The effects of physical activity calorie equivalent food labelling to reduce food selection and consumption: systematic review and meta-analysis of randomised controlled studies

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Abstract

Background: There is limited evidence that nutritional labelling on food/drinks is changing eating behaviours. Physical activity calorie equivalent (PACE) food labelling aims to provide the public with information about the amount of physical activity required to expend the number of kilocalories in food/drinks (e.g. calories in this pizza requires 45 minutes of running to burn), to encourage healthier food choices and reduce disease.

Objective: We aimed to systematically search for randomised controlled trials and experimental studies of the effects of PACE food labelling on the selection, purchase or consumption of food/drinks.

Methods: PACE food labelling was compared with any other type of food labelling or no labelling (comparator). Reports were identified by searching electronic databases, websites, and social media platforms. Inverse variance meta-analysis was used to summarise evidence. Weighted mean differences (WMD) and 95% confidence intervals were used to describe between group differences using a random effects model.

Results: 15 studies were eligible for inclusion. When PACE labelling was displayed on food/drinks and menus, significantly fewer calories were selected, relative to comparator labelling (weighted mean difference=-64.9 kilocalories: 95% CI: -103.2 to -26.6, p=0.009, n=4606). Presenting participants with PACE food labelling results in the consumption of significantly fewer calories (weighted mean difference=-80.4 kilocalories:95% CI:-136.7 to -24.2, p=0.005, n=486) relative to comparator food labelling.

Conclusion: Based on current evidence PACE food labelling may reduce the number kilocalories selected from menus and decrease the number of kilocalories/grams of food consumed by the public, compared to other types of food labelling/no labelling.

Keywords: calorie labelling, labelling, physical activity, review, meta analysis, kilocalorie

Registration: Protocol was registered with PROSPERO on 12th December 2018:registration number CRD42018088567.

What is already known on this topic?

- There is little evidence that current nutritional labelling on food and drinks is having any impact on changing the eating behaviours of the public.
- Many people do not understand the meaning of kilocalories (calories) or grams of fat in terms of energy balance leading to a substantial underestimation of the energy content of food and drinks by the public.
- Regular over consumption of a small amount of calories can lead to overweight and obesity

What this study adds?

- PACE food labelling may reduce the number kilocalories selected from menus and decrease the number of kilocalories/grams of food consumed by the public, compared to other types of food labelling/no labelling at meals times.
- Findings highlight the importance of easily understood food labels to reduce the calorie intake of the population, by decreasing the selection of higher calorie food and drinks.
- Public health agencies may want to consider the possibility of including policies to promote PACE food labelling as a strategy that contributes to the prevention and treatment of obesity and related diseases.

Introduction

Obesity is a key contributor to many nutrition related chronic diseases including type 2 diabetes, cardiovascular disease and cancer.[1-3] There has been no long term success in reducing obesity rates and changing behaviour to halt and reverse rises to prevent disease is difficult. There is growing recognition that this is in part is due to the physical environments that surround the public, which can exert considerable influences on health behaviors.[4] One way of reducing kilo-calorie (herein referred to as calorie) consumption is nutritional labelling but current evidence shows that current front-of-pack (FoP) nutrition information on food/drinks, is having a limited effect on changing purchasing or eating behaviours.[5-6] Many people do not understand the meaning of calories or grams of fat in terms of energy balance. A key challenge to limiting energy consumption is the significant underestimation by the public of the amount of calories/fat in food/drinks.[7-8]

An alternative approach to current nutrition labelling, in and out of home settings, is providing calorie information with a clear interpretation of what the calorie content of the item/meal means in terms of energy expenditure. This approach has been termed physical activity calorie equivalent (or expenditure) labelling (PACE), which aims to show the public how many minutes (or miles/kilometres) of physical activity (e.g. walking or running) are equivalent to the calories contained in food/drinks.[9] For example, "the calorie in this chocolate bar requires 55 minutes of walking to burn off" (Figure 1). PACE food labelling could be a useful tool to help the public understand what a calorie means and therefore more able to decide whether the calories are 'worth it'.[10] PACE labelling is an example of an environmental intervention that seeks to nudge the public towards making healthy food choice and to demonstrate restraint in their eating.[11] Unlike other types of food labelling, PACE labelling has the potential to serve as a continual reminder to the public about the importance of participating in regular physical activity to ensure good energy balance. There

is also observational evidence that the public prefer PACE food labelling over other types of food labelling.[12]

The Royal Society for Public Health in the United Kingdom has called for PACE labelling to be implemented as a front of pack (FoP) food labelling, but evidence to support this view is lacking.[13] A systematic review of PACE labelling was published recently and showed no effect. However, the review included only a small number of studies (n=7) and only the impact of PACE labelling on the number of calories selected from menus was assessed, not the amount of food actually consumed, which is what impacts health.[14] This systematic review aims to provide up-to-date synthesis of the evidence regarding the effects of PACE food labelling and estimate its potential impact on the selection, purchase and consumption of food/drinks, to inform future implementation of PACE food labelling.

Methods

Registration and reporting

This meta-analysis has been reported in line with the preferred reporting items for systematic reviews and meta-analysis (PRISMA) and was registered with PROSPERO on 12th December 2018.

Selection of studies

We aimed to be inclusive as possible and identify randomised controlled trials (RCTs) and randomised controlled acute experimental studies that reported data relating to the effects of PACE labelling on the selection, purchase or consumption of food/drinks (non-alcoholic). Both between-subjects and within-subjects designs were suitable for inclusion. A scoping search was conducted (by SB & AC) initially, focusing on systematic reviews, some background and grey literature to estimate the volume of research on this question. Our initial searches of principal biomedical databases (MEDLINE, MEDLINE In Process, EMBASE), combined terms for exercise and physical activities with terms for food labelling.

The initial search strategy used a combination of sensitivity and precision alongside the blending of indexing terms with free text searches. The main searches covered the following electronic databases; MEDLINE (Ovid), MEDLINE In Process (Ovid), EMBASE (Ovid), CINAHL (EBSCO) and Science Citation Index SCI (Web of Science). Conference Proceedings Citation Index (Web of Science), ZETOC and Electronic Theses Online (ETHOS) were also searched, as were appropriate websites and sources of grey literature, including social media platforms. A full list of grey literature and social media platforms can be found in supplementary file 1. Registers of on-going trials were examined for research in progress (ClinicalTrials.gov, WHO International Clinical Trials Registry Platform & Cochrane CENTRAL Register of Controlled Trials). There were no date or language limits. In addition, a brief search of the last 12 months (prior to the end search date below) of PubMed ensured no more recent studies and as yet unindexed studies were missed.

A detailed description of the MEDLINE search strategy is provided in the supplementary file 1. The main database searches took place between 16th February and 6th March 2018. Searches of other resources took place were between 16 February- 28 March 2018. Reference lists of relevant and related publications were hand searched for additional studies that were not identified by the main searches.

Inclusion and exclusion criteria

Studies were eligible for inclusion if participants were randomly allocated to study conditions/groups, if participants were exposed to study conditions in a random order, or menu conditions in study locations were displayed in a random order. Conditions or interventions needed to have focused on assessing the effect or impact of PACE labelling on the selection, purchase or consumption of food/drinks, in any setting, context or population to be eligible for inclusion. Studies involving children were eligible. Only studies written in English were eligible, as were published dissertations. Studies were excluded if there was no

comparator group or if the aim was to assess the selection/purchases of food for others to consume. PACE labelling could be included as a single intervention or co-intervention. Initial title screenings and abstract review was undertaken by two independent reviewers (AD & HP). Full text of potentially eligible studies were then retrieved and assessed for eligibility by two independent reviewers (AD & HP). Any disagreement over the eligibility of studies was resolved through discussion with a third reviewer (EM).

Study characteristics and data extraction

Study characteristics were extracted and summarised by two independent reviewers (AD, HP, EM). The following data were extracted where applicable: study setting, country, participants, setting, type of study, methodology, outcomes and results. Study authors were contacted by email for additional information when required. The means and standard deviations (or other sources of variation) were also extracted and independently checked by two reviewers.

Risk of bias

The risk of bias within the included studies was assessed using the Review Manager 5.3 risk of bias software tool. Risk of bias assessments were conducted by two independent reviewers (AD & HMP). For the criteria 'other bias studies were assessed according to three sub-criteria. Studies needed to meet all three of the following criteria to be considered free from other bias; between-group design adopted, groups generally balanced at baseline and whether the population recruited was likely to produce generalizable findings.

Outcomes and data synthesis

Data on the selection, purchase or consumption of food/drinks in relation to number of kilocalories (calories), grams of food or number of food/drink items were extracted from included studies. We combined studies using an inverse variance meta-analysis with Review Manager. Weighted mean differences (WMD) and 95% confidence intervals were used to

describe between group differences using a random effects model. Heterogeneity was assessed using the I^2 statistic.[15] Where studies contributed more than one intervention or comparator group to the analysis or subgroup analyses we divided the number of participants in a group by the number of comparisons that group contributed to in the analysis. PACE labelling is a new concept and our aim was to summarise as much of the available data as possible. Therefore, as per previous studies,[16] when studies used within-subject designs, data was treated as though they were from between-subjects studies and we conducted a sensitively analysis to investigate the effect of within-subject design studies on the overall effect of PACE labelling on the selection of food. The primary analysis compared PACE labelling with any other type of labelling or no labelling (comparator). Subgroup analyses were conducted according to type of comparator food labelling and no labelling. We did not make comparisons between different types of PACE labelling. If studies reported confidence intervals or standard errors we converted these data to standard deviations. Only one trial reported data related to purchasing therefore meta-analysis of this outcome was not performed. A funnel plot was conducted but not presented here as there were less than 10 studies in any comparison and can be obtained from the first author on request.

Results

A total of 2,331 reports were identified through our search strategy and 288 reports were screened based on title and abstract, with 38 full text reports screened in full. Reasons for exclusion are listed in Figure 2. Fourteen reports (15 studies) were considered as eligible.[17-30] Montford reported four independent studies in one publication, two of which were eligible for inclusion here (studies 1 & 3).[28.] Of included studies, one was a cluster RCT,[29] eight were hypothetical food selection trials[17-24.]and five trials (six reports) involved food consumption.[25-28,30] One trial assessed food purchasing.[29] Nine trials assessed the number of calories selected.[17-24, 27] One trial assessed the purchasing of drinks only.[29]. Three

197 trials used variations of within-subject repeated measures designs.[24-25,30] The trial by
198 Platkin[26] was considered a between subject design as only data from lunch 2 was used and
199 relevant here. All studies except Bleich reported data on adults.[25] See supplementary Table 1
200 for study characteristics. The trial by Hartley[25] included a fake labelling condition which was
201 not relevant and excluded. Data relating to post exposure to labelling were used in the meta-
202 analysis.

203 Effects of PACE labelling on selection of food/drinks (Figure 3)

204 When PACE labelling was displayed on food items and menus, on average, the public
205 selected significantly less calories (WMD=-64.9 calories: 95% CI: -103.2 to -26.6, p=0.009,
206 n=4,606). Significant heterogeneity was present (I^2=87%). The sensitivity analysis where
207 within-subject design studies (n=1)[24] were removed from the analysis reduced the overall
208 effect for PACE labelling (WMD= -37.2 calories: 95% CI: -61.4 to -13.0, p=0.003, n=4,515)
209 and heterogeneity was 60%. In subgroup analyses PACE labelling was more effective than
210 no labelling (WMD=-103.4 calories: 95% CI:-158.9 to -47.9, n=2,065, I^2=71%).
211 Comparisons of PACE labelling versus other types of food labelling are reported in Figure 3.

212 Effects of PACE labelling on purchasing of food/drinks

213 The study by Bleich did not report data suitable for meta-analysis.[29] No significant
214 difference in the number of purchases of sugar and sweetened beverages (SSBs) between
215 labelling conditions were reported by the authors. Compared with providing no information,
216 PACE labelling reduced the odds of a purchase of SSBs by 50% (OR=0.51, 95% CI: 0.31 to
217 0.85) and percentage of daily intake labelling reduced purchases by approximately 40%
218 (OR=0.59, 95%: CI: 0.34 to 1.02). Calorie only labelling had no effect.

219 Effects of PACE food labelling on the number of calories of food/drinks consumed (Figure 4)

220 The inclusion of PACE labelling on food packaging/display and menus resulted in the
221 consumption of significantly less calories (WMD=-80.4 calories: 95% CI:-136.7 to -24.2,

p=0.005, n=486) than when other types of labelling or no labelling were provided (non-significant heterogeneity). Subgroup analyses showed that PACE labelling was more effective than no labelling (WMD=-109.9 calories, 95% CI: -189.6 to -30.2, p=0.007, n=243) but not calorie only labelling (WMD=-51.2 calories, 95% CI: -130.7 to 28.3, p=0.21, n=243). Sensitivity analysis was not conducted because the results above were already based on the two included within-subject studies.

Effects of PACE labelling on the amount of grams of food/beverages consumed (Figure 5)

PACE labelling resulted in the public consuming less grams of food (WMD=-8.3 grams, 95% CI: -14.1 to -2.5, p=0.005, n=1,145) relative to comparators, but with significant heterogeneity (I^2=91%). In a sensitivity analysis excluding within-subject studies and involving two studies of nutritional labelling as the comparator,[25,30] the effect of PACE labelling was increased (WMD=-27.1 grams: 95% CI: -33.8 to -20.4, p<0.00001, n=225) with heterogeneity at 5%. In subgroup analyses PACE labelling was not more effective than no labelling, (p=0.31) but was significantly more effective than nutritional labelling in reducing the amount of food consumed (WMD=-27.1 grams: 95% CI: -33.8 to -20.4, p<0.00001, n=225) with heterogeneity at 5%.

Risk of bias

For most studies we were not able to assess whether risk of bias criteria were met and therefore most studies were considered unclear. Only 2/15 studies clearly stated the generation process for random sequence allocation, 3/15 stated that allocation concealment had occurred, 5/15 blinded participants/study personnel and 2/15 included the blinding of outcome assessments. A total of 2/15 studies met the criteria for reporting complete outcome data and zero studies met the criteria for no reporting bias (selective reporting) and 4/15 were considered free from other biases. See supplementary file 3. The overall the summary

246 evidence according to GRADE[31] is not reported due to the large number of unclear risk of
247 bias assessments.

248 **Discussion**

249 PACE labelling shows some promise in reducing the number of kilocalories (calories)
250 selected from menus, as well as the number of calories and the amount of food (grams)
251 consumed by the public, relative to comparator food labelling/no labelling. However, the
252 number of studies in the comparisons of PACE labelling with calorie and nutritional labelling
253 for the outcome number of calories/grams of food consumed was small and heterogeneity
254 was present for some comparisons. The trial not included in the meta-analysis also reported
255 PACE labelling decreased the number of purchases of sugar and sweetened beverages.[29]
256 Based on current evidence this systematic review showed that PACE labelling is more
257 effective than no food labelling and other types of food labelling.

258 Our findings are not consistent with the review by Seyedhamzeh,[15] which reported no
259 effect from PACE labelling on the number of calories selected from menus. However, the
260 previous review included only a small number of low quality trials and did not assess the
261 number of calories consumed or purchased. We were able to include 15 trials of varying
262 quality. Most of the evidence has been from laboratory settings or hypothetical meal
263 selection scenarios but it is possible that the effects of PACE food labelling may vary
264 according to context (e.g. restaurants & supermarkets) and/or eating occasions (e.g. snacks
265 versus meals). Future research should investigate the effects of PACE labelling in more real
266 life or naturalistic settings. Real life studies would introduce variables that are not present
267 during hypothetical studies (e.g. marketing, price, time constraints).

268 Evidence indicates that even a small decrease in calorie intake and increases in
269 physical activity that are sustained are likely to be beneficial for health.[32-34] Regular over
270 consumption of a small amount of calories lead to overweight/obesity; evidence suggests that

271 if the population decreased consumption by as little as ~100 calories per day, population
272 obesity could be prevented,[32] This review has reported that PACE food labelling may have
273 the potential to help people to achieve this goal. Most people eat three meals per day (plus
274 two snacks); based on our findings for the number of calories consumed after exposure to
275 PACE labelling (-65 calories), PACE labelling could potentially reduce calorie intake by up
276 to 195 calories per day (-65x3 meals per day=~195 calories), although across repeated
277 meals/snacks and over time this effect is likely to be reduced. PACE labelling is a simple
278 strategy that could be easily included on food/beverage packaging by manufacturers, on
279 shelving price labels in supermarkets and/or on menus in restaurants/fast food outlets. When
280 a consumer sees a visual symbol that denotes it will take four hours to walk off a pizza and
281 only 15 minutes to burn off a salad, this in theory should create an awareness of the 'energy
282 cost' of food/drink.

283 In the absence of international agreements, there is considerable variation in the
284 information provided and the presentation format for nutritional labelling, which may lead to
285 confusion amongst consumers. PACE labelling could be a simple universal method by which
286 policy makers around the world unite to reduce energy consumption and encourage the
287 population to be more active. Gains in public health are unlikely to be made unless decisions
288 are taken in favour of food labels that can actually improve the ability of the public to
289 differentiate products according to their calorie contribution. Our findings are consistent with
290 previous studies reporting that this improvement is most likely to occur with the use of
291 contextual or interpretive food labels.[35] A further benefit of PACE food labelling is that it
292 may encourage restaurants and retailers to alter the range of products available and encourage
293 the whole food industry and supply chain to reduce portion sizes and/or reformulate food
294 products to contain fewer calories so they meet government calorie reduction targets, in a
295 similar way to the sugar tax.[36]

296 This study has several methodological strengths. PACE labelling is a relatively new
297 concept and as such there are limited data testing the merits of this approach with the public.
298 To our knowledge this is the first meta-analysis to summarise evidence regarding the effects
299 of PACE labelling on food/beverage consumption. We searched widely for evidence in
300 diverse fields including social media platforms. Two independent reviewers selected studies,
301 extracted data and assessed study quality, thus reducing the potential for error and bias. The
302 included studies that assessed food/drink consumption weighed the amount of food
303 eaten/drunk by participants, rather than rely on self-reported accounts. Similarly, Bleich
304 reported the number of purchases of SSB, not self-reported recall.[29] The main analysis was
305 based on a large number of participants (n=4,606).
306 This study should also be interpreted in light of some methodological limitations. It
307 was difficult to assess the risk of bias in most studies because information to allow such
308 assessment was not reported in trials. The only criteria that was clearly reported in studies
309 related to 'other bias'. For this criteria only 4/15 studies were considered free of other bias
310 highlighting that data from this review should to be interpreted with some caution.
311 Heterogeneity was high for some comparisons and was not explained by subgroups analyses.
312 It is possible the observed heterogeneity is due to the variability in the types of studies
313 designs used, the different types of PACE messages tested (e.g. miles versus minutes), and
314 the populations recruited. This would be an important question for future research as more
315 evidence becomes available to allow such analyses to be conducted. It is not clear from the
316 current evidence what the long(er) term impact of PACE labelling might be on consumption
317 patterns, therefore studies that include assessments over time are needed. One of the
318 additional benefits of PACE labelling over other types of food labelling is that is has the
319 potential to encourage the population to engage in regular physical activity. We were not
320 able to assess the effects of PACE labelling on future physical activity behaviour due to a

lack of data; this should be a priority for future research. As most of the included studies adopted hypothetical eating methodologies/scenarios this research constitutes evidence of efficacy rather than effectiveness. The first trial to examine the effects of PACE food labelling was published in 2012,[29] Thus, we felt that the infancy of this research question warranted the inclusion of as much of the randomised evidence as possible, regardless of study design, but longer RCTs in naturalistic settings are required.

Conclusion

PACE food labelling may reduce the number calories selected from menus and decrease the number of calories/grams of food consumed by the public, compared to other types of food labelling/no labelling. The findings emphasise the potential of easily understood food labels to reduce the calorie intake of the population by facilitating increased selection of lower calorie foods and decreased selection of higher calorie ones.

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Contributions
AD conceived the original idea for the study. AD wrote the protocol with contributions from HMP, SB, AC and EM. AJD wrote the first version of the manuscript with input from all other authors. AD and HMP extracted the data and conducted the analyses. All authors had full access to the data, take responsibility for the integrity of the data and the accuracy of the data analysis, contributed to the interpretation of the results, and reviewed and approved the final manuscript. AD is the guarantor. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Competing Interest
None declared.

Data sharing:
Data from this study are available from the corresponding author at a.daley@lboro.ac.uk. The study protocol is available from the PROSPERO website (registration number: CRD42018088567). All requests for data access will need to specify the planned use of data and requests will require approval from the study team prior to release.

Transparency:
The guarantor (AD) affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained. The manuscript follows the PRISMA guidelines for the reporting of systematic reviews.

Ethics approval: None required
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