individuals are able to determine the amount of sugars they add to their diet). We calculated the proportion of excessive free sugar intake that could be potentially avoided in each scenario considering the prevalence of excessive free sugar intake in the UK population and the predicted prevalence of excessive free sugar intake that would be expected had the consumption of each of these main sources of free sugars been zero. The estimation was obtained by subtracting the predicted prevalence from the observed prevalence in the population divided by the observed prevalence in the population. The text now reads:

Page 9: 'Finally, we estimated the proportion of excessive free sugar intake that could be potentially avoided if exposure to the risk factors were eliminated (theoretical minimum risk exposure level scenarios) [22, 23]. The counterfactual scenarios were defined considering the main dietary sources of free sugars. The first counterfactual scenario assumed no consumption of ultra-processed food (potentially hidden sugars), while in the second scenario table sugar consumption was set to zero. Table sugar included honey, molasses, maple syrup (100%), and sugar added to coffee/juice and homemade dishes (potentially sugar that can be measured by the consumer).'

Page 9: In both scenarios, we first calculated the prevalence of excessive free sugar intake in the UK population ($P_{population}$). We then estimated the predicted prevalence of excessive free sugar intake that would be expected had the consumption of each of these main sources of free sugars being zero ($P_{nonexposed}$). Lastly, we calculated the proportion of excessive free sugar intake that could be potentially

avoided in each scenario using the following formula: ($P_{population}$ - $P_{nonexposed}$) / $P_{population}$. Prevalences were adjusted for sex, age, ethnicity, region, survey year, and household income.'

We have also added more detail in the discussion section (first paragraph and limitations) to make it clear.

Page 17: 'Using theoretical minimum risk exposure level scenarios, we also showed that by eliminating ultra-processed food consumption, the prevalence of excessive free sugar intake (10% or more of total energy intake) could be potentially reduced from 60% to 28%.'

Page 19: 'Finally, our theoretical minimum risk exposure models estimate the potential impact of eliminating each of the main sources of free sugars on excessive free sugar intake, ignoring substitutions that may occur in the consumption of other foods. Although our findings suggest that greater reduction in excessive free sugar intake could be achieved by eliminating ultra-processed food consumption, guidance to the public about reducing the consumption of table sugar remains an important component of any public health guidance.'

- Steenland K, Armstrong B. An overview of methods for calculating the burden of disease due to specific risk factors. Epidemiology. 2006 Sep;17(5):512-9.
- Rezende LFM, Eluf-Neto J. Population attributable fraction: planning of diseases prevention actions in Brazil. Rev Saúde Pública 2016;50:30.

f. Please also explain your choice of second counterfactual – was this to make the point that eliminating ultra-processed foods, with potentially hidden sugars, has a greater impact than telling people to cut down on table sugars?

R: Thank you for your suggestion. As explained in response to your comment above, we aimed to estimate the proportion of excessive free sugar intake that could be potentially avoided under the two contrafactual scenarios regarding the consumption of the main sources of free sugar. These main sources in the UK population can be clearly divided in 1) the sugar added by the food industry (hidden sugars presented mostly in ultra-processed foods) and 2) the sugar added by consumers (individuals are able to determine the amount of table sugars they add). Our findings show that about 47% of excessive free sugars intake could be potentially avoided if the consumption of ultra-processed foods was eliminated (from 56.82 to 0%); while eliminating table sugar (1.66% to 0%) could potentially avoid 9.4% of the excessive free sugar intake. Therefore, reducing the consumption of ultra-processed foods has a greater impact in reducing the percentage of excessive free sugar intake, since the consumption of ultra-processed foods in the population is greater (almost 60%) than the consumption of table sugar (1.66%). We have made changes throughout the manuscript to clarify this (please, see example of sentences included in the response to your comment above).

3. It would be helpful to know what food groups were major culprits as ultra-processed sources of free sugars. The large proportion of food energy that comes from ultra-processed foods suggests that many of the foods are eaten as core rather than as discretionary items. Are these the major sources, or are the discretionary items more to blame?

R: Although several subgroups of ultra-processed foods contributed substantially to the percentage of total energy intake from free sugars, soft drinks and fruit juices, confectionary, milk-based drinks, and biscuits, together, contributed more than 50% of the total energy intake from free sugar in the UK diet. These subgroups were the largest contributors of dietary free sugar in all age groups, although the proportion of free sugar varied according to age.

Our main objective was to describe the dietary sources of free sugar in different age groups considering the following NOVA food groups: unprocessed or minimally processed foods plus culinary ingredients, processed foods and ultra-processed foods. The contribution to total free sugar intakes for some specific foods, such as biscuits and soda, has been described in reports published by the Public Health England. Furthermore, we believe that the number of tables and information would be excessive in this

paper if we added the percentage of total energy intake from free sugar of each ultra-processed subgroup by age groups

- Public Health England. Sugar Reduction: Achieving the 20% A technical report outlining progress to date, guidelines for industry, 2015 baseline levels in key foods and next steps. UK: Public Health England, 2017.

Other minor comments:

1. Because the term 'added sugars' is also commonly used, it might be useful to define 'free sugars' in the Introduction, and to distinguish this from 'added sugars'.

R: Thank you, your suggestion has been incorporated (page 4): 'Free sugars include sugars added to foods by the manufacturer, cook and consumer, plus sugars naturally present in honey, syrups and fruit juices [5], while added sugars captures all free sugars, but exclude naturally occurring sugars in fruit juices.'

2. It would be helpful to edit more carefully to correct grammatical errors throughout.

R: We have revised the entire manuscript to correct grammatical errors. Thank you!

VERSION 2 – REVIEW

REVIEWER	Robert H Lustig UCSF, USA
REVIEW RETURNED	03-May-2019

GENERAL COMMENTS	The authors have done an admirable job in responding to the reviewer's criticisms and suggestions. The results of the study have not changed appreciably.

REVIEWER	Anna Rangan The University of Sydney I have co-authored a paper (currently submitted) with 3 of these authors (Monteiro, Levy and Martinez-Steele).
REVIEW RETURNED	23-Apr-2019

GENERAL COMMENTS	Thank you, my issues have now been addressed.

REVIEWER	Marilyn Tseng Cal Poly San Luis Obispo – USA
REVIEW RETURNED	03-May-2019

GENERAL COMMENTS	Thank you for your careful attention and detailed responses to the comments - my own as well as those of the other reviewers. My only remaining comments relate to presentation of the % of prevalence of excessive free sugar intake that can be prevented by eliminating ultra-processed foods: 1. Abstract Data Analysis section still refers to the statistic as population attributable fraction. Since you are no longer referring to it as a PAF, consider replacing with 'the percent reduction in prevalence of excessive free sugar intake from eliminating ultra-processed foods and table sugar.'

	2. Abstract Results and Results p.16: Is it correct to say that '47% of excessive free sugar intake could be avoided'? I don't see Figure 1 in the manuscript, but the numbers given in the first paragraph of the Discussion indicate that the prevalence would be reduced from 60% to 28%, which is a 53% decrease. 3. Abstract and Results p.16: Wording in presentation of these results is unclear. I think you mean the percentage of the PREVALENCE of excessive free sugar intake? Similarly, for the sentence on eliminating table sugar, it might more clearly be stated: 'Eliminating table sugar could potentially reduce the prevalence of excessive free sugar intake by x%'. (You state it this way in the first paragraph of the Discussion.) One final, very minor suggestion: on p.18, consider replacing 'generally rich in free sugars' with 'often rich in free sugars'. Might it be that some ultra-processed foods are not rich in free sugars, but that people might eat a lot of these foods containing modest / moderate amounts of hidden free sugars? Thank you for what will be a valuable contribution to the literature.

VERSION 2 – AUTHOR RESPONSE

Reviewer: 2

Reviewer Name: Anna Rangan

Institution and Country: The University of Sydney

Please state any competing interests or state ‘None declared’: I have co-authored a paper (currently submitted) with 3 of these authors (Monteiro, Levy and Martinez-Steele).

Please leave your comments for the authors below

Thank you, my issues have now been addressed.

Our response: Thank you for your review.

Reviewer: 1

Reviewer Name: Robert H Lustig

Institution and Country: UCSF, USA

Please state any competing interests or state ‘None declared’: None declared

Please leave your comments for the authors below

The authors have done an admirable job in responding to the reviewer's criticisms and suggestions. The results of the study have not changed appreciably.

Our response: Thank you for your review.

Reviewer: 3

Reviewer Name: Marilyn Tseng

Institution and Country: Cal Poly San Luis Obispo – USA

Please state any competing interests or state ‘None declared’: None declared

Please leave your comments for the authors below

Thank you for your careful attention and detailed responses to the comments - my own as well as those of the other reviewers. My only remaining comments relate to presentation of the % of prevalence of excessive free sugar intake that can be prevented by eliminating ultra-processed foods:

1. Abstract Data Analysis section still refers to the statistic as population attributable fraction. Since you are no longer referring to it as a PAF, consider replacing with 'the percent reduction in prevalence of excessive free sugar intake from eliminating ultra-processed foods and table sugar.'

Our response: Thank you! As suggested, we have revised the sentence. The new version reads as follows: ‘We estimated the percent reduction in prevalence of excessive free sugar intake from eliminating ultra-processed foods and table sugar.’

2. Abstract Results and Results p.16: Is it correct to say that '47% of excessive free sugar intake could be avoided'? I don't see Figure 1 in the manuscript, but the numbers given in the first paragraph of the Discussion indicate that the prevalence would be reduced from 60% to 28%, which is a 53% decrease.

Our response: Thank you! This error has been corrected in the revised manuscript. The new version reads as follows: ‘the prevalence of excessive free sugar intake (10% or more of total energy intake) could be potentially reduced from 60% to 31%. In children and adolescents, the potential reduction could be from 74% to 45% and from 83% to 53%, respectively.’

3. Abstract and Results p.16: Wording in presentation of these results is unclear. I think you mean the percentage of the PREVALENCE of excessive free sugar intake? Similarly, for the sentence on eliminating table sugar, it might more clearly be stated: 'Eliminating table sugar could potentially reduce the prevalence of excessive free sugar intake by x%'. (You state it this way in the first paragraph of the Discussion.)

Our response: We have modified it. Thank you! The new version reads as follows:

Abstract: ‘Prevalence of excessive free sugar intake increased linearly across quintiles of ultra-processed food consumption for all age groups, except among the elderly. Eliminating ultra-processed foods could potentially reduce the prevalence of excessive free sugar intake by 47%.’

Results: ‘We estimated that about 47% of the prevalence of excessive free sugars intake in the UK population could be potentially avoided if the consumption of ultra-processed foods was eliminated. Eliminating table sugar could potentially avoid 9.4% of the prevalence of excessive free sugars intake.’

One final, very minor suggestion: on p.18, consider replacing 'generally rich in free sugars' with 'often rich in free sugars'. Might it be that some ultra-processed foods are not rich in free sugars, but that people might eat a lot of these foods containing modest / moderate amounts of hidden free sugars?

Our response: As suggested, we have changed the word ‘generally’. The new version reads as follows: ‘The analyses presented here suggest that actions to reduce the consumption of ultra-processed foods often rich in free sugars could lead to larger public health benefits.’

Thank you for what will be a valuable contribution to the literature.

Our response: Thank you for your very careful review of our paper.

VERSION 3 – REVIEW

REVIEWER	Dr Bernard Srour Nutritional Epidemiology Research Team EREN, French Institute of Health and Medical Research, University of Paris 13, France German Cancer Research Center DKFZ, Cancer Epidemiology division, Heidelberg, Germany.
REVIEW RETURNED	22-Aug-2019

GENERAL COMMENTS	In this paper, Rauber and colleagues investigated the cross-sectional associations between ultra-processed food intake and the prevalence of excessive free sugar intake (≥ 10% of total daily energy intake), in a nationally representative survey in the UK. The authors concluded that the prevalence of excessive free sugar intake is positively associated with the consumption of ultra-processed foods. On the other hand, the authors found, using counterfactual scenarios, that eliminating ultra-processed foods could be associated with a 47% reduction in the prevalence of excessive free sugar intake. The manuscript is well written, the analyses are thorough and the findings are of a great public health interest, in the actual state of sugar reduction policies changes in the UK. The authors should be commended for the scientific quality of the statistical analyses, and for the study design. I unfortunately do not have access to previous versions of the manuscript, to assess the evolution of the content according to other reviewer's comments. I have several statistical minor questions that need a little bit more clarification, and that I would like to see in the final version of the manuscript, and I am sure the authors would be able to answer these queries: 1- I am no expert, but as far as I suppose, there is no a priori assumption on how the geographic region in England interferes with the consumption of ultra-processed foods or the prevalence of excessive free sugar intakes. The authors used a fixed effect for the region in their adjustment; however, it would be interesting to see, in a sensitivity analysis, if attributing a random effect to "region" rather than a fixed effect, results in a significant change in the findings. 2- Multiple imputations: There is no mention on how the results were combined across the 20 imputations? 3- Outliers' exclusion: please provide (in supplemental material) the graphic distribution of total energy intake in all the age groups, before the exclusion of outliers. 4- I have a small concern with combining the groups of unprocessed/minimally processed foods, and culinary ingredients. As explained by the authors in the supplemental material, processed food products (group 3) are products manufactured with the addition of group 2 substances (e.g. salt, sugar, oil, and fats) to group 1 foods. It seems not very intuitive to the reader why a group constituted from [A (NOVA group 1) + B (NOVA group 2)] would be compared to the group C (NOVA group 3) (which is

	basically constituted from products obtained from A, prepared with products from B). I understand the group 2 might not be relevant in a stand-alone analysis, but this approach needs more clarification. 5- Linear trends: a. In table 3, as regards to processed foods, the PR estimates do not seem to have a linear trend among quintiles, however, the p-value for trend is ≤0.001. Kindly, double check this analysis. b. As stated in the results and the abstract, no association was found between UPF and free sugars exceeding in elderly. However, in table 5, a significant association was found in the fourth quintile (PR =1.35 (1.09-1.66)). This is an interesting finding, and needs to be discussed, as it might be a “true” non-linear association in elderly. The characteristics of the fifth quintile of UPF in the elderly deserve to be a bit more investigated, to try to explain this non-linear association. 6- Counterfactual scenarios: the approach used by the authors is quite interesting, and the method they used is relevant. However, the used counterfactual scenario for UPF is a bit “ambitious” and unlikely, in terms of public health policies: it is highly unlikely that public health policies would ‘ban’ the use of UPF. However, nutritional and public health recommendations in several countries are now recommending to reduce the consumption of UPF. It is therefore more relevant to consider, if possible and feasible, a counterfactual scenario where the consumption of ultra-processed food is reduced by 25% or 50% for instance, rather than no consumption at all. Also, please provide more detail about the used method for counterfactual scenarios, if the space allows. I thank the authors in advance for taking into account these queries, so their manuscript would be suitable for publication.

VERSION 3 – AUTHOR RESPONSE

Reviewer(s)' Comments to Author:

Reviewer: 4

Reviewer Name: Dr Bernard Srour

Institution and Country: Nutritional Epidemiology Research Team EREN, French Institute of Health and Medical Research, University of Paris 13, France; German Cancer Research Center DKFZ, Cancer Epidemiology division, Heidelberg, Germany.

Please state any competing interests or state ‘None declared’: None declared

Please leave your comments for the authors below

In this paper, Rauber and colleagues investigated the cross-sectional associations between ultra-processed food intake and the prevalence of excessive free sugar intake (≥ 10% of total daily energy intake), in a nationally representative survey in the UK. The authors concluded that the prevalence of excessive free sugar intake is positively associated with the consumption of ultra-processed foods. On the other hand, the authors found, using counterfactual scenarios, that eliminating ultra-processed foods could be associated with a 47% reduction in the prevalence of excessive free sugar intake.

The manuscript is well written, the analyses are thorough and the findings are of a great public health interest, in the actual state of sugar reduction policies changes in the UK. The authors should be commended for the scientific quality of the statistical analyses, and for the study design. I unfortunately

do not have access to previous versions of the manuscript, to assess the evolution of the content according to other reviewer's comments.

R: We appreciate your careful reading of this manuscript and your comments and constructive suggestions.

I have several statistical minor questions that need a little bit more clarification, and that I would like to see in the final version of the manuscript, and I am sure the authors would be able to answer these queries:

1- I am no expert, but as far as I suppose, there is no a priori assumption on how the geographic region in England interferes with the consumption of ultra-processed foods or the prevalence of excessive free sugar intakes. The authors used a fixed effect for the region in their adjustment; however, it would be interesting to see, in a sensitivity analysis, if attributing a random effect to "region" rather than a fixed effect, results in a significant change in the findings.

R: Thank you for your comments. In order to address them, we have consulted colleagues in the department of Statistics of our university. Based on this consultation, we concluded that the model used in our paper is the most appropriate, since we treated the region as a confounding variable for the association between ultra-processed foods and sugar intake, and both the consumption of ultra-processed foods and sugar vary substantially across regions. We also concluded that a model using random effects would be useful to evaluate the explained variance associated with each covariate, which would be very interesting for a future paper.

2- Multiple imputations: There is no mention on how the results were combined across the 20 imputations?

R: As suggested by the reviewer, we have included more information about the multiple imputations.

Methods – Page 8: "We used the average of estimates from each imputed dataset. Sensitivity analysis was conducted comparing findings from imputed data and complete case analysis."

Results – Page 13: "Sensitivity analysis performed by considering complete cases only indicated that the results of the multiple imputations did not differ significantly from the complete case analysis (data not shown)."

3- Outliers' exclusion: please provide (in supplemental material) the graphic distribution of total energy intake in all the age groups, before the exclusion of outliers.

R: As suggested by the reviewer, we have included the graphic distribution of total energy intake in all the age groups, before the exclusion of outliers, in a supplementary material (please, see the Supplementary figure S1).

4- I have a small concern with combining the groups of unprocessed/minimally processed foods, and culinary ingredients. As explained by the authors in the supplemental material, processed food products (group 3) are products manufactured with the addition of group 2 substances (e.g. salt, sugar, oil, and fats) to group 1 foods. It seems not very intuitive to the reader why a group constituted from [A (NOVA group 1) + B (NOVA group 2)] would be compared to the group C (NOVA group 3) (which is basically constituted from products obtained from A, prepared with products from B). I understand the group 2 might not be relevant in a stand-alone analysis, but this approach needs more clarification.

R: We have included more details to clarify it.

Methods – Page 8: "We combined the group of unprocessed or minimally processed foods with the group of processed culinary ingredients, as foods belonging to these two groups are usually mixed together in culinary preparations and, therefore, consumed together. Thus, we performed the analyses considering three groups of foods: unprocessed or minimally processed foods and processed culinary ingredients (individuals are able to determine the amount of table sugars they add), processed foods (sugar added by the food industry), and ultra-processed foods (sugar added by the food industry)."

5- Linear trends:

a. In table 3, as regards to processed foods, the PR estimates do not seem to have a linear trend among quintiles, however, the p-value for trend is ≤0.001. Kindly, double check this analysis.

R: We have checked it and we confirm that the p-value for trend was statistically significant (0.039 for Adjusted). We clarified it in the text.

b. As stated in the results and the abstract, no association was found between UPF and free sugars exceeding in elderly. However, in table 5, a significant association was found in the fourth quintile (PR =1.35 (1.09-1.66)). This is an interesting finding, and needs to be discussed, as it might be a "true" non-linear association in elderly. The characteristics of the fifth quintile of UPF in the elderly deserve to be a bit more investigated, to try to explain this non-linear association.

R: Thank you for your comment. As suggested, we have added more details throughout the manuscript to clarify this.

Results: Page 12 – "Although no linear trend was found between quintiles of ultra-processed food consumption and excessive free sugars intake among elderly (p>0.05), the fourth quintile group had a prevalence of excessive free sugar intake 35% higher (PRadj 1.3; 95% CI 1.1 to 1.7) than those in the lowest quintile group."

Discussion: Page 18 – "In our study there was no linear association between ultra-processed food consumption and dietary content of free sugars among the elderly. Although the prevalence of excessive free sugar intake was higher in the fourth in regards to the first quintile of ultra-processed food consumption, the prevalence in the highest quintile group was not different from the first. A possible explanation for this finding could be changes in the composition of different types of ultra-processed across quintiles in the elderly. Actually, while in the overall population, ultra-processed sweetened products such as soft/fruit drinks, confectionary, milk-based drinks, and biscuits monotonically increased across quintiles (from 18% to 23% of the total calories from ultra-processed foods), in the elderly a drop in consumption was observed between the fourth and fifth quintiles (from 18 to 15%) (data no shown)."

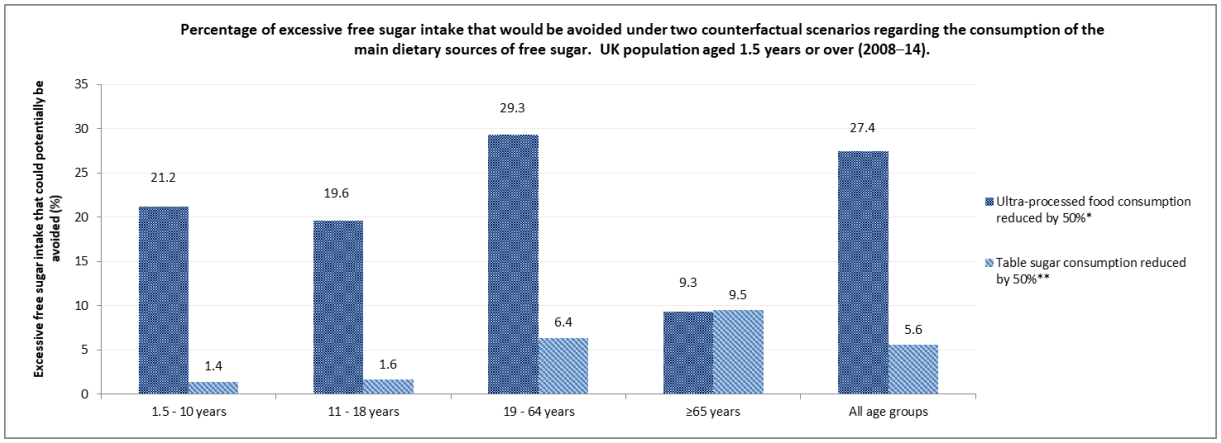
6- Counterfactual scenarios: the approach used by the authors is quite interesting, and the method they used is relevant. However, the used counterfactual scenario for UPF is a bit "ambitious" and unlikely, in terms of public health policies: it is highly unlikely that public health policies would 'ban' the use of UPF. However, nutritional and public health recommendations in several countries are now recommending to reduce the consumption of UPF. It is therefore more relevant to consider, if possible and feasible, a counterfactual scenario where the consumption of ultra-processed food is reduced by 25% or 50% for instance, rather than no consumption at all. Also, please provide more detail about the used method for counterfactual scenarios, if the space allows.

R: We appreciate your comment. We carried out analyses considering your suggestion and included it as a supplementary figure.

Methods: Page 10 – "To test more feasible scenarios, we also estimated the percent reduction in prevalence of excessive free sugar intake from reducing the consumption of ultra-processed foods and table sugar by 50%."

Results: Page 17 – "For the more feasible scenario, we found a similar trend where a greater reduction in the percentage of excessive free sugar intake due to a 50% reduction of ultra-processed foods, relative to table sugar, was observed in all age groups, except in the elderly group (see Suppl. Figure S2)."

Suppl. Figure S2. Percentage of excessive free sugar intake that would be avoided under possible counterfactual scenarios regarding the consumption of the main dietary sources of free sugar. UK population aged 1.5 years or over (2008–14).



* The consumption of ultra-processed food was reduced by 50% of the average intake for each age group (1.5-10y: from 63.5 to 28.4% of total energy intake; 11-18y: from 68 to 34%; 19-64y: from 54.8 to 27.4; ≥65y: from 52.9 to 26.4%; all age groups: from 56.8 to 28.4%).
** The consumption of table sugar (including honey, molasses, maple syrup) was reduced by 50% of the average intake for each age group (1.5-10y: from 0.48 to 0.24% of total energy intake; 11-18y: from 1.0 to 0.5%; 19-64y: from 1.8 to 0.9; ≥65y: from 1.9 to 0.9%; all age groups: from 1.6 to 0.8%).

I thank the authors in advance for taking into account these queries, so their manuscript would be suitable for publication.

VERSION 4 – REVIEW

REVIEWER	Dr Bernard Srour Nutritional Epidemiology Research Team EREN, French Institute of Health and Medical Research, University of Paris 13, France; German Cancer Research Center DKFZ, Cancer Epidemiology division, Heidelberg, Germany.
REVIEW RETURNED	09-Sep-2019

GENERAL COMMENTS	The authors have successfully adressed my comments. The paper is now suitable for publication