PEER REVIEW HISTORY

This paper was submitted to the BMJ but declined for publication following peer review. The authors addressed the reviewers' comments and submitted the revised paper to BMJ Open where it was re-reviewed and accepeted.

ARTICLE DETAILS

TITLE (PROVISIONAL)	Do Healthier Foods and Diet Patterns Cost More Than Less Healthy Options? A Systematic Review and Meta-Analysis
AUTHORS	Rao, Mayuree; Afshin, Ashkan; Singh, Gitanjali; Mozaffarian, Dariush

VERSION 1 - REVIEW

REVIEWER	Loh, Lawrence University of Toronto, Dalla Lana School of Public Health
REVIEW RETURNED	18-Aug-2013

GENERAL COMMENTS	Thank you very much for the opportunity to review this interesting research article. The topic is an important one, given the conventional research and anecdotal wisdom that suggests eating a "healthy" diet is often more expensive than eating an "unhealthy" one. As a research question, being able to clearly demonstrate this with compelling evidence would have the potential to affect various changes in policy and programs that enable people to access healthier food at a lower cost. The paper describes a systematic review and meta-analysis comparing various studies which have compared healthy and unhealthy food choices or dietary profiles in the last 13 years. This is a tall order and the authors have made a good effort at putting together a reasonable synthesis. However, in its present form, I must unfortunately and respectfully recommend against publication in the BMJ. My biggest concern is that the paper focuses heavily on a meta-analysis when a systematic review is really the only valuable synthesis that can be drawn from such heterogeneous data. Given the enormous revision that would be required to remove the quantitative meta-analysis portion of the piece, I don't believe additional revision would resolve this significant concern. This concern is more clearly explained in my detailed comments below. I hope that my comments will help the authors in strengthening their synthesis and having it published. *** Detailed comments: The introduction does a good job of reviewing the importance of the

	research question and discusses the literature gap. Methods described provide a basic overview of the selection of articles and the strategy for statistical analysis. This section would benefit from more detail. It would be beneficial for the authors to specify the inclusion / exclusion criteria that was used to conduct the initial review of abstracts. This would, in turn, help me better understand how many different studies with different inputs / exposures and outcomes were ultimately selected for full-text review (and ultimately for inclusion in various sub-analyses.) In the data extraction phase, it's not clear to me what value the inclusion of the "rated intensity of contrast" adds to the overall manuscript. It seems to me that this adds a qualitative component to the study that is most likely subjective. If the quantitative data itself does not stand (see concerns described later), then that would suggest that perhaps a meta-analysis is not the best vehicle to conduct the synthesis, and a simple descriptive systematic analysis would suffice. The systematic review of included papers is well done and provides insight into the nature of a number of very different studies that analyse healthy vs. not healthy options. The decision, however, to put these into meta-analyses weakens the overall paper and the argument. In many of the analyses carried out, each study is measuring an entirely different intervention, which would typically preclude the conduct of a meta-analysis. For example, in the meats/proteins group, the authors have grouped together peanut butter, beef and pork comparisons, and chicken comparisons together. I don't believe that these are substitutes of one another that would make all these studies immediately "combinable." I have similar issues, for example, with the snacks/sweets group, which are already immediately heterogeneous based on the studies themselves: crackers, chips, biscuits, and sugar substitutes are all pooled into a meta-analysis. Naturally the high I2 reflects the heterogeneity and a quick glance at the combined studies immediately raises the question of "how appropriate is it to combine these studies?" As a simple follow-on question I would ask - if indeed unhealthy snacks are more expensive than healthy snacks, based on these data, what would the authors propose to target for price reductions? At a glance one can see that the produce vs. snacks study provided a large price finding favouring the unhealthy choice. But similarly, the comparison between low and high fat chocolates (arguably both snacks) is equivocal. These two studies are obviously not measuring the same thing and thus should not be combined. This issue exists for all six groups that are presented in each meta-analysis. To that end, I would like to point out that the systematic review as done by the authors, while less quantitative, still has significant value. They can highlight a number of studies that have individually found that various comparisons show the nature of healthy foods being more expensive than unhealthy foods and achieve the same effect. At present, however, the presence of the meta-analysis is problematic and the decision to put together studies that are not technically combinable / substitutable weakens the author's arguments. Finally, with regards to the discussion and conclusions, the

	discussion will require will require major revisions should the authors decide to present the data of individual studies in a systematic review rather than the combined meta-analysis results. However, using individual studies, the authors could still make very strong arguments that healthy food appears to be more expensive in documented literature without the need for a combined statistic (based on the earlier systematic review findings.) The conclusions drawn by the author are expected and highlight a few additional hypotheses that would benefit from additional research. Of note, however, is the author's statement that "for many low-income families, the additional cost might represent a barrier to healthier eating"... and then goes on to assert "daily price is similar to a price of a cup of coffee and quite trivial in comparison to the lifetime financial burdens..." - as this is phrased, it seems to imply that low-income families are to blame for not spending the $1.50/day (note that I use this statistic carefully, since I do not believe the combined statistic has any statistical merit given my comments above) - but more that this is a value judgement. Many of the most socioeconomically disadvantaged among us likely do not drink coffee on a daily basis, and $550 annually is not an insignificant sum for many of these individuals and their families. Making this comparison immediately jumps out as judgmental, suggestive that they're "not spending their money appropriately." Furthermore, a comparison like this fails to account for other expenses and the variability of price (e.g. in different cities, among the urban poor vs. the rural poor, the fact that this combined statistic takes in transnational studies) etc. For such an important topic this comment seems out of place and overly simplistic. It might be better to comment more in-depth on the systemic need for better policy and diet support, food stamp programs and funding, appropriate subsidies, community programs etc. to enable poorer people to be supported in making healthier choices around their eating. Regardless, I thank you for the opportunity to review this paper. It focuses on an important topic. I believe if the authors chose to, they could very easily remove the meta-analysis portion of the paper, increase clarity on the nature of the review conducted, and using individual studies from a broad systematic review, restructure their discussions and conclusions around the findings in literature to make a strong argument supporting the hypothesis that healthy foods are more expensive than unhealthy foods. I hope my comments have been helpful in making your decision and supporting the authors' work. I wish them well in their efforts to publish this important data.

REVIEWER	Ravasco, Paula
REVIEW RETURNED	19-Aug-2013

GENERAL COMMENTS	Information on costs with the consequences of eating not-health diets in the long term are necessary.

REVIEWER	Laranjo, Liliana

	Portuguese School of Public Health
REVIEW RETURNED	28-Aug-2013

GENERAL COMMENTS	Positive aspects: - Original, novel. First systematic review of the relationship between food healthfulness and price. - This work belongs in a general journal and it matters to clinicians, patients, teachers, and especially policymakers. - The research question is clearly defined and appropriately answered. The introduction gives a good background to the problem being studied. - The overall design of the study is adequate. - Sufficient information for each of the studies included is given. - Methods are adequately described. - Complies with MOOSE guidelines. - The results answer the research question and are well presented. - The interpretation and conclusions are clear and warranted by the data. Questions and issues: - Was the protocol for the systematic review registered (e.g. in PROSPERO). Were there any modifications made to the initial protocol? - Inter-rater agreement for the intensity of the healthfulness contrast should be reported if possible. - Was the quality of included studies assessed? - Some limitations should be acknowledged in the discussion section: 1. Inclusion of English papers only. 2. Use of one single database (e.g. Embase could have found additional papers). - Order of the references in the text is not correct (line 12 – first reference to appear is number 6). - List of citations excluded is not provided. - From the inclusion and exclusion criteria provided I do not understand why the following papers were not included: 1. Ni Mhurchu C, Ogra S. The price of healthy eating: cost and nutrient value of selected regular and healthier supermarket foods in New Zealand. N Z Med J. 2007;120(1248):U2388. 2. Jetter KM, Cassady DL. The availability and cost of healthier food alternatives. Am J Prev Med. 2006 Jan;30(1):38-44. 3. Burns CM, Gibbon P, Boak R, Baudinette S, Dunbar JA. Food cost and availability in a rural setting in Australia. Rural Remote Health. 2004 Oct-Dec;4(4):311. - Keywords are missing.

- The manuscript received five reviews at BMJ but the other reviewers have declined to make their comments public. Please contact BMJ Open Editorial office for further information.

VERSION 1 – AUTHOR RESPONSE

Reviewer: 1 Recommendation: Comments: Thank you very much for the opportunity to review this interesting research article. The topic is an important one, given the conventional research and anecdotal wisdom that suggests eating a "healthy" diet is often more expensive than eating an "unhealthy" one. As a research question, being able to clearly demonstrate this with compelling evidence would have the potential to affect various changes in policy and programs that enable people to access healthier food at a lower cost. The paper describes a systematic review and meta-analysis comparing various studies which have compared healthy and unhealthy food choices or dietary profiles in the last 13 years. This is a tall order and the authors have made a good effort at putting together a reasonable synthesis. My biggest concern is that the paper focuses heavily on a meta-analysis when a systematic review is really the only valuable synthesis that can be drawn from such heterogeneous data. Given the enormous revision that would be required to remove the quantitative meta-analysis portion of the piece, I don't believe additional revision would resolve this significant concern. This concern is more clearly explained in my detailed comments below. I hope that my comments will help the authors in strengthening their synthesis and having it published.
Author response: The reviewer's concerns about the heterogeneity of the data are well-taken, yet the quantitative synthesis continues to have notable value beyond a systematic narrative review. First, the meta-analysis demonstrates the central estimates of the magnitudes of price differences, an important contribution to the current understanding of the cost of healthy foods/diet patterns. Second, the meta-analysis demonstrates and quantifies the heterogeneity in the current literature, a very important finding in itself. Third, although statistical heterogeneity was high, the magnitude of clinically relevant heterogeneity was much lower. Fourth, although similar types of foods were analyzed together, it was necessary to permit some remaining differences within each analysis in order to preserve the generalizability and relevance of the results. More detailed responses are specified below.
*** Detailed comments: The introduction does a good job of reviewing the importance of the research question and discusses the literature gap. Methods described provide a basic overview of the selection of articles and the strategy for statistical analysis. This section would benefit from more detail. It would be beneficial for the authors to specify the inclusion / exclusion criteria that was used to conduct the initial review of abstracts. This would, in turn, help me better understand how many different studies with different inputs / exposures and outcomes were ultimately selected for full-text review (and ultimately for inclusion in various sub-analyses.)
Author response: The inclusion/exclusion criteria are detailed in the "Search strategy and selection of articles" subsection on p. 8 of the methods section. We revised this subsection to clarify that the inclusion/exclusion criteria described were applied to both abstract and full-text screening. We also added a sentence to make it explicit that no specific foods or diet patterns were excluded.
In the data extraction phase, it's not clear to me what value the inclusion of the "rated intensity of contrast" adds to the overall manuscript. It seems to me that this adds a qualitative component to the study that is most likely subjective. If the quantitative data itself does not stand (see concerns described later), then that would suggest that perhaps a meta-analysis is not the best vehicle to conduct the synthesis, and a simple descriptive systematic analysis would suffice.
Author response: In the introduction of the paper, we identified the magnitude of differences in healthfulness between foods/diet patterns as one potential source of heterogeneity. For example, a fast food meal vs. a healthier home-cooked meal is a more extreme comparison than a low-fat vs. high-fat cookie, and this variation could influence differences in prices. For this reason, it is valuable to evaluate the intensity of contrast between each pair of foods and diet patterns compared. Additionally, although subjective, the ratings were based on specific principles; e.g., comparisons of different types of foods and diet patterns were rated as higher intensity than comparisons of foods that varied by a single nutrient. Furthermore, the ratings were assigned independently and in duplicate with good concordance; any differences were resolved by group discussion. We have added these points to the data extraction and synthesis section on p. 9. We have also added more detail on this issue in the limitations section of the discussion on p. 20. The systematic review of included papers is well done and provides insight into the nature of a number of very different studies that analyse healthy vs. not healthy options. The decision, however, to put these into meta-analyses weakens the overall paper and the argument. In many of the analyses carried out, each study is measuring an entirely different intervention, which would typically preclude the conduct of a meta-analysis. For example, in the meats/proteins group, the authors have grouped together peanut butter, beef and pork comparisons, and chicken comparisons together. I don't believe that these are substitutes of one another that would make all these studies immediately "combinable." I have similar

issues, for example, with the snacks/sweets group, which are already immediately heterogeneous based on the studies themselves: crackers, chips, biscuits, and sugar substitutes are all pooled into a meta-analysis. Naturally the high I2 reflects the heterogeneity and a quick glance at the combined studies immediately raises the question of "how appropriate is it to combine these studies?" As a simple follow-on question I would ask - if indeed unhealthy snacks are more expensive than healthy snacks, based on these data, what would the authors propose to target for price reductions? At a glance one can see that the produce vs. snacks study provided a large price finding favouring the unhealthy choice. But similarly, the comparison between low and high fat chocolates (arguably both snacks) is equivocal. These two studies are obviously not measuring the same thing and thus should not be combined. This issue exists for all six groups that are presented in each meta-analysis. To that end, I would like to point out that the systematic review as done by the authors, while less quantitative, still has significant value. They can highlight a number of studies that have individually found that various comparisons show the nature of healthy foods being more expensive than unhealthy foods and achieve the same effect. At present, however, the presence of the meta-analysis is problematic and the decision to put together studies that are not technically combinable / substitutable weakens the author's arguments. Finally, with regards to the discussion and conclusions, the discussion will require will require major revisions should the authors decide to present the data of individual studies in a systematic review rather than the combined meta-analysis results. However, using individual studies, the authors could still make very strong arguments that healthy food appears to be more expensive in documented literature without the need for a combined statistic (based on the earlier systematic review findings.)

Author response: In the quantitative analysis, similar classes of foods were grouped together in order to assess average overall price differences. In practice, the relevant public health question is not whether one specific product costs more than another, but whether healthier foods in a broad class of foods cost
more, on average, than less healthy foods in a broad class of foods. As the reviewer points out, foods were not exactly the same within each food category. We believe these differences are reasonable and necessary; a meta-analysis of a single, highly specific type of food would indeed minimize heterogeneity but at the unacceptable cost of substantially reducing generalizability and meaning. The research question driving our analysis was not whether the healthier version of a single specific food costs more, but rather whether healthier foods and diet patterns overall cost more than less healthy options. The discussion has been revised on p. 19 to clarify these points.

Additionally, as explained in the discussion, clinically relevant heterogeneity observed across comparisons was much lower than the statistical heterogeneity. High I2 values are partly explained by the relatively small uncertainty for each within-study price difference. Lower within-study uncertainty produces higher I2 values, even when absolute magnitudes of price heterogeneity among studies are modest. Thus, the calculated heterogeneity in each summary estimate should be interpreted in light of the actual range of observed price differences across studies. The quantitative synthesis still provides valuable insight into the cost of a healthy diet and potential sources of variation in price. This point has been further emphasized in the discussion on p. 18.

We have also revised the first paragraph of the discussion and the strengths and limitations section on pp. 16 and 20 to summarize these points. The conclusions drawn by the author are expected and highlight a few additional hypotheses that would benefit from additional research. Of note, however, is the author's statement that "for many low-income families, the additional cost might represent a barrier to healthier eating"... and then goes on to assert "daily price is similar to a price of a cup of coffee and quite trivial in comparison to the lifetime financial burdens..." - as this is phrased, it seems to imply that low-income families are to blame for not spending the $1.50/day (note that I use this statistic carefully, since I do not believe the combined statistic has any statistical merit given my comments above) - but more that this is a value judgement. Many of the most socioeconomically disadvantaged among us likely do not drink coffee on a daily basis, and $550 annually is not an insignificant sum for many of these individuals and their families. Making this comparison immediately jumps out as judgmental, suggestive that they're "not spending their money appropriately." Furthermore, a comparison like this fails to account for other expenses and the variability of price (e.g. in different cities, among the urban poor vs. the rural poor, the fact that this combined statistic takes in transnational studies) etc. For such an important topic this comment seems out of place and overly simplistic. It might be better to comment more in-depth on the systemic need for better policy and diet support, food stamp programs and funding, appropriate subsidies, community programs etc. to enable poorer people to be supported in making healthier choices around their eating.

Author response: We have revised the conclusions section on p. 21-22 to make it clear that an additional cost of $1.50/day per person is a significant financial burden for many low-income families.

We have also removed the comparison to the price of a cup of coffee in order to avoid trivializing the additional cost, which was not our intent. We have retained the statement that the price difference remains small relative to the financial burden of chronic disease. From a public health perspective, the cost of a healthy diet relative to the cost of diet-related chronic disease is an important point relevant to crafting policies that reduce the price of healthy foods and encourage healthier food purchasing decisions.
Additionally, in response to the reviewer's concern that the combined statistic includes trans-national studies, we have reported the results of the analysis of food-based and nutrient-based diet patterns restricted to US-based studies only on p. 14 of the results section. The summary estimate for food-based patterns is very similar, with healthier patterns costing $1.49/day more (95% CI $0.60 to $2.37).
Regardless, I thank you for the opportunity to review this paper. It focuses on an important topic. I believe
if the authors chose to, they could very easily remove the meta-analysis portion of the paper, increase clarity on the nature of the review conducted, and using individual studies from a broad systematic review, restructure their discussions and conclusions around the findings in literature to make a strong argument supporting the hypothesis that healthy foods are more expensive than unhealthy foods. I hope my comments have been helpful in making your decision and supporting the authors' work. I wish them well in their efforts to publish this important data. Lawrence Loh, MD, MPH, CCFP, FRCPC Medical Health Officer, Fraser Health Authority Adjunct Lecturer, Epidemiology and Global Health, Dalla Lana School of Public Health, University of Toronto Vancouver, Canada Additional Questions: Please enter your name: Lawrence Loh Job Title: MD, MPH, CCFP, FRCPC Institution: University of Toronto Reimbursement for attending a symposium?: No A fee for speaking?: No A fee for organising education?: No Funds for research?: No Funds for a member of staff?: No Fees for consulting?: No Have you in the past five years been employed by an organisation that may in any way gain or lose financially from the publication of this paper?: No Do you hold any stocks or shares in an organisation that may in any way gain or lose financially from the publication of this paper?: No If you have any competing interests <A HREF='
http://bit.ly/VW8GVB'target='_new'>(please see BMJ Group policy) please declare them here:
Reviewer: 2 Recommendation: Comments: information on costs with the consequences of eating not-health diets in the long term are necessary.
Author response: On pp. 21-22 of the conclusions, we have reported the contribution of poor diet to DALYs in the United States. We have also reported our own calculation of the share of national health expenditure that may be attributed to poor diet assuming that it is similar to the percentage contribution to DALYs.
Additional Questions: Please enter your name: Paula Ravasco Job Title: Professor; Principal Investigator Institution: Faculty Medicine University of Lisbon Reimbursement for attending a symposium?: No A fee for speaking?: No A fee for organising education?: No Funds for research?: No Funds for a member of staff?: No Fees for consulting?: No Have you in the past five years been employed by an organisation that may in any way gain or lose financially from the publication of this paper?: No Do you hold any stocks or shares in an organisation that may in any way gain or lose financially from the publication of this paper?: No If you have any competing interests <A HREF='http://bit.ly/VW8GVB'target='_new'>(please see BMJ Group policy) please declare them here: **Reviewer: 3** Recommendation: Comments: Positive aspects: - Original, novel. First systematic review of the relationship between food healthfulness and price. - This work belongs in a general journal and it matters to clinicians, patients, teachers, and especially policymakers. - The research question is clearly defined and appropriately answered. The introduction gives a good background to the problem being studied. - The overall design of the study is adequate. - Sufficient information for each of the studies included is given. - Methods are adequately described. - Complies with MOOSE guidelines. - The results answer the research question and are well presented. - The interpretation and conclusions are clear and warranted by the data. Questions and issues:
- Was the protocol for the systematic review registered (e.g. in PROSPERO). Were there any modifications made to the initial protocol?
Author response: The protocol was not registered but is available upon request, which is now specified on p. 8 of the methods section. We have also specified in the text of the protocol that no modifications were made.
- Inter-rater agreement for the intensity of the healthfulness contrast should be reported if possible.
Author response: Unfortunately, inter-rater agreement for the intensity of contrast was not recorded. Based on our discussions, differences in the ratings among the investigators were nearly always less than or equal to 2 points, and any discrepancies were easily resolved by discussion.

- Was the quality of included studies assessed?
Author response: The quality of each study was not explicitly assessed, and we have added this limitation to the discussion section on p. 20.
- Some limitations should be acknowledged in the discussion section: 1. Inclusion of English papers only. 2. Use of one single database (e.g. Embase could have found additional papers).
Author response: We have added these limitations to the discussion section on p. 20.
- Order of the references in the text is not correct (line 12 – first reference to appear is number 6).
Author response: The first reference in the body of the paper was #6 because five references had been previously cited in the "What this paper adds" box. The numbering of the references has now changed with the deletion of this box and the addition of the Article Summary section for BMJ Open.
- List of citations excluded is not provided.
Author response: We are happy to provide a list of excluded citations on request, and we have added this statement in the methods section on p. 9.
- From the inclusion and exclusion criteria provided I do not understand why the following papers were not included: 1. Ni Mhurchu C, Ogra S. The price of healthy eating: cost and nutrient value of selected regular and healthier supermarket foods in New Zealand. N Z Med J. 2007;120(1248):U2388.
Author response: This study was excluded because the sample size, standard deviation, and standard error were not reported, and the authors could not provide this information.
2. Jetter KM, Cassady DL. The availability and cost of healthier food alternatives. Am J Prev Med. 2006 Jan;30(1):38-44.
Author response: This study was indeed included in the systematic review and meta-analysis. It appears in the table and figures.
3. Burns CM, Gibbon P, Boak R, Baudinette S, Dunbar JA. Food cost and availability in a rural setting in Australia. Rural Remote Health. 2004 Oct-Dec;4(4):311.
Author response: This study was excluded because it does not compare the cost of a healthier and less healthy food/diet pattern. The cost of a healthy food basket is reported but not compared to the cost of a less healthy basket.
- Keywords are missing.
Author response: Keywords have been provided on p. 1. Additional Questions: Please enter your name: Liliana Laranjo Job Title: Research Assistant. MD, MPH. Institution: Portuguese School of Public Health Reimbursement for attending a symposium?: No A fee for speaking?: No A fee for organising education?: No Funds for research?: No Funds for a member of staff?: No Fees for consulting?: No Have you in the past five years been employed by an organisation that may in any way gain or lose financially from the publication of this paper?: No Do you hold any stocks or shares in an organisation that may in any way gain or lose financially from the publication of this paper?: No If you have any competing interests <A HREF='http://bit.ly/VW8GVB'target='_new'>(please see BMJ Group policy) please declare them here: