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Restricting promotions of 'less healthy' foods and beverages by price and location: A big data application of UK Nutrient Profiling Models to a retail product dataset

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Abstract

The UK government plans to limit price-based and location-based promotions for products high in saturated fat, salt and sugars. The 2004/2005 UK Nutrient Profiling Model (NPM) is the proposed legislative basis, but may be superseded by the draft 2018 NPM. This study develops an algorithm to apply both NPMs to a large food composition database (FCDB), and assesses implementation challenges. UK NPMs were applied algorithmically to the *myfood24* FCDB, representing ~45 000 retail products. Pass rates – indicating free or restricted promotions – and micronutrient compositions were compared. Challenges were assessed, and recommendations addressed the legislation's public consultation questions. For products in scope (75% of total), 6% fewer passed the 2018 NPM (36%, $P < 0.001$) compared with the 2004/2005 NPM (42%). Beverages showed the greatest reduction in pass rate (75%). Under both models, micronutrient contents (per 100 g of product) were generally lower for products that passed; except folate, vitamin C and vitamin D were no different for passed and failed products. Compared with products passing the 2004/2005 NPM, products passing the 2018 NPM on average had marginally higher amounts of iron (0.05 mg, 95% CI: 0.02, 0.08, $P < 0.001$) and magnesium (1.00 mg, 95% CI: 0.00, 1.17, $P = 0.029$), but marginally lower levels of calcium (−0.42 mg, 95% CI: −2.00, −0.40, $P = 0.025$). Missing ingredient information and heterogeneous product categories were challenges for both NPMs. Free sugars calculation further complicated 2018 NPM application. To balance feasibility and public health benefit, the proposed legislative basis may not be appropriate.

Keywords: food choice, nutrients, nutrition, obesity, public health

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Introduction

Childhood obesity is a growing health concern in the UK (Johnson *et al.* 2015; NHS Digital 2017, 2018) and a focus of the government's public health strategy (HM Government 2018). Obesity can track from childhood to adolescence and adulthood (Clarke & Lauer 1993) increasing the risk of obesity-related comorbidities earlier in life (Ehtisham *et al.* 2000; Haines *et al.* 2007). Caloric overconsumption (PHE 2018b), particularly of foods and beverages high in free sugars (SACN 2015; Roberts *et al.* 2018), is a risk factor for obesity. Restricting the consumption of high-saturated fat, salt and free sugar (HFSS) foods has wider health benefits too, including reduced risk of dental caries (Moynihan 2016), type 2 diabetes (Forouhi *et al.* 2018), cardiovascular disease (Bowen *et al.* 2018) and cancer (WCRF 2018).

The food industry invests substantial sums of money into marketing strategies for processed foods which encourage overconsumption (PHE 2015a). Even small-scale overconsumption resulting from promotional activities will accumulate in weight gain over the life course (Swinburn *et al.* 2004), unless balanced with sufficient physical activity or changes in other dietary behaviours. As a result, food promotions form an important aspect of the obesogenic environment which people in developed societies are exposed to on a daily basis. These promotions are especially effective at targeting children (Carter *et al.* 2011) and may translate to purchasing through 'pester power' (Marshall *et al.* 2020). Therefore, legislative approaches to restrict the promotion of unhealthy foods, particularly to children, are a welcome part of the UK's obesity prevention strategy (HM Government 2018).

Newly proposed legislation aims to improve the in-store food environment and encourage healthier choices by restricting the promotions of less healthy products by location and price. It has been projected that these initiatives could amount to a total of £4.2 billion in savings to the NHS, social care and premature mortality over 25 years (DHSC 2018a, 2018b). Yet the effect of legislation is dependent upon successful implementation. In the short-term, retailers and manufacturers are expected to incur significant costs (DHSC 2018a, 2018b) and proposals have been met with opposition from the food industry (FDF 2019). With retailers set to play a central role in the success of the proposed legislation, we sought to better understand the barriers they face to implementation, and how these might be mitigated. Taking a data science perspective, this study aims algorithmically to apply the UK Nutrient Profiling Model (NPM) to a large product dataset developed by *myfood24* (Carter *et al.* 2016) and explore the challenges to the food industry of implementing this legislation.

Overview of legislation

Current legislation, implemented by the UK's communications regulator Ofcom, prevents the advertisement of unhealthy foods and beverages during children's television programmes and other media, such as non-broadcast and social media (ASA 2017a, 2018). But a new proposal in Chapter 2 of the UK Government's Childhood Obesity Plan will further restrict the marketing of less healthy foods at the point of purchase (HM Government 2018), which is likely to have wider benefits for adults too. Under the proposed legislation, price-based and location-based promotions which encourage consumption of HFSS products (DHSC 2019) will be banned (HM Government 2018). The ban would include multi-buy offers such as 'buy one get one free', and strategic product placement in prime locations such as the checkout and the ends of aisles for less healthy products within legislative scope (HM Government 2018).

Products in scope for legislation

Presently, the legislation remains under consultation; therefore it is unclear to which products promotional restrictions would apply and how the legislation would be implemented in practice. The categorisation of food and beverage products as 'healthier' or 'less healthy' is subjective. NPMs are a set of rules used to categorise foods and beverages according to their relative 'healthiness' based on a variety of nutritional factors (Scarborough *et al.* 2007). A number of NPM approaches exist, including categorical and continuous score-based methods, which may be based on absolute or relative values for single or multiple nutrient components (Lobstein & Davies 2009).

The current 2004/2005 UK NPM, applied by Ofcom for the restriction of food advertisement to children, scores products on seven components: four negative components: energy, total sugars, saturated fat, and sodium, and three beneficial components: fruit, vegetables and nuts, fibre, and protein (DH 2011). This aims to account for micronutrients, which are overlooked by many NPMs, which focus on calorie-contributing macronutrients (Poon *et al.* 2018).

Under the UK NPM, points for positive components are subtracted from points for negative components to derive an overall score which determines whether a product passes (is considered 'healthier' and can be placed anywhere in store and with price-based promotions applied) or fails (is 'less healthy' and subject to restrictions).

Two potential options are proposed for the new legislation to restrict price-based and location-based promotions (DHSC 2019). Option 1 states that all HFSS products (failing the UK NPM), which are included in Public Health England's (PHE) reformulation programmes or the Soft Drinks Industry Levy (SDIL), would be liable for promotional restrictions. Option 2 looks to explore alternatives, such as permitting up to 20% of promotions to be for HFSS products. The government's response to comments received during the consultation on these proposals and future plans have yet to be published (but are expected before the end of 2020), making this paper a timely contribution to discussions of implementation feasibility which we hope will shape legislative decision-making. To this end, the analysis in this paper is pragmatically based on products deemed in scope according to Option 1 of the proposal.

However, the current 2004/2005 NPM may be imminently superseded by the new draft 2018 NPM (PHE 2018a) which accounts for recent changes to UK nutritional recommendations. Reduction in the reference intake for sugar, a switch in focus from total to free sugars, and an increase in the reference intake for dietary fibre result in a stricter model overall, under which around 8% fewer products are expected to pass (PHE 2018a). Although the draft 2018 NPM (which has yet to be adopted) was designed specifically for the restriction of advertisements to children, there is speculation of the potential for its wider use, as industry stakeholders question the co-existence of two UK NPMs (Jenneson & Morris 2020). This paper explores the hypothetical scenario of applying the draft 2018 NPM as the basis for price-based and location-based promotional restrictions, which may produce greater public health impacts. Given the draft status of the new NPM, this study is timely in its exploration of what changes to the UK NPM could mean for wider policy.

Currently, the governing of food advertisements to children requires application of the 2004/2005 NPM on a case-by-case basis for products being specifically advertised to children or during prime-time viewing (ASA 2017b). Yet, adoption of the UK NPM as the legislative basis for price-based and location-based promotional restrictions would require retailers to apply the NPM across their full product portfolios, to maintain compliant store layouts. While some food businesses routinely assess their whole product portfolios against the UK NPM, this practice is not commonplace (Jenneson & Morris 2020). Due to the quality and completeness of data available to food retailers (Jenneson & Morris 2020), the need for wide-scale application of the UK NPM within the current retail data landscape is likely to pose significant challenges, not least the need for scalable automation.

These challenges must be overcome to ensure legislative compliance and to better understand the implications from both a retail and public health perspective. While the proposed legislation aims to alter customer purchase behaviours, it is likely to have wide-reaching business consequences. These include changes to store layouts, retailer promotional activities, product innovation, reformulation and portfolio changes, which may all affect revenue and supplier contracts, with knock-on cost implications for manufacturers. Additionally, automatic application of the UK NPM to retailer product portfolios could provide a valuable contribution to the growing body of work utilising supermarket transaction records in population dietary research (Tin *et al*. 2007).

This paper will explore the feasibility of applying the current and draft UK NPMs as the basis for restricting in-store food and beverage marketing. The challenge of data availability and automation capacity to enable scalability will be explored to aid understanding of where responsibility for implementation should lie, with retailers or with manufacturers. The paper addresses two key objectives, with aligned hypotheses.

Objectives

Objective 1: To assess the real-world challenges to retailers, of portfolio-wide identification of products in scope for price-based and location-based promotional restrictions, and to assess implementation of the 2004/2005 and draft 2018 UK NPMs by applying each algorithmically to the *myfood24* food composition database (FCDB) (Carter *et al*. 2016).

Hypothesis: The proposed legislation poses significant real-world challenges associated with the large-scale assessment of legislative scope and implementation of the UK NPM, and these challenges will be greatest for the draft 2018 NPM.

Objective 2: To compare the performance of each NPM by comparing pass rates and the micronutrient compositions of compliant products.

Hypothesis: There will be a difference in pass rates between the two NPMs, and products passing the NPMs will have higher micronutrient quantities than products that fail.

Methods

Algorithm development and statistical analysis was conducted in R statistical software version 3.4.3; code is available to view online at https://github.com/VickiJenneson/NPM_Promotional_Restrictions

Description of the myfood24 dataset

This research uses product nutritional data from an electronic FCDB developed in 2016 for *myfood24*, a UK online dietary assessment tool. The *myfood24* FCDB is described in more detail elsewhere (Carter *et al.* 2016), but briefly it contains information on 120 macro- and micronutrients for a convenience sample of more than 45 000 generic and branded food and beverage items from McCance and Widdowson (PHE 2015b), a commercial branded product database, and own-brand product data from a leading UK retailer.

Retail product nutritional information typically contains data for only the seven mandatory back of pack (BOP) nutrients (energy, fat, saturated fat, carbohydrate, sugars, protein and salt) (DH 2016) , and the optional addition of fibre. With the exception of salt, the BOP focuses on calorie-contributing macronutrients, downplaying the contribution of micronutrients to dietary quality (WHO 2019). Uniquely, the *myfood24* FCDB offers a more comprehensive product nutritional breakdown than BOP information, thanks to semi-automated mapping (Carter et al. 2016) to UK food composition tables (PHE 2015b).

While the *myfood24* FCDB is not used by retailers in practice, for the purposes of this study it represents a retailer's product portfolio. For comparability with the scale of the task faced by retailers, duplicate products (by brand, flavour variant or packaging format) were not removed. The additional nutrient coverage enables assessment of NPMs from a micronutrient perspective of dietary quality, which was not previously included in the NPM review (PHE 2018a). The data items and product categories found in the *myfood24* FCDB are outlined in Appendices S1 and S2.

Identifying products in legislative scope

Products in scope for promotional restrictions were determined according to Option 1 in the legislative proposal (DHSC 2019); that is, they are eligible for the PHE calorie or sugar reduction programmes or the SDIL. *myfood24* FCDB product categories were mapped to categories defined under the PHE calorie and sugar reduction programmes, to identify products in scope for legislation. It was not possible to match categories exactly due to differences in the granularity of categorisation approaches. For example, the FCDB 'dairy and eggs' category included ice creams, yogurts and fromage frais, which are within scope for sugar reduction, as well as plain unsweetened milk and egg products which are outside of scope. To avoid disaggregating the broad FCDB categories, where a category in the FCDB contained some foods within scope of PHE sugar and calorie reduction, the whole category was determined in scope. This approach prioritised sensitivity over specificity; inclusion of some out of scope products is tolerated to minimise the exclusion of in-scope products. FCDB categories which did not map onto any of the PHE calorie and sugar reduction categories were deemed out of scope and removed from the FCDB.

Beverages in scope were identified using SDIL criteria (HMRC 2018), containing added sugars (excluding sugars from fruit and vegetable juices or milk), with a total sugar content at least 5 g per 100 ml and less than 75% milk. An R script was developed, employing text matching to identify added sugar keywords in the product description and ingredients fields. Keywords for added sugars were based on guidance in the 2018 review of the UK NPM (honey, syrup, nectar, glucose, fructose and sucrose) (PHE 2018a) . To minimise misclassification, 'sugar' was considered indicative of added sugar only if it was found in the ingredients list, as it is commonly included in the context of 'zero sugar' or alike in the product description.

Total lactose and galactose, as a proportion of total sugars, were a proxy for milk proportion to exclude products with a milk sugar content over 75% of total sugars. Although milk alternatives such as soya or almond milk are not liable for the SDIL provided they meet certain qualifications (HMRC 2018), these could not be reliably identified in an automated manner for exclusion. Product volume expressed in millilitres was considered equivalent to its weight in grams; specific gravity conversions were not applied. Alcoholic beverages and non-alcoholic beverages not liable for the SDIL were excluded from the FCDB.

Table 1 Scoring criteria for UK Nutrient Profiling Model (NPM) 2004/2005 and draft 2018 NPM (PHE 2018a)

		UK NPM 2004/2005							Draft 2018 NPM						
		'A' points				'C' points			'A' points				'C' points		
		Energy kJ (kcal) 8950 kJ (2130 kcal)	Saturated fat (g) 11% food energy	Total sugars (g) 21% food energy	Sodium (mg) 2400 mg	Protein (g) 42 g	FVN (%) 400 g	Fibre (AOAC; g) 24 g	Energy kJ (kcal) 8400 kJ (2000 kcal)	Saturated fat (g) 11% food energy	Free sugars (g) 5% dietary energy	Salt (g) 6 g	Protein (g) 42 g	FVN (%) 400 g	Fibre (AOAC; g) 30 g
0	≤	335	1	4.5	90	1.6	40	0.9	315	0.9	0.9	0.2	1.6	40	0.7
1	>	335	1	4.5	90	1.6	40	0.9	315	0.9	0.9	0.2	1.6	40	0.7
2	>	670	2	9	180	3.2	60	1.9	630	1.9	1.9	0.5	3.2	60	1.4
3	>	1005	3	13.5	270	4.8	–	2.8	945	2.8	2.8	0.7	4.8	–	2.2
4	>	1340	4	18	360	6.4	–	3.7	1260	3.7	3.7	0.9	6.4	–	2.9
5	>	1675	5	22.5	450	8	80	4.5	1575	4.7	4.6	1.1	8	80	3.6
6	>	2010	6	27	540	–	–	–	1890	5.6	5.6	1.4	–	–	4.3
7	>	2345	7	31	630	–	–	–	2205	6.6	6.5	1.6	–	–	5.0
8	>	2680	8	36	720	–	–	–	2520	7.5	7.4	1.8	–	–	5.8
9	>	3015	9	40	810	–	–	–	2835	8.4	8.3	2.0	–	–	–
10	>	3350	10	45	900	–	–	–	3150	9.4	9.3	2.3	–	–	–

FVN, fruit, vegetables and nuts.

2018 Nutrient Profiling Models scoring criteria

Scoring criteria for the draft 2018 NPM (Table 1) were taken from the review of UK NPM (PHE 2018a). A change in scoring bands for energy reflected a reduction in the daily energy base from 2133 to 2000 kcal, maintaining a one-point increment for every 3.75% of total daily energy contributed by the product, as per the current model (DH 2011). The reduction in the energy base translated to a reduction in the scoring bands for saturated fat (maintaining 11% of food energy) and free sugars (5% of food energy), which replaced total sugars (21% of food energy). Scoring bands for sodium (g) remained equivalent to the current model but were multiplied by 2.5 to express as salt (g). Finally, fibre scoring bands were adjusted to reflect an increase in the recommended daily intake from 24 to 30 g AOAC fibre, enabling a maximum of eight points to be awarded for fibre, replacing the previous maximum of five points.

Applying Nutrient Profiling Models to products in scope

An R script was developed to apply scoring criteria for the 2004/2005 and 2018 NPMs to 'in-scope' products in the FCDB. The final NPM score was calculated by subtracting 'C' points for positive components (percentage of fruit, vegetables and nuts combined, fibre, and protein) from 'A' points for negative components (energy, saturated fat, sugar and salt). Where a product scores 11 or more 'A' points, no points were awarded for protein unless a score of five or more was also received for fruit, vegetables and nuts. As such, a higher overall score indicates a less healthy product.

Fruit and vegetables percentage was available for 92% of products in the FCDB and determined using product websites and mapping to their closest equivalent in UK Food Tables (PHE 2015b) using FSA Food Portion Sizes (Nelson *et al.* 1997). Missing values for fruit and vegetables percentage were assumed to be zero. Nut percentage was unavailable and could not be determined from the ingredients list due to high levels of missing data and lack of quantity information (33% of the total FCDB had missing ingredient information). For products expected to have a high nut percentage [*i.e.* those categorised as 'fruit and vegetables' (capturing whole nuts) or 'home baking, jam and spreads' (capturing peanut butter)] which contained the word 'nut' in the product description, nut content was coded as 100%. For all other products, nut content was expected to be low and coded zero. Where total fruit, vegetable and nut percentage was greater than 100, such as mixed dried fruit and nuts in the fruit and vegetable category, this was recoded to 100%.

As free sugars were defined after the development of the *myfood24* FCDB (Carter *et al.* 2016), resulting from a review of UK dietary recommendations for sugar (SACN 2015; Swan *et al.* 2018), quantity was unavailable in the FCDB. To apply the 2018 NPM, an R script was developed to determine the presence of added sugars by identifying keywords in the product description and ingredients field (honey, syrup, nectar, glucose, fructose, sucrose, sugar, juice, puree). The premise was to automate the free sugars decision tree found in the appendix of the 2018 review of the UK NPM (PHE 2018a).

Where a product was identified as containing free sugars, a value estimate was assigned based on product type (identified using string matching) under assumptions from the 2018 review of the UK NPM (PHE 2018a) (summarised in Appendix S3). Where foods were deemed not to contain any free sugars, content was coded zero. Total sugars were considered free sugars for all non-dairy drinks. For dairy drinks containing added or other sugars, free sugars were estimated as 50% of total sugars, based on guidance for calculating free sugars in chocolate milk (PHE 2018a). For all other dairy drinks without added or other sugars, free sugars were coded zero.

Total score was calculated for both NPMs using 2004/2005 NPM guidance (DH 2011). Foods scoring ≥4 points and drinks scoring ≥1 point failed the NPM and were considered liable for promotional restrictions by location and price (DHSC 2019).

Comparing products compliant under 2004/2005 and draft 2018 UK Nutrient Profiling Models

To understand whether the chosen NPM has a significant impact on which products may be eligible for promotion, the number of products passing each of the 2004/2005 and 2018 NPMs is compared at a category level, using Pearson's chi-squared test for independence at the 95% significance level. Agreement between the models was assessed in three domains: percentage inter-rater reliability (absolute agreement), Cohen's kappa statistic, using the 2004/2005 NPM as the reference, and the proportion of products failing the 2004/2005 NPM which also fail under the 2018 NPM.

Further, to assess whether the models account for micronutrient composition as a factor in dietary quality, micronutrient contents (/100 g or /100 ml of product) of those products which pass and fail under each NPM are compared. As no adjustment for specific gravity was made, we assume that 100 ml of liquid is equal to 100 g. Due to bimodality resulting from a high number of zero values, the non-parametric Mann–Whitney *U* test was performed. The difference in medians was assessed for each micronutrient, and the 95% confidence interval computed by bootstrapping, using the percentile method. As the legislation aims to restrict promotions of HFSS products, which are energy dense and nutrient poor, we expect products which pass NPM criteria to have higher micronutrient quantities than products which fail.

Results

Identifying products in legislative scope

In-scope products, eligible for inclusion in the final FCDB, were identified by mapping *myfood24* categories to PHE calorie and sugar reduction programme categories, summarised in Appendices S4 and S5, respectively. Three FCDB categories (oil, fruit and vegetables and alcoholic beverages) were removed as they did not map to any of the PHE reformulation categories. Canned foods did not map directly to any PHE categories but were included given the presence of some in-scope products such as hotdog sausages and desserts in this category. All products in the remaining 16 categories were included in the FCDB. After removing drinks outside the SDIL scope, the final in-scope FCDB included 30 522 products (76% of the total *myfood24* FCDB), of which 814 were drinks.

Applying Nutrient Profiling Models to products in scope

Applying the UK NPMs across a whole product portfolio to determine eligibility for in-store promotional restrictions posed three key challenges: the first of which applies to both NPMs, while the third is unique to the draft 2018 NPM and made it more difficult to apply than the 2004/2005 NPM. Implications of the following challenges are considered later in the discussion section:

(1) Identifying products in scope for promotional restriction legislation
(2) Estimation of combined fruit, vegetables and nuts percentage (FVN%) , to calculate positive 'C' points

Table 2 Number of products which pass and fail under UK Nutrient Profiling Model (NPM) 2004/2005 and draft 2018 NPM

Results of 2004/2005 NPM	Results of draft 2018 NPM		
	Fail	Pass	Total (%)
Fail	10 883	6719	17 602 (57.67)
Pass	8576	4344	12 920 (42.33)
Total (%)	19 459 (63.75)	11 063 (36.25)	30 522 (100.00)

(3) Estimation of free sugars for application of the 2018 NPM

Comparing products compliant under 2004/2005 and draft 2018 UK Nutrient Profiling Models

Of the 30 522 products in the test FCDB, 6 percentage points fewer passed under the draft 2018 NPM (36%) compared with the 2004/2005 NPM (42%; Tables 2 and 3). This translates to an additional 1857 products identified as liable for promotional restrictions under the draft 2018 NPM. The greatest change was seen for beverages, which recorded a 75% reduction in pass rate overall, under the draft 2018 NPM, compared with the current model. Low agreement between models for beverages (absolute = 25%, kappa = 7%) reflects a substantial shift in products which currently pass the 2004/2005 NPM, now failing the stricter draft 2018 NPM. For beverages which failed the 2004/2005 NPM, there was no divergence in agreement, with 100% of these also failing the draft 2018 NPM (Table 3).

Food products also reported an overall reduction in pass rate under the 2018 NPM (−4 percentage points, $P < 0.001$), but at the subcategory level this was only significant for breakfast cereals (−11 percentage points, $P = 0.015$), dairy and eggs (−5 percentage points, P −0.016) and frozen foods (−6 percentage points, $P < 0.001$). An increase in pass rate was reported for cakes and biscuits under the draft 2018 NPM, but this was only small (+3 products, $P = 0.024$; Table 3). Among food subcategories, the percentages of 2004/2005 NPM fails which also failed the 2018 NPM were lowest for fish (26%), canned/tinned foods (28%), frozen foods (31%), bread and grains (32%) and ready meals (35%), indicating that a high proportion of products which failed under the 2004/2005 NPM were deemed to pass the draft 2018 NPM.

Table 3 Number of 'In Scope' ɪ products passing under each Nutrient Profiling Model (NPM), by category

myfood24 FCDB category (*N*)	Description of NPM test dataset category*	*N* in scope (% of total)	2004/2005 NPM Pass, *n* (%)	2018 NPM Pass, *n* (%)	Change in pass rate, *n* (% points)	Difference *P*-value	Absolute agreement %***	Cohen's kappa (%)	% 2004/2005 fails which fail 2018 NPM****
Drinks									
Drinks, Hot (331)	Hot drinks powders and syrups	64 (19)	9 (14)	0 (0)	−9 (−14)	<0.001	14.5	0.1	100
Drinks, Fizzy (483)	Energy drinks, carbonated diet and full sugar non-alcoholic	236 (49)	221 (93)	1 (0.4)	−220 (−92)	N/A**	6.8	0.1	100
Drinks, Fruit juice (1127)	Juices with added sugar; from concentrate and not from concentrate, cordials, smoothies	346 (31)	297 (86)	1 (0.3)	−296 (−85.7)	N/A**	14.5	0.1	100
Drinks, other (597)	Flavoured waters, sports drinks and drink powders	168 (28)	95 (57)	8 (4.8)	−87 (−52.2)	0.030	48	7.4	100
Total drinks (2538)		814 (32)	622 (76)	10 (1)	−612 (−75)	0.164	25	0.7	100
Foods									
Bread and grains (2475)	Breads, pasta, rice, noodles, baked goods	2475 (100)	1901 (77)	1708 (69)	−193 (−8)	0.496	61	1.4	32
Breakfast cereals (740)	Sweet and unsweetened breakfast cereal, muesli, porridge oats	740 (100)	331 (45)	248 (34)	−83 (−11)	0.015	47	−8.9	63
Cakes, biscuits, chocolates and other snacks (6920)	Cakes, sweet and savoury biscuits, chocolate and confectionary, crisps, popcorn, savoury snacks	6920 (100)	498 (7)	501 (7)	3 (0)	0.024	86	−2.8	93
Canned/tinned foods (1370)	Canned fruits and vegetables, fish, meat, desserts	1370 (100)	1091 (80)	977 (71)	−114 (−9)	0.937	62	−0.4	28
Dairy and eggs (3654)	Milk, cheese, yoghurt, cream, ice cream, eggs	3654 (100)	1247 (34)	1058 (29)	−189 (−5)	0.016	58	4.0	72
Fish (511)	Fresh, frozen, raw and cooked fish and seafood	511 (100)	366 (72)	358 (70)	−8 (−2)	0.292	57	−5.1	26
Frozen foods (1594)	Frozen potato products, fish, ready meals, meat, meat alternatives	1594 (100)	1080 (68)	981 (62)	−99 (−6)	<0.001	49	−11.1	31
Homebaking, jams and spreads (1874)	Flour, sugar, icing, dessert preparations, custard, jams, marmalades, honey, savoury pates, spreads	1874 (100)	514 (27)	585 (31)	71 (4)	0.312	59	2.5	69
Meat and poultry (2313)	Raw, cooked, cured meat, offal	2313 (100)	895 (39)	799 (35)	−96 (−4)	0.510	54	1.5	66
Ready meals, quiches, pizza, pasta, soup (3631)	Ready meals, side dishes, deli counter, ready to eat salads, sandwiches	3631 (100)	2596 (71)	2322 (64)	−274 (−7)	0.509	55	−1.1	35

Table -0003 *Continued*

myfood24 FCDB category (N)	Description of NPM test dataset category*	*N* in scope (% of total)	2004/2005 NPM Pass, *n* (%)	2018 NPM Pass, *n* (%)	Change in pass rate, *n* (% points)	Difference *P*-value	Absolute agreement %***	Cohen's kappa (%)	% 2004/2005 fails which fail 2018 NPM****
Sauces and condiments (4004)	Fresh and dry herbs and spices, vinegar, gravy granules, dips	4004 (100)	1500 (37)	1279 (32)	−221 (−5)	0.592	54	−0.9	68
Speciality/ethnic foods (622)	Curry pastes, sides, Yorkshire puddings, fajita kits, olives	622 (100)	279 (45)	237 (38)	−42 (−7)	0.232	54	5.1	64
Total foods		29 708	12 298 (41)	11 053 (37)	−1245 (−4)	<0.001	51	−3.4	61
Total foods & drinks		30 522	12 920 (42)	11 063 (36)	−1857 (−6)	<0.001	50	−4.6	62

FCDB, food composition database.
'Alcoholic drinks', 'fruits and vegetables', and 'oils' categories were excluded as out of scope.
*Category descriptions are not exhaustive.
**Chi-squared test invalids due to small numbers.
***Absolute agreement refers to the inter-rater reliability, expressed as a percentage, with the 2004/2005 NPM as the reference.
****% of products classified as failing the 2004/2005 NPM, which also failed the 2018 NPM.

Micronutrient contents (/100 g, or /100 ml of product) were marginally lower for products that passed compared with those that failed under each NPM, with the exception of folate, for which there was no significant difference between passed and failed products under the 2004/2005 NPM (0.00 μg, 95% CI: 0.00, 1.13, $P = 0.307$) and the draft 2018 NPM (0.80 μg, 95% CI: 0.00, 1.00, $P = 0.477$; Table 4). Compared with products which passed the 2004/2005 NPM, products passing the 2018 NPM, on average, had marginally higher amounts of iron (0.05 mg, 95% CI: 0.02, 0.08, $P < 0.001$) and magnesium (1.00 mg, 95% CI: 0.00, 1.17, $P = 0.029$), but marginally lower quantities of calcium (−0.42 mg, 95% CI: −2.00, −0.40, $P = 0.025$; Table 4). The zinc and vitamin C contents of products that passed the 2004/2005 NPM were significantly different from those which passed the 2018 NPM, but these did not translate to a difference in medians (Table 4).

Discussion

Introduction of in-store price-based and location-based promotional restrictions would see a need for retailers to assess their whole product portfolios against the legislative criteria. Assuming PHE's reformulation categories and the UK NPM are used as the legislative basis, as outlined in Option 1 of the proposal (DHSC 2019), the primary objective of this study was to assess portfolio-wide implementation feasibility from a data perspective. A recent stakeholder consultation by the authors revealed that, presently, retailers rely on case-by-case assessment against the NPM, only for products which might be advertised to children (Jenneson & Morris 2020). Additionally, products are not routinely mapped against PHE reformulation categories in retailer product datasets (Jenneson & Morris 2020). Therefore, scaling up assessment to the whole product portfolio is likely to be extremely time-consuming and prone to human error. Automation is desirable, but as this study demonstrates, is not without its own challenges.

To the authors' knowledge, this study is the first of its kind to attempt automated application of the UK NPM across the *myfood24* FCDB (Carter *et al.* 2016), a large product database containing more than 40 000 products. The *myfood24* FCDB combines BOP data for Tesco own-brand products and branded products from Brandbank, a leading provider of product content for fast-moving consumer goods (FMCG) used by retailers. A strength of the chosen FCDB is the close alignment to retail data availability, enabling assessment of feasibility challenges in a near real-world context. The *myfood24* FCBD is additionally supplemented with micronutrient data from UK food tables (Carter *et al.* 2016). Building upon PHE's review of the NPM (PHE 2018a), this study uniquely compares the performance of the current (2004/2005 UK NPM) and draft 2018 UK NPM from a micronutrient perspective of dietary quality.

The algorithm used to apply the NPMs was developed by a nutritionist (lead author, VJ) and aims to automate the rules outlined in Option 1 of the legislative guidance (DHSC 2019), simulating a hypothetical scenario faced by retailers. As the legislation is yet to be finalised, this study is timely and uniquely positioned to provide insight into the real-world data-related challenges posed by assessing the whole retail product portfolio against the proposed legislative criteria. Three key implementation challenges were identified, which we propose would affect retailers, and thus the potential impact of the legislation, to a similar degree.

The first challenge was identifying products within legislative scope under option 1 of the proposal (DHSC 2019). Based on *product use and storage*, the broad and nutritionally heterogeneous FCDB categories mis-matched with PHE's *nutritionally* defined reformulation categories (PHE 2018b, 2018c). This resulted in the inclusion of a number of out of scope products, such as canned and frozen vegetables. We therefore suggest our finding that up to three quarters of a supermarket's product portfolio may be considered in scope for price-based and location-based promotional restrictions is likely to be a top estimate. As the FCDB categories are akin to those held by retailers (Brinkerhoff *et al.* 2011), this represents a real-world challenge faced by retailers in the application of the legislative proposal (Jenneson & Morris 2020). Alignment of retail and legislative categories would improve retailers' ability to automate large-scale assessment of legislative scope.

Additionally, determining beverages in scope according to SDIL criteria (HMRC 2018) was challenging. Added sugar is not reported on the BOP (current legislation requires total sugars), so the ingredients list was used as a proxy for estimation. However, on-pack ingredients data were missing at random for 33% of products, hindering estimation, and are likely to have erroneously excluded some in-scope beverage products. As the FMCG data provider is used by both the FCDB and by retailers, missing data is likely to affect retailers to a similar degree. Misclassifying whether a product falls in or out of scope of the proposed legislation (DHSC 2019) could have financial and trust implications for retailers and unintended consequences for consumers.

The second challenge was estimating FVN%, which hindered the assignment of UK NPM points. Fruit and vegetable percentage values in the *myfood24* FCDB were imputed from generic UK food tables (PHE 2015) by the *myfood24* team. They therefore lack product specificity and are missing for around 8% of products. However, nut percentages were not imputed and FVN weights were unavailable for calculation of NPM points according to published guidance (DH 2011). Stakeholder engagement revealed that the problem of poor data coverage for FVN is shared by retailers and manufacturers (Jenneson & Morris 2020), forcing them to make broad estimation assumptions. We acknowledge that nut estimation in this study is imperfect as it assumes that nut products contain no other ingredients, overestimating their nut content, but fails to account for nuts in composite dishes. Further work is needed to improve the accuracy of FVN% estimation at scale, which could utilise other data sources available to retailers and manufacturers, such as allergen declarations and product specifications.

We also anticipate that calculation of fibre points could be problematic for retailers, given that declaration of fibre content is not a legal requirement (it is voluntary BOP and cannot be included in the FOP declaration), meaning that some contributions to fibre may not be declared on pack (DH 2016). However, due to supplementation of the *myfood24* FCDB with data from UK food tables (McCance & Widdowson 2002; Carter *et al.* 2016), the dataset is relatively complete for fibre and did not pose a problem in this study.

The third implementation challenge was estimating free sugars, for the draft 2018 NPM. As free sugars are not present on the BOP (the legal requirement is for total sugars), they were estimated based on broad assumptions established by PHE (PHE 2018a), according to product type and the presence of sugar keywords in the product description or ingredients list. For example, for dairy drinks containing other sugars, free sugars were coded as 50%, based on guidance for estimating free sugar content in chocolate milk, though this assumption may not be accurate for all products. However, missing ingredient information (33% of total products) and related quantities likely resulted in a large number of products being wrongly classified as containing no free sugars, overinflating the pass rate. Missing data is likely to affect retailer

Table 4 Comparison of micronutrient contents

Micronutrient	Median (/100 g or /100 ml of product)				Difference in medians (95% CI), *P*-value from Mann–Whitney *U* test		
	Pass 2018	Fail 2018	Pass 2004/2005	Fail 2004/2005	Pass 2018 – Fail 2018	Pass 2004/2005 – Fail 2004/2005	Pass 2018 – Pass 2004/2005
Iron (mg)	0.80	1.01	0.75	1.09	-0.21 (−0.24, −0.20) $P < 0.001$	-0.34 (−0.38, −0.31) $P < 0.001$	0.05 (0.02, 0.08) $P < 0.001$
Calcium (mg)	25.00	52.00	25.42	56.03	−27.00 (−30.00, −25.97) $P < 0.001$	−30.61 (−33.00, −28.00) $P < 0.001$	−0.42 (−2.00, −0.40) $P = 0.025$
Potassium (mg)	171.50	173.00	170.00	174.00	−1.50 (−4.00, 4.53) $P < 0.001$	−4.00 (−8.00, −2.68) $P < 0.001$	1.50 (−0.81, 5.00) $P = 0.211$
Magnesium (mg)	18.00	19.00	17.00	19.40	−1.00 (−2.00, −1.00) $P < 0.001$	−2.40 (−3.10, −1.37) $P < 0.001$	1.00 (0.00, 1.17) $P = 0.029$
Zinc (mg)	0.50	0.60	0.50	0.70	−0.10 (−0.11, −0.10) $P < 0.001$	−0.20 (−0.20, 0.17) $P < 0.001$	0.00 (0.00, 0.00) $P = 0.007$
Retinol equivalents (µg)	1.50	5.00	1.53	5.00	−3.50 (−5.00, −2.00) $P < 0.001$	−3.47 (−5.95, −3.00) $P < 0.001$	−0.03 (−1.00, 1.00) $P = 0.874$
Vitamin C (mg)	0.00	0.00	0.00	0.00	0.00 (0.00, 0.00) $P < 0.001$	0.00 (0.00, 0.00) $P < 0.001$	0.00 (0.00, 0.00) $P = 0.019$
Vitamin D (µg)	0.00	0.00	0.00	0.00	0.00 (0.00, 0.00) $P < 0.001$	0.00 (0.00, 0.00) $P < 0.001$	0.00 (0.00, 0.00) $P = 0.340$
Vitamin E (mg)	0.12	0.51	0.13	0.52	−0.39 (−0.41, −0.37) $P < 0.001$	−0.39 (−0.43, −0.38) $P < 0.001$	−0.01 (−0.02, 0.1) $P = 0.266$
Folate (µg)	7.80	7.00	7.00	7.00	0.80 (0.00, 1.00) $P = 0.477$	0.00 (0.00, 0.13) $P = 0.307$	0.80 (0.00, 1.00) $P = 0.862$

databases to a similar extent. Removal of products with missing ingredient information may have improved the accuracy of NPM scores, but this could not be assessed. Furthermore, it is likely to systematically exclude products from smaller manufacturers and would not represent the real-world problem faced by retailers.

The secondary objective of this study was to compare the performance of the 2004/2005 NPM and the draft 2018 NPM in terms of pass rate and micronutrient composition. As we hypothesised, there was a difference in pass rate under the two models. In line with findings from the recent NPM review (PHE 2018a), we found the draft 2018 NPM (36% of in-scope products passed) to be more restrictive than the current model (42% of in-scope products passed). This translates to 43% and 48% of the retailer's total product portfolio eligible for promotional restrictions under the 2004/2005 and 2018 NPMs, respectively, a significant proportion of retailer's shelf space. However, the magnitude of the difference between the models (six percentage points) was not as great as that observed in the PHE review (eight percentage points) (PHE 2018a).

Characteristics of the product datasets used may explain differences in findings to some extent. The FCDB used in this study (n = 30 522 products) was restricted to product categories in scope for PHE calorie and sugar reduction (PHE 2018b, 2018c) and the SDIL (HMRC 2018). Yet the test FCDB in the 2018 review (PHE 2018a) contained a much smaller sample (n = 2620) of products commonly consumed by children, across all categories and had duplicate products removed. The FCDB in this study was developed in 2016, so does not capture products on the market at the time of writing. Additionally, it retains duplicates and represents all products in scope, regardless of consumption frequency and inclusive of products consumed predominantly by adults. It therefore better represents a full retailer product portfolio to offer an impression of the real-world challenges of implementing the proposed legislation.

Assigned pass/fail labels are subject to the previously described challenges, which translated to errors borne by the assumptions of the algorithmic models. We do not anticipate NPM scores calculated in this study to necessarily represent 'truth'. Instead, they provide a best estimate given the constraints of BOP product data, representing a hypothetical real-world scenario in which retailers must assess their whole product portfolios. The poor level of agreement between the NPMs shows that the models came to different conclusions about whether products should pass or fail. For example, there was a small increase in the number of cake and biscuit products passing the draft 2018 NPM, compared with the 2004/2005 NPM.

Additionally, for a number of food categories (including breads and grains, ready meals, and frozen foods), a large proportion of products which failed the 2004/2005 NPM were deemed to pass the 2018 NPM (indicated in the final column in Table 3). This finding opposes the purpose of revisions, which was to restrict the number of products high in sugar passing the UK NPM (PHE 2018a). We conclude that these unexpected findings are likely to result from errors in estimating free sugars content, resulting in underestimation of the NPM score. In line with findings from the PHE review (PHE 2018a), the new NPM was significantly more restrictive for drinks. We propose that the simpler process for estimating free sugars for beverages, than for foods, represented in the free sugars decision tree (PHE 2018a), resulted in less misclassification error. It should also be noted that product numbers were small in some beverage categories.

Uniquely, this study assessed NPM performance from a micronutrient perspective. We hypothesised that for both models, products which passed ('healthier') should have higher distributions of micronutrients per 100 g than those which failed ('less healthy'). However, for the majority of micronutrients, the opposite was true. This may be due to the high proportion of micronutrient-rich dairy and meat products which fail under both models. Or, it may be an artefact of challenges in FVN estimation; resulting in micronutrient-rich products incorrectly failing the model. Additionally, the high number of zero values for micronutrients in the FCDB represents both true zeros and unknown values from The Composition of Foods integrated dataset (McCance & Widdowson 2002; Carter *et al.* 2016) and is likely to have artificially skewed the results to the left, underestimating true medians and masking true differences.

While the proposed changes to the NPM are likely to be beneficial in improving the energy and macronutrient profiles of promoted products, this study suggests that amends may be detrimental from a micronutrient perspective of healthiness, as micronutrient-rich foods failing the NPM would be ineligible for promotion. Yet, a more in-depth review of the impacts of changes to the NPM from a micronutrient perspective, using the SAIN, LIM model for example (Darmon *et al.* 2019), is warranted. For the majority of micronutrients assessed by this study, there was no significant difference in their distributions between products which passed under the 2004/2005 NPM, and with those which passed the draft 2018 NPM. However, the calcium profile of products passing the draft 2018 NPM was significantly lower than for those passing the 2004/2005 NPM, which may be the result of a reduction in the pass rate of calcium-rich dairy products under the new model, due to added sugars. However, this difference is very small and, without data on typical consumption patterns, we cannot understand to what extent this finding is significant in the context of dietary intake.

Our findings suggest the current data landscape restricts retailers' abilities to automate accurate application of the UK NPM across their whole product portfolios, as the basis for in-store promotional restrictions. Resultant errors in the classification of products in scope and calculated NPM scores would lead to poor legislative compliance, reducing policy effectiveness and putting retailers at risk of penalties and loss of consumer trust. We anticipate that product specifications, held by manufacturers, may hold sufficient product level detail to improve NPM score estimates. However, collaboration between manufacturers and retailers would be required to bridge the gap between responsibility and data availability.

As we hypothesised, in the light of data availability, the 2004/2005 NPM is the more pragmatic choice of the two models assessed. The additional challenge of calculating free sugars required for application of the 2018 NPM introduces uncertainty into the model outcomes. Conversely, findings suggest that, the 2018 NPM promises greater restriction of soft drink promotions, a current topic of public health concern, reflected in the recent introduction of a 'sugar tax' in the UK (HMRC 2018). However, given the data available to retailers, we support the consideration of other approaches to define the scope of legislation to restrict in-store food promotions.

Affecting such a large proportion of the retailer's portfolio, the proposed legislation (DHSC 2019) is likely to have a significant impact on store layouts, contracts with suppliers, revenues and reformulation efforts. However, our analysis does not account for the quantity and frequency of product purchases and therefore cannot predict the extent to which the legislative proposal may translate to meaningful dietary differences at the population or individual level. To illustrate, while 76% of products in the FCDB were considered 'in scope' for legislation, this is expected to translate to only 38% of food sales by volume (DHSC 2019). We suggest that the algorithm generated in this study provides a useful starting point for future work, modelling the impact of in-store promotional restrictions: for retailers – store revenue and layouts; for manufacturers – reformulation and supply contracts; and for public health – accessibility and affordability of 'less healthy' products.

Conclusions

The proposed legislation to restrict price-based and location-based promotions is likely to have a wide-reaching impact across the product portfolio. Automated portfolio-wide application of the UK NPM is required to enable the modelling of potential financial, structural and public health impacts, and to ensure legislative compliance. The algorithm produced for this study is a useful starting point but highlights data availability challenges which introduce inaccuracies into model outcomes.

Within the current data landscape, this study finds the 2004/2005 NPM a more pragmatic basis for the proposed legislation than the draft 2018 NPM. Difficulties in calculating free sugars resulted in misclassification errors under the 2018 NPM, which translated to modest reductions in pass rates and a relatively small proportion of products failing both models in a number of food subcategories. If applied accurately, the 2018 NPM may promote greater public health benefits, particularly around increased restriction of promotions on soft drinks.

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Conflict of interest

Victoria Jenneson and Michelle Morris declare their work in partnership with a national UK retailer. Janet Cade is Director of Dietary Assessment Ltd., and Neil Hancock and Michelle Morris are inventors and shareholders at Dietary Assessment Ltd. and own *myfood24* and the FCDB used in this study.

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