The effectiveness of policies for reducing dietary trans fat: a systematic review of the evidence

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Objective To systematically review evidence for the effectiveness of policies, including self-regulation, aimed at reducing industrially produced trans fatty acids (TFAs) in food.

Methods The Medline, Embase and Cinahl databases were searched to identify peer-reviewed articles examining the effect of TFA policies. In addition, the first 20 pages of Google searches were examined for articles from the grey literature. A study was included if: (i) it was empirical and conducted in a "real-world" setting (i.e. modelling studies were excluded); (ii) it examined a TFA policy involving, for example, labelling, voluntary limits or bans; and (iii) it examined a policy's effect on TFA levels in food, people's diets, blood or breast milk.

Findings Twenty-six articles met the inclusion criteria: 5 involved voluntary self-regulation; 8, labelling alone; 4, labelling and voluntary limits; 5, local bans and 4, national bans. Overall, the TFA content of food decreased with all types of policy intervention. In general, saturated fat levels increased or decreased, depending on the product type, and total fat content remained stable. National and local bans were most effective at eliminating TFAs from the food supply, whereas mandatory TFA labelling and voluntary TFA limits had a varying degree of success, which largely depended on food category.

Conclusion Policies aimed at restricting the TFA content of food were associated with significant reductions in TFA levels, without increasing total fat content. Such policies are feasible, achievable and likely to have an effect on public health.

Abstracts in عربي, 中文, Français, Русский and Español at the end of each article.

Introduction

Trans fatty acids (TFAs) are unsaturated fats found in foods obtained from ruminants, such as dairy products and meat, and in industrially produced partially hydrogenated vegetable oils.[1] Human consumption of naturally occurring TFAs from ruminants is generally low and there is evidence to suggest that it does not adversely affect health.[2] In contrast, consumption of industrially produced partially hydrogenated vegetable oils has been associated with an increased risk of cardiovascular disease, infertility, endometriosis, gallstones, Alzheimer's disease, diabetes and some cancers.[3,4] In the 1960s, following public health campaigns aimed at decreasing the use of animal fats, the food industry began using substantial amounts of partially hydrogenated vegetable oils in processed food.[2] Their use is favoured by industry – and their removal resisted – because: they are cheap; they are semisolid at room temperature, which makes them easier to use in baked products; they have a long shelf-life; and they can withstand repeated heating.[2]

The removal of partially hydrogenated vegetable oils containing industrially produced TFAs from the food supply has been described as one of the most straightforward public health interventions for improving diet and reducing the risk of noncommunicable disease.[2] In fact, the World Health Organization (WHO) has called for the elimination of TFAs from the global food supply.[1] In response to the rise in the prevalence of noncommunicable diseases, of which cardiovascular disease is the most common, the United Nations hosted a high-level meeting on the topic in September 2011. The political declaration that resulted from this meeting led to the development, in consultation with Member States, of a WHO global framework for monitoring noncommunicable diseases. This framework stipulates global indicators and targets for monitoring noncommunicable diseases up to 2025,[5] including a small number of indicators associated with specific time-dependent targets and core indicators that will be monitored but are not linked to specific targets.[5] One core indicator is the "adoption of national policies that virtually eliminate partially hydrogenated vegetable oils in the food supply and replace [them] with polyunsaturated fatty acids".[5]

Although the removal of TFAs from the food supply has been identified as a "best-buy" public health intervention for low- and middle-income countries,[6] WHO Member States that took part in consultations indicated "low (no) support" for including the removal of TFAs as a global monitoring target because of concerns about the feasibility, achievability and public health effect of removing them from the food supply.[7] However, both national and local bans of TFAs in foodstuffs have been implemented throughout the world (Fig. 1), which demonstrates that the removal of TFAs is both feasible and achievable. However, there has never been a systematic review of the effect of TFA policies on the amount of TFAs in the food supply. The aim of this study was to review the evidence surrounding the effectiveness of policies aimed at reducing TFAs in food, including those involving self-regulation.

Methods

A systematic literature search was conducted using the Medline, Embase and Cinahl databases to identify peer-reviewed articles that examined the effect of a TFA policy. In addition, the first 20 pages of Google searches were examined to identify articles from the grey literature. The main search terms were *trans fat* and *policy*. Additional search terms related to trans fat were: *trans fatty acids*, *hydrogenation*, *vanaspati*, *elaidic acid* and *margarine*. Additional search terms related to policy were: *regulation*, *nutrition policy*, *health policy*, *legislation*, *ban*, *intervention*, *labelling*, *law*, *standards* and *restriction*. These terms

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Fig. 1. **Trans fat policies around the world, 2005–2012**

[a] Trans fat labelling was mandatory locally in Hong Kong Special Administrative Region and Taiwan, China.
[b] There were local bans in Albany, Baltimore, Boston, Cleveland, Montgomery, New Jersey, New York City, Philadelphia and Seattle in the United States of America.
[c] There was a state, provincial or territorial ban in British Columbia, Canada; California and Colorado in the United States; and Puerto Rico.

were used as keywords and in free text searches of titles and abstracts, depending on the database being searched. When a Google search identified a TFA policy that had been implemented but whose effects had not been reported online, one of the study authors (SMD) contacted the government department monitoring the ban to ascertain whether or not an evaluation had been conducted.

A study was included in the review if: (i) it was empirical and conducted in a "real-world" setting (i.e. modelling studies of hypothetical policy interventions were excluded); (ii) it examined a TFA policy involving, for example, labelling, voluntary limits or bans; and (iii) it examined a policy's effect on TFA levels in, for example, food, diet, blood or breast milk. We intended to include only articles published after 1990, when evidence of the health effects of TFA consumption first appeared.[8] However, all articles identified were published between 2005 and 2012.

One author (SMD) carried out the initial review of study titles and two authors (SMD and AMT) assessed abstracts using the aforementioned inclusion criteria. The reference lists of the articles were also examined. If the two reviewers disagreed, the full article was reviewed. The main reason for excluding studies was that they did not involve empirical research. The principal reviewer read the full text of 45 articles and subsequently received Google alerts on any new studies that could be included. Ultimately, the review involved 26 studies that were found to meet the inclusion criteria (Fig. 2). Although the majority were published in peer-reviewed journals, four were reported in the grey literature. The quality of the study evidence was ranked from level I (strongest) to level IV (weakest) using a previously published classification that primarily considered study design.[9]

Results

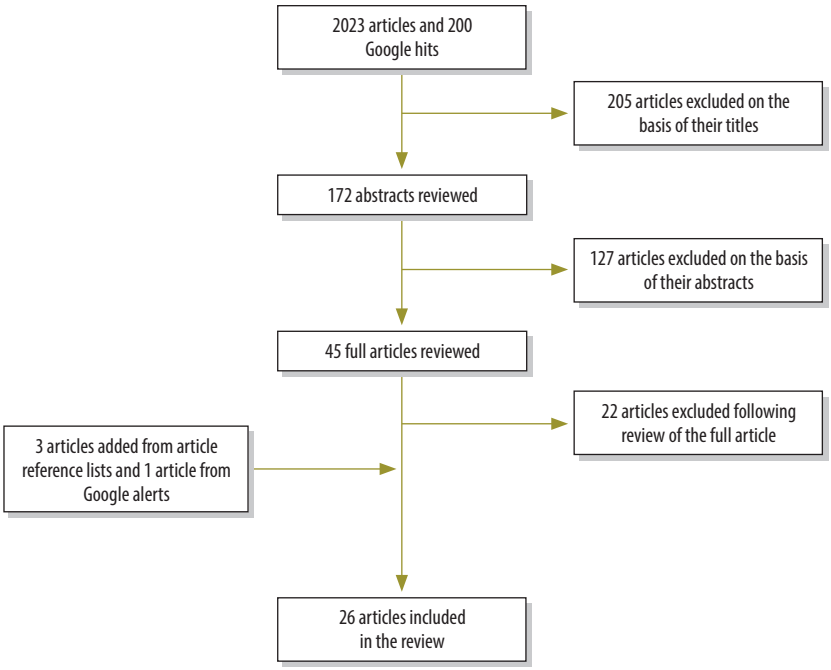
Table 1 (available at: http://www.who.int/bulletin/volumes/91/4/12-111468) lists the relevant results of the 26 studies included in the review, grouped by TFA policy intervention: 5 involved voluntary self-regulation; 8, labelling alone; 4, labelling and voluntary limits; 5, local bans and 4, national bans. The countries covered were Brazil, Canada, Costa Rica, Denmark, the Netherlands, the Republic of Korea and the United States of America. All policy interventions were associated with a reduction in the availability of TFAs. The majority of studies had either a post-test or a pretest–post-test design, both of which provide level-IV evidence. Although only one study used a case–control design, which provides level-III evidence, three other studies compared TFA levels in the study country with levels in other countries, which acted as "pseudo" control groups. Three studies used an interrupted case series design, which provides level-III evidence. Four of the nine studies of TFA bans did not include detailed descriptions of the study methods.[27,29,30,35]

Ten studies examined the formulation of food products before and after the TFA policy intervention. Table 2 gives details of the resulting changes in fatty acid composition. For most products, saturated fatty acid levels did not increase as the TFA level decreased. However, after the intervention the level of saturated fatty acids was higher in specific foods, such as bakery products and popcorn. Mono- and polyunsaturated fatty acid levels generally increased with product reformulation and total fat levels remained relatively constant, with a decrease in the combined level of TFAs and saturated fatty acids.

National bans virtually eliminated TFAs from the food supply (Table 3) and local bans were very successful in removing TFAs from fried foods. The effects of mandatory TFA labelling and voluntary limits were more variable and depended largely on the food category. In particular, changes in TFA levels in margarines and bakery products were smaller in countries without a national ban.

Four studies examined TFA intake before and after TFA policy interventions. Each study used a different measure of intake. In Canada, mandatory TFA labelling combined with voluntary limits was associated with a 35% reduc-

Fig. 2. **Selection of articles for the review of policies designed to reduce trans fatty acids in food, 2005–2012**



tion in TFAs in breast milk[23] and a 30% reduction in dietary intake in the general population.[26] In the United States, mandatory TFA labelling was associated with a 58% reduction in TFA levels in blood plasma.[21] Voluntary self-regulation of TFA levels in the Netherlands was associated with a 20% reduction in dietary intake.[11] Intake was not measured in studies of countries where national bans virtually eliminated TFAs from the food supply or where local bans removed TFAs from fried fast foods.

Two studies examined the relationship between policy interventions aimed at reducing TFA levels in food and health outcomes. Vesper et al.[21] found that mandatory TFA labelling in the United States was associated with a reduction in low-density lipoprotein cholesterol and triglyceride levels and an increase in high-density lipoprotein cholesterol levels. Colón-Ramos et al.[36] examined the effect of voluntary self-regulation in Costa Rica on the risk of myocardial infarction and found a significant association between the risk of myocardial infarction and the level of TFAs in subcutaneous fat before the intervention but not after.

Table 2. **Change in fat composition of foods after trans fatty acid regulation, 2005–2012**

Policy intervention	Study	Change in content after regulation			
		TFA	SFA	MUFA and PUFA	Total fat
Mandatory TFA labelling	Republic of Korea, 2010, Lee et al.[15]	Dec.	Inc. in bakery products	Inc. in restaurant food	Dec.
	USA, 2010, Mozaffarian et al.[19]	Dec.	Inc. in supermarket food; Dec. in restaurant food	Not assessed	Dec. in SFA and TFA combined[a]
	USA, 2012, Van Camp et al.[20]	Dec.	Inc. in bakery products	Inc. in oils high in PUFA and MUFA in potato crisps	No change
Mandatory TFA limit (ban)	USA, 2009, Angell et al.[27]	Dec.	Dec.	Not assessed	Dec. in SFA and TFA combined[a]
	USA, 2012, Angell et al.[28]	Dec	Inc.	Not assessed	Dec. in SFA and TFA combined[a]
Mandatory TFA labelling with voluntary limits	Canada, 2009, Ricciuto et al.[24]	Dec.	No change	Dec. MUFA Inc. PUFA	Dec.[b]
	Canada, 2009, Ratnayake et al.[25]	Dec.	Dec.	Inc.	No change
	Canada, 2009, Ratnayake et al.[26]	Dec.	Inc. in crackers, biscuits, garlic spreads and donuts	Inc.	No change
Voluntary TFA self-regulation	Netherlands, 2011, Temme et al.[11]	Dec.	No change	No change; Dec. in biscuits	No change
	14 countries, 2009, Stender et al.[14]	Dec.	Inc. in popcorn, cakes and biscuits	Inc.	Inc.[b]

Dec, decrease; Inc., increase; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid; TFA, trans fatty acid; USA, United States of America.

[a] When the change in total fat content was not reported in the study, it was calculated by adding together the changes in the content of individual fatty acids; in these cases, the significance of the change was not assessed.

[b] For studies that did not examine monounsaturated and polyunsaturated fatty acid levels, the change in the combined SFA and TFA level is reported.

Table 3. **Foods classified as being free of trans fatty acids (TFAs) after policy interventions, 2005–2012**

Policy intervention	Food category	Percentage classified as TFA-free[a]
National TFA ban	All	Close to 100
Local TFA ban	Fried restaurant food	95–99.5
	Other restaurant food	92–97
	All fast food purchases	59
Mandatory TFA labelling with voluntary limits	Margarines and spreads	0–62
	Bakery products	25–100
	Restaurant food (including restaurants in institutions)	50–100
	All	76
Mandatory TFA labelling	Margarines and spreads	67–79
	Fried restaurant food	80
	Supermarket food	95
	Bakery products	42–77
	Savoury snacks	40–100
Voluntary TFA self-regulation	Restaurant frying oil	45

[a] Studies conducted in the United States of America classified foods with a TFA content < 0.5 g per serving as TFA-free, whereas other countries used a limit of 0.2 g per serving. In Canada, there was the additional requirement that ≤ 15% of dietary energy intake should come from TFAs and saturated fatty acids combined.

Two studies examined the effect of TFA policy interventions on product price.[17,24] Both found a significant negative relationship between price and TFA content in margarines and one found a similar relationship in savoury snacks.

Discussion

The findings of this review show that the policies introduced to decrease TFA levels in the food supply have been effective, regardless of the intervention employed. National and local bans were the most effective. Although significant progress has been made with labelling regulation in countries such as Canada and the United States, TFA levels need to be reduced more, particularly in margarines and bakery products.

Our observation that national and local bans were far more effective than mandatory TFA labelling reflects the Danish Nutrition Council's decision to opt for a ban when considering how to remove TFAs from the food supply.[35] Labelling policies have several limitations. First, TFA intake can remain extremely high in pockets of the population.[26,37] In Canada, even after mandatory labelling led to 76% of foods meeting voluntary TFA limits, intake in the population still exceeded the WHO recommendation that less than 1% of dietary energy intake should come from consuming TFAs. In particular, intake by teenage boys was double the recommended level.[26] Second, some foods with low TFA levels are costlier, which will be felt more by consumers with a low socioeconomic status.[17,24,38] Ricciuto et al.[24] found that some margarine companies in Canada offered products with a low TFA level while continuing to sell products with a high level at a lower price. Thus, price-conscious consumers would be more likely to consume the less healthy product, thereby increasing their risk of diet-related chronic disease.[39] Third, for labelling regulation to be effective, the population must be both aware of TFAs and able to interpret nutrition labels accurately. In high-income countries, where literacy levels are high, labelling is more likely to be effective in reducing TFA intake than in low- and middle-income countries.

Perhaps one of the strongest arguments in favour of mandatory TFA labelling is that it will lead to product reformulation. The impetus for product reformulation often comes from consumers who value and demand products low in TFAs. In countries where awareness of TFAs is low, the food industry may be less likely to reformulate their products. In Brazil, the TFA level in some margarines remained over 50% after regulation,[22] perhaps due to a low level of consumer awareness.

Labelling regulation often applies solely to packaged foods and not foods purchased at restaurants and fast-food outlets. None of the national policies on mandatory TFA labelling investigated by studies included in this review applied to non-packaged food. However, many large fast-food companies do provide information on the TFA content of their foods, either in store or on their web sites. Moreover, in many low- and middle-income countries, the main source of TFAs is food purchased from street vendors and the unorganised food sector rather than pre-packaged food,[2,40,41] which may further limit the effectiveness of labelling regulation.

During consultations on the global framework for monitoring noncommunicable diseases, some WHO Member States indicated that they preferred a voluntary to a mandatory approach to reducing TFAs.[7] Although voluntary regulation may reduce TFA levels in some contexts, mandatory regulation appears to have a greater effect.[42] In New York City in the United States, voluntary regulation was tried first to reduce TFA levels in restaurant food. However, the number of restaurants using partially hydrogenated vegetable oils as frying fats did not decrease and the city banned TFAs in restaurants.[27] Although the Netherlands succeeded in reducing TFAs through voluntary measures and intake is now below the WHO recommended limit, this outcome was regarded by the authors as "typically Dutch" since the country has a long history of resolving social issues through the engagement of and collaboration between various branches of society.[10] Other countries may need mandatory measures to reduce TFA levels in the food supply. Even in countries where there is substantial societal pressure to reduce TFA intake, levels are still high in some foods.[33]

In North and South America, many large multinational companies signed a declaration to help reduce TFAs in food but few have provided data to show their progress towards this goal.[13] However, a voluntary approach may be more effective when the agriculture sector is engaged.[12,43] In particular, making the transition from partially hydrogenated vegetable oils to "healthier" oils may be easier for countries that grow crops producing oils rich in mono- or poly-unsaturated fatty acids. For example, Argentina was able to shift production to high-oleic sunflower oil to aid product reformulation, whereas similar changes may be more difficult in countries such as India that rely heavily on imports.[41,42]

Product reformulation that involves the removal of TFAs from food may simply lead to higher levels of saturated fatty acid, thereby limiting the public health effect of TFA policies. However, our findings indicate that reformulation resulted in the removal of TFAs with little change in saturated fatty acid content in the majority of products; bakery products were an exception. Moreover, the fatty acid profile of many reformulated products improved while the total fat content remained constant. The resulting health benefits may exceed those associated with simply removing TFAs from food.[44]

Nevertheless, all but three studies included in this review were conducted in high-income countries. Many multinational companies have switched sources of fat to reduce TFA levels in products sold in high-income countries but tend to resist making these changes in low- and middle-income countries.[45] Moreover, product reformulation may involve replacing partially hydrogenated vegetable oils with palm oil, which increases the level of saturated fatty acids. For example, recently PepsiCo in India switched the frying oil used in producing Lays potato crisps from rice bran oil to palm oil in an effort to cut costs after previously marketing the product as a "smart snack" cooked in healthier oil.[46] Progress in low- and middle-income countries will have to be monitored to ensure that partially hydrogenated vegetable oils are not replaced exclusively with palm oil, which is cheap, abundant and high in saturated fatty acid. It may be necessary to provide incentives to oil producers and the manufacturers of food products containing TFAs to dissuade them from replacing oils rich in TFAs with palm oil.

The studies that included information on dietary TFA intake or biomarkers showed that all forms of intervention resulted in significant declines. A study conducted in the United States[21] found a 58% reduction in TFA in plasma following mandatory TFA labelling and two Canadian studies observed a 30% decrease in dietary intake[26] and a 35% decrease in TFA in breast milk,[23] respectively, after the introduction of a more restrictive policy. Although these studies are not directly comparable because the outcome measures were different, since the only source of TFA in plasma and breast milk is from dietary intake, the difference is worth noting. However, it is important to be aware that, in both countries, labelling policy was only one factor influencing TFA intake. Twenty per cent of the United States population live in areas covered by a TFA ban,[47] which may help explain why the reduction in plasma TFA was more substantial than the reductions in dietary and breast milk levels observed in Canada, in which only one province, containing approximately 12% of the Canadian population, has a TFA ban.

Political awareness and commitment were important for the success of many of the policy interventions aimed at reducing TFAs in the food supply.[48] Although bans proved to be most effective, many countries, states and cities lack the political will to introduce the necessary legislation. Even when the political commitment is there, the prospect of legislation often provokes resistance from food and agriculture industries. In addition, resistance can sometimes come from within other parts of government as well as from individuals who may hold strong libertarian views. For example, the local government in the city of Cleveland in the United States recently introduced legislation to ban TFAs in food but this was later blocked by the Ohio state government.[47]In response, the city sued the state government and won. When Denmark introduced its ban on TFAs, the country experienced resistance from the European Union, which regarded the legislation as creating a barrier to trade given that all food in the country, including imports, had to abide by the restriction on TFAs.[49] Perhaps unsurprisingly, in the months leading up to the United Nations high-level meeting on noncommunicable diseases, many European countries were "furiously watering down" their commitment to reduce TFA levels in food.[37] Nevertheless, including the removal of TFAs from the food supply as an indicator in the WHO global monitoring framework is an encouraging step towards reducing TFA levels in food worldwide.

Natural experiments lack the strength of controlled experiments, which are frequently infeasible. This makes it difficult, if not impossible, to determine the direct effect of policy interventions on TFA levels in the food supply. The most conclusive studies examine both TFA intake and its effect on health outcomes; unless these specific outcomes are measured, doubt about an intervention's effectiveness often persists. Consequently, some studies in this review were limited because they used compliance with regulations or the TFA level in blood or breast milk as an intermediate outcome and did not examine TFA intake and its associated disease risk. Nevertheless, the studies reviewed generally supported the view that TFA policies can be effective.

Another limitation is that studies examining TFA policy interventions in a "real-world" setting may overestimate the resulting reduction in TFA levels because of sampling limitations: many studies of product reformulation considered only a small number of foods; some studies examined products cross-sectionally rather than testing the same products before and after reformulation; and some examined foods that had already been reformulated.

In addition, the studies in the review were not directly comparable. For example, labelling policy in the United States allows foods with up to 0.5 g TFA per serving to be labelled TFA-free, whereas all other countries included in this review defined TFA-free as less than 0.2 g TFA per serving.[50] Moreover, there are important differences between local and national TFA bans. To date, local bans have focused on foods served in restaurants rather than all foods. Outcomes can also be different. In Denmark, for example, the national ban was applied to all food sold within the country and led to the complete elimination of TFAs from the food supply, whereas in New York City it is still possible to purchase a fast-food meal containing 5 g of TFA despite a local TFA ban.[28]

This review indicates that TFA policies were associated with significant reductions in TFA levels in the food supply: such policies are feasible, achievable and likely to have an effect on public health. Although product reformulation in high-income countries has improved the fatty acid profile of foods, further research is needed in low-resource settings to identify context-specific challenges and policy responses. Moreover, monitoring TFA levels in the food supply is important for ensuring that progress continues, particularly in low-income settings where little information on consumption is available. Encouraging the agriculture sector to increase the supply of suitable alternative oils may facilitate product reformulation. Finally, it is important to note that reducing the TFA content of food is only one component of a multipronged strategy to improve diet and reduce the risk of diet-related chronic disease. ■

Competing interests: None declared.

ملخص

فعالية السياسات الرامية إلى تقليل الدهون المهدرجة في الأنظمة الغذائية: استعراض منهجي للبيّنات

الغرض استعراض بيّنات فعالية السياسات على نحو منهجي، بما في ذلك التنظيم الذاتي، الذي يستهدف تقليل الأحماض الدهنية المهدرجة (TFAs) التي يتم إنتاجها بأساليب صناعية من الأطعمة.

الطريقة تم البحث في قواعد بيانات Medline وEmbase و Cinahl بُغية تحديد المقالات التي تم مراجعتها من قبل النظراء والتي تتناول أثر سياسات الأحماض الدهنية المهدرجة. بالإضافة إلى ذلك، تم دراسة العشرين صفحة الأولى من نتائج البحث في موقع غوغل للبحث عن مقالات الكتابات غير الرسمية. وتم إدراج الدراسة عندما تتوافر فيها الشروط التالية: (1) كانت تجريبية وتم إجراؤها في بيئة "العالم الحقيقي" (تم استبعاد دراسات النمذجة)؛ (2) قامت بدراسة إحدى سياسات الأحماض الدهنية المهدرجة التي تشتمل، على سبيل المثال، على التوسيم أو الحدود الاختيارية أو الحظر الاختياري؛ (3) قامت بدراسة أثر إحدى هذه السياسات على مستويات الأحماض الدهنية المهدرجة في الأطعمة أو الأنظمة الغذائية للأشخاص أو الدم أو لبن الأم.

النتائج توافرت معايير الإدراج في ستة وعشرون مقالاً: اشتمل 5 منها على التنظيم الذاتي الاختياري؛ و8 منها على التوسيم وحده؛ و4 منها على التوسيم والحدود الاختيارية؛ و5 منها على الحظر المحلي و4 منها على الحظر الوطني. وإجمالاً، انخفض محتوى الأغذية من الأحماض الدهنية المهدرجة في جميع أنواع تدخلات السياسة. وبشكل عام، ارتفعت مستويات الدهون المشبعة أو انخفضت، حسب نوع المنتج، وظل إجمالي محتوى الدهون ثابتاً. وكان الحظر الوطني والمحلي أكثر فعالية في استئصال الأحماض الدهنية المهدرجة من إمدادات الأغذية، في حين حظى التوسيم الإجباري للأحماض الدهنية المهدرجة والحدود الاختيارية للأحماض الدهنية المهدرجة بدرجة متباينة من النجاح، والذي اعتمد بشكل كبير على فئة الأغذية.

الاستنتاج ارتبطت السياسات التي استهدفت تقييد محتوى الأغذية من الأحماض الدهنية المهدرجة بانخفاضات كبيرة في مستويات الأحماض الدهنية المهدرجة، دون زيادة إجمالي محتوى الدهون. وتعد هذه السياسات مجدية وقابلة للتحقيق ويُرجح أن يكون لها تأثير على الصحة العمومية.

摘要

减少饮食反式脂肪政策的效果：证据的系统评价

目的 系统评价政策有效性的证据，政策包括自律在内，旨在减少食品中工业生产的反式脂肪酸（TFA）。

方法 搜索Medline、Embase和Cinahl数据库，识别出考查TFA政策影响的同行审阅文章。此外，考查Google的搜索前20 页，查找是否有灰色文献文章。将满足以下条件的研究纳入：(i) 研究以经验为基础并在“现实”环境中执行（即：排除建模研究）；(ii) 研究考查涉及诸如标识、自愿限制或禁令的TFA政策；(iii) 研究考查政策对食品、人们的膳食、血液或母乳TFA水平的影响。

结果 26 篇文章符合纳入标准：5 篇涉及自愿自律；8 篇仅涉及标识；4 篇涉及标签和自愿限制；5 篇涉及地方禁令，4 篇涉及国家禁令。总体而言，食品的TFA含量随各种政策干预有所降低。一般情况下，饱和脂肪含量或增或减，具体取决于产品类型，而脂肪总含量保持稳定。国家和地方禁令对消除食品供应的TFA最有效，而强制性TFA标识和自愿TFA限制取得成功的程度有所不同，这很大程度上取决于食品种类。

结论 旨在限制食物TFA含量的政策与TFA水平显著下降相关，且不增加总脂肪含量。这种政策可行、可实现并可能对公共健康产生效果。

Résumé

Efficacité des politiques de réduction des acides gras trans alimentaires: une revue systématique des données probantes

Objectif Examiner systématiquement la preuve de l'efficacité des politiques, y compris l'autorégulation, visant à réduire les acides gras trans (AGT) industriels dans l'alimentation.

Méthodes Les bases de données Medline, Embase et Cinahl ont été exploitées pour identifier les articles évalués par des pairs, portant sur l'effet des politiques AGT. En outre, on a recherché dans les 20 premières pages de recherches Google des articles de la littérature grise. Une étude était prise en compte si: (i) elle était empirique et conduite dans des conditions «réelles» (c'est-à-dire que les études de modélisation ont été exclues), (ii) elle portait sur une politique AGT impliquant, par exemple, l'étiquetage, les limitations ou interdictions volontaires, et (iii) elle examinait l'effet d'une politique sur les niveaux d'AGT dans les aliments, l'alimentation des personnes, le sang ou le lait maternel.

Résultats Vingt-six articles répondaient aux critères d'inclusion: 5 impliquaient l'autorégulation volontaire, 8 l'étiquetage seul, 4 l'étiquetage et les limitations volontaires, 5 des interdictions locales et 4 des interdictions nationales. Dans l'ensemble, la teneur en AGT des aliments a diminué avec tous les types de politique d'intervention. En général, les niveaux de graisses saturées ont augmenté ou diminué, selon le type de produit, et la teneur totale en matières grasses est restée stable. Les interdictions nationales et locales ont été les plus efficaces dans l'élimination des AGT dans l'approvisionnement alimentaire, alors que l'étiquetage obligatoire AGT et les limitations volontaires ont eu un degré de succès variable, qui dépendait en grande partie de la catégorie des aliments.

Conclusion Les politiques visant à limiter la teneur en AGT des aliments ont été associées à des réductions significatives des niveaux d'AGT, sans augmentation de la teneur totale en graisses. Ces politiques sont faisables, réalisables et susceptibles d'avoir un effet sur la santé publique.

Резюме

Эффективность политики, направленной на сокращение содержания транс-жиров в рационе: систематический обзор данных

Цель Систематический обзор свидетельств эффективности политики, в том числе политики саморегулирования, направленной на снижение содержания транс-жирных кислот (ТЖК) промышленного производства в пищевых продуктах.

Методы В базах данных Medline, Embase и Cinahl был выполнен поиск рецензируемых статей, в которых рассматривается эффективность политики в отношении ТЖК. Кроме того, были исследованы первые 20 страниц результатов поиска Google для выявления статей из малоизвестной литературы. Исследование включалось в объем рассматриваемых материалов, если: (i) оно является эмпирическим и было проведено в реальных условиях (т.е. исследования с моделированием исключались), (ii) оно анализирует политику в отношении ТЖК, связанную, например, с маркировкой, добровольными ограничениями или запретами, и (iii) в нем рассматривается влияние политики на содержание ТЖК в продуктах питания, рационе людей, крови и грудном молоке.

Результаты Критериям включения соответствовали двадцать шесть статей: 5 из них касались добровольного саморегулирования, 8 — только маркировки, 4 — маркировки и добровольных ограничений; 5 — местных запретов и 4 — национальных запретов. В целом, содержание ТЖК в пище снижалось при политическом вмешательстве в любой форме. В большинстве случаев уровень насыщенных жиров увеличивался или снижался в зависимости от типа продукта, а общее содержание жира оставалась стабильным. Национальные и местные запреты оказались наиболее эффективны в устранении ТЖК из продуктов питания, в то время как обязательная маркировка ТЖК и добровольные ограничения уровней ТЖК применялись с переменным успехом, который в значительной мере зависел от категории пищи.

Вывод Политика, направленная на ограничение содержания ТЖК в пище, связана со значительным снижением уровней ТЖК без увеличения общего содержания жира. Такая политика является рациональной, осуществимой и с высокой степенью вероятности оказывает положительное влияние на общественное здравоохранение.

Resumen

La eficacia de las estrategias para reducir las grasas trans en la dieta: examen sistemático de los datos disponibles

Objetivo Examinar sistemáticamente los datos disponibles sobre la eficacia de las estrategias (incluida la autorregulación) dirigidas a reducir los ácidos grasos de tipo trans (AGT) de producción industrial en los alimentos.

Métodos Se examinaron las bases de datos Medline, Embase y Cinahl para identificar artículos revisados por expertos en los que se estudiara el efecto de las estrategias acerca de las grasas trans. Además, también se buscaron artículos de literatura gris en las primeras 20 páginas de resultados de Google. Los estudios se incluyeron cuando: (i) se trataba de un estudio empírico que se desarrolló en un entorno del «mundo real» (esto es, se excluyeron estudios de modelamiento); (ii) se examinaba una estrategia relacionada con los AGT que incluyera, por ejemplo, etiquetado, límites voluntarios o prohibiciones; y (iii) se examinaba el efecto de una estrategia sobre los niveles de AGT en los alimentos, la dieta de las personas, la sangre o la leche materna.

Resultados Veintiséis artículos cumplieron con los criterios de inclusión. De ellos, cinco incluyeron una autorregulación voluntaria; ocho, sólo etiquetado; cuatro, etiquetado y límites voluntarios; cinco, prohibiciones locales y cuatro, prohibiciones nacionales. En su conjunto, todas las estrategias redujeron el nivel de AGT en los alimentos. Por regla general, los niveles de grasas saturadas aumentaron o disminuyeron según el tipo de producto, y el contenido total de grasa permaneció estable. Las prohibiciones locales y nacionales resultaron ser las más eficaces a la hora de eliminar los AGT de los alimentos, mientras que el etiquetado obligatorio y los límites voluntarios obtuvieron resultados variados, dependiendo, en su mayor parte, de la categoría de alimento.

Conclusión Las estrategias dirigidas a la reducción del contenido de AGT en los alimentos estuvieron asociadas a reducciones significativas de los niveles de AGT sin un aumento del contenido total en grasas. Estas estrategias son factibles, viables y pueden tener un efecto sobre la salud pública.

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Table 1. **Studies of policies designed to reduce trans fatty acids (TFAs) in food, 2005–2012**

Study	Study type[a]	Study population or sample	Aim and main outcomes	Relevant results
Voluntary self-regulation				
Netherlands,[b] 2006, Katan et al.[10]	Post-test	Four samples of French fries from Dutch restaurant chains in 2004, one sample of French fries from McDonald's in 2004 in the Netherlands and seven samples from the USA	Aim: to assess the reduction in TFA levels in food after industry initiatives to remove TFAs. Outcomes: TFA levels in fast foods, comparison of TFA levels in French fries in the Netherlands and the USA.	After the introduction of self-regulation, major restaurant chains switched frying oils to meet the agreed limit of 5% TFA content; the level of SFA in oil was also reduced. In 2004, McDonald's French fries in the Netherlands had a TFA content of 4% compared to 21% in the USA; by June 2005, 45% of all fast food outlets were using oils with < 5% TFA content.
Netherlands, 2011, Temme et al.[11]	Pretest–post-test	750 Dutch participants aged 19–30 years	Aim: to estimate the impact of the reformulation of task force food groups by estimating TFA intake in young Dutch individuals. Outcome: usual intake of fatty acids before and after task force activities.	TFA intake: energy intake in the form of TFAs decreased from 1.0% before reformulation to 0.8% after; the contribution of task force foods to TFA consumption declined from 45% to 29%; the decrease in TFAs mainly occurred in pastries, cakes, biscuits and snacks; TFA intake from fats and margarines was unchanged. TFA content: TFA content was 0.3 g per 100 g lower in packaged potatoes used for baking or frying and bread, 0.8 g per 100 g lower in biscuits (i.e. cookies) and 0.6 g per 100 g lower in snacks and salads. SFA: SFA intake did not change. MUFA and PUFA content did not change significantly, with the exception of a slight decrease in PUFA content in biscuits. There was no change in total fat content.
Costa Rica,[c] 2007, Colón-Ramos et al.,[12]	Case–control	1797 case–control pairs from metropolitan Costa Rica, sampled in 1994–1999 (before industrial modification of TFAs) and 2000–2003 (after modification)	Aim: to assess the risk of nonfatal acute myocardial infarction before and after TFA levels in the food supply were reduced. Outcomes: fatty acid levels in subcutaneous adipose tissue samples, responses to a food frequency questionnaire and questions about oil and fat use (the answers were confirmed by visual inspection on home visits)	TFA in adipose tissue: the median values of TFA quintiles were higher in 1994–1999 than 2000–2003. Tissue TFA levels in those who reported using soybean oil decreased over time. Risk of acute myocardial infarction: before self-regulation, the total TFA content in adipose tissue was associated with an increased risk after controlling for several confounders; this relationship was not seen in 2000–2003.
Americas,[d] 2011, Monge-Rajos et al.[13]	Pretest–post-test	Self-reported surveys by corporations ($n = 12$) that had signed the "trans-fat-free Americas" declaration: 3 provided all data requested; the remainder completed only portions of the survey ($n = 3$) or refused to provide data ($n = 6$)	Aim: to assess progress towards the goal of achieving "trans-fat-free Americas". Outcomes: amounts and types of fats and oils used to replace TFAs; current and past (i.e. 2006) TFA amounts in specific foods; description of obstacles to TFA reduction.	In the three companies that provided data, some progress had been made in reducing TFAs, though high quantities remained in biscuits (i.e. cookies), crackers, seasonings and sauces. PepsiCo had virtually eliminated TFAs in biscuits and crackers sold in Mexico and the Caribbean but in North America those products still contained 11–28 g of TFA per 100 g. The Brazilian Association of Food Industries reported reductions ranging from 25–92% in oils and fats to 100% in breakfast cereals; TFA levels in seasoning and sauces averaged 11.5 g per 100 g. McDonald's reported a 100% reduction in TFAs in oils used in Brazil. Other companies reported that they had made efforts to reduce TFAs but did not provide data.

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Study	Study type[a]	Study population or sample	Aim and main outcomes	Relevant results
14 countries, 2009, Stender et al.[14]	Cross-sectional	19 products containing high amounts of TFA and 19 similar food items containing low amounts from large supermarkets and fast food outlets in 14 countries, sampled between 2005 and 2008	Aim: to compare the fatty acid composition of similar types of food purchased within the same country. Outcome: fatty acid composition of food.	Baked goods: low-TFA cakes and biscuits (i.e. cookies) had 40 percentage points less TFA than high-TFA equivalents. Savoury snacks: low-TFA microwave popcorns had 46 percentage points less TFA than high-TFA equivalents and low-TFA French fries had 18 percentage points less. SFA: low-TFA baked goods had 33 percentage points more SFAs, 5 percentage points more MUFAs and 4 percentage points more PUFAs than high-TFA equivalents. Low-TFA microwave popcorns had 24 percentage points more SFAs, 15 percentage points more MUFAs and 8 percentage points more PUFAs. MUFA and SFA levels were similar in low- and high-TFA French fries but PUFA levels were 19 percentage points higher in low-TFA fries.
Mandatory labelling				
Republic of Korea,[e] 2010, Lee et al.[15]	Pretest–post-test	21 food products in 7 different categories of food from local markets and fast food restaurants, sampled in both 2005 and 2008	Aim: to examine the impact of mandatory TFA regulation on TFA levels in food products. Outcome: fatty acid composition of food products sampled in 2005 (before regulation) and 2008 (after regulation).	Before regulation, TFA levels ranged from 0.6–44.6% of total fatty acids. After regulation, TFA levels were significantly ($P < 0.05$) lower with the exception of one breakfast cereal and fried chicken. TFA levels were < 1% in breakfast cereals, French fries and fried chicken in 2008. Cream-filled biscuits and cakes had TFA levels ranging from not detectable to 5.4%. Savoury snacks: TFA content in French fries decreased by 91–98% and, in fried chicken, by 50–96% Baked goods: the reduction in TFA content ranged from 69–89% in cream-filled biscuits and 88–97% in cream-filled cakes. SFA: SFA content increased significantly in biscuits, by 29–135%, and cakes, by 48–69% ($P < 0.05$ for both). Unsaturated fatty acid content increased by 35–185% in French fries and by 17–76% in fried chicken.
USA,[f] 2005, Centre for Science in the Public Interest[16] (grey literature)	Cross-sectional	Manufacturers ($n = 14$), restaurants ($n = 30$) and supermarkets ($n = 24$)	Aim: to assess companies' intentions to reduce PHVOs in response to labelling regulation. Outcome: self-reported progress towards reducing TFAs in food products.	Manufacturers: 71% reported either reformulating some or all of their products to eliminate TFAs or were in the process of doing so. Restaurants: 30% of large restaurant companies had reformulated their products or were in the process of doing so; 47% were testing alternatives and had plans to change. In the restaurants that listed TFA information on their web sites, TFA levels in foods were generally high. Supermarkets: 55% had made changes to their house brands or were in the process of doing so. Whole Foods Market grocery stores did not carry any products containing PHVOs. Substitution: PHVO was substituted using a variety of oils, including canola, rice bran, cottonseed, palm, soybean, coconut and sunflower oils.
USA, 2008, Albers et al.[17]	Post-test	113 products from 3 food categories (i.e. margarines or butters, biscuits or snack cakes, and savoury snacks) at a Walmart Supercentre in Minneapolis–St. Paul (July 2006); follow up sample of all 29 microwave popcorns available in the same store	Aims: to assess the TFA content of foods in categories that were previously found to be high in TFA; to evaluate the association between TFA and SFA levels in products in each category; to examine the association between price and fatty acid content. Outcomes: TFA, SFA and total fat content, price of products.	Spreads and baked goods after regulation: 72% of margarines and butters and 77% of biscuits (i.e. cookies) and cakes were labelled as TFA-free. All products sampled in this category were labelled as containing < 3 g per 100 g of TFA. Savoury snacks after regulation: 78% of savoury snacks were labelled as TFA-free, 7.5% were labelled as containing ≤ 3 g per 100 g of TFA. Popcorns were labelled as containing higher levels of TFA than potato crisps or crackers. SFA: the only significant association between the percentage of SFA and TFA in total fat was found for popcorn: there was a strong inverse relationship ($r = -0.96$). Price: There were inverse correlations between product price and SFA and TFA content for all categories of food; however, the correlation was significant only for savoury snacks ($r = -0.32$) and margarines ($r = -0.45$).

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Study	Study type[a]	Study population or sample	Aim and main outcomes	Relevant results
USA, 2009, Niederdeppe and Frosch[18]	Pretest–post-test	Sales of seven TFA-containing products in a major Los Angeles County grocery store chain between 2005 and 2007 (n = 11 997 store–weeks)	Aim: to assess whether news coverage influenced sales of products containing TFAs between December 2004 (before labelling regulation) and June 2007 (after labelling regulation). Outcomes: weekly unit sales and price data on seven TFA-containing products, average number of TFA stories per week across five news outlets and trends in product purchase patterns.	Before regulation there was little evidence (in 2 of the 7 products) that news coverage affects unit sales of products containing TFAs. Coverage affected only stick margarine and hot dogs. After regulation there was strong evidence (in 5 of the 7 products) that news coverage affects sales. There were significant negative interactions between unit sales and TFA news coverage for the two products with the highest TFA content: Crisco shortening and buttered popcorn. The effects dissipated after 3 weeks.
USA, 2010, Mozaffarian et al.[19]	Pretest–post-test	83 reformulated products (58 supermarket foods and 25 restaurant foods) identified using consumer magazines, health newsletters, a non-profit-making organization database and Food and Drug Administration food composition databases	Aim: to assess levels of TFA and SFA in major brand-name supermarket and restaurant foods that were reformulated to reduce TFA levels, sampled between 1993 and 2006 and between 2008 and 2009. Outcomes: TFA, SFA and total fat content before and after reformulation.	Supermarket foods: TFA content declined to < 0.5 g per serving in 95% of foods; the average reduction was 1.8 g per serving (i.e. 84%). Restaurant foods: TFA content declined to < 0.5 g per serving in 80% of foods; the average reduction was 3.3 g per serving (i.e. 92%). SFA: 65% of supermarket foods and 90% of restaurant foods had SFA levels that were lower, unchanged or only marginally higher (i.e. increase: < 0.5 g per serving) than before reformulation. The average SFA content increased slightly (by < 0.5 g per serving for one third of foods) in supermarket foods and decreased in restaurant foods. The reduction in TFA content nearly always exceeded any increase in SFA content. Overall, the combined content of both fats was reduced in 90% of supermarket foods (average reduction: 1.2 g per serving) and 96% of restaurant foods (average reduction: 3.9 g per serving).
USA, 2012, Van Camp et al.[20]	Pretest–post-test	5012 potato crisp and biscuit (i.e. cookie) products in 2001–2002 and 2008–2009	Aim: to assess the impact of mandatory TFA labelling on snack foods in the USA. Outcomes: TFA media citations, changes in lipid ingredients used, change in reported TFA and SFA content and use of the declaration "0 g TFA".	Savoury snacks: 45% reduction in PHVO use in potato crisps (sunflower oil was the main replacement). Only 1% of potato crisps introduced after regulation reported > 0 g TFA. Baked goods: 42% reduction in PHVO use in biscuits (palm oil was the main replacement). The proportion of biscuits introduced after regulation that contained palm or palm kernel oil increased by 41% and 5%, respectively; 9% of biscuits introduced after regulation reported > 0 g TFA. SFA: in potato crisps, there was no difference in SFA levels; in biscuits, there was an average increase of 0.49 g SFA per 30-g serving but no increase in total fat.
USA, 2012, Vesper et al.[21]	Pretest–post-test	229 non-Hispanic white participants in 2000 and 292 in 2009	Aim: to assess the impact of TFA regulation on TFA levels in blood. Outcomes: TFA levels in blood in 2000 vkcal 2009; LDL and HDL cholesterol and triglyceride levels.	Blood: mean TFA level decreased from 43.7 µmol/L in 2000 to 19.4 µmol/L in 2009 (i.e. 58% decrease). Cholesterol and triglycerides: LDL cholesterol levels were lower in 2009 (mean: 119.2 mg/dL) than 2000 (mean: 128.2 mg/dL); HDL cholesterol levels were higher in 2009 (mean: 55.8 mg/dL) than 2000 (mean: 49.6 mg/dL); triglyceride levels were lower (mean: 131 mg/dL) in 2000 than 2009 (mean: 109 mg/dL).

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Study	Study type[a]	Study population or sample	Aim and main outcomes	Relevant results
Brazil,[e] 2009, Benincá et al.[22]	Post-test	Six different margarines representing eight brands from five supermarkets in Curitiba, Brazil, sampled in December 2006; 200 consumers interviews	Aims: to assess how 46 different trade-marked hydrogenated vegetable oils and margarines produced in Brazil changed in response to labelling regulation; and to assess consumers' use of labelling information and dietary practices. Outcomes: comparison of actual fatty acid composition of six margarines brands, assessed using gas chromatography, and composition on nutrition labels, TFA content of margarines, consumers' self-reported knowledge of TFAs and use of nutrition labels.	After regulation, 30% of margarines were labelled as having > 2 g TFA per 100 g, 52% were labelled as TFA-free and 13% were improperly labelled. Of those that contained > 2 g TFA per 100 g, 15% had 11–50% TFA per 100 g. 50% of manufacturers and 13% of trade-mark brands investigated violated the regulation by not including TFA levels on product label.
Mandatory labelling and voluntary limits				
Canada,[g] 2006, Friesen et al.[23]	Pretest–post-test	Breast milk samples from women ($n = 87$) who gave birth between 2004 and 2006; breast milk samples from women ($n = 103$) collected in 1998	Aim: to compare TFA levels in breast milk before (i.e. in 1998) and after (i.e. in 2004–2006) Canadian TFA regulation. Outcome: TFA levels in women's breast milk in 2004–2006 compared with 1998.	TFA: the mean TFA level was 35% lower in 2004–2006 than in 1998. TFA levels decreased progressively over 5-month intervals between 2004 and 2006. TFA intake estimated from breast milk was 4.0 g per person per day in 1998 compared with 2.2 g per person per day in 2005. SFA: SFA levels were slightly higher; no change in MUFA or PUFA levels.
Canada, 2009, Ricciuto et al.[24]	Pretest–post-test	229 margarines sold in 9 Greater Toronto Area supermarkets in 2002 and 274 margarines sold in 10 supermarkets in 2006	Aim: to examine the effectiveness of TFA labelling regulation on the fat composition and price of margarines. Outcome: comparison of price and fatty acid composition in 2002 and 2006.	TFA: the proportion of products containing ≤ 0.2 g of TFA per 10 g increased significantly from 31% to 69%. TFA levels decreased in 13 of 18 margarines that were on the market in both years (decease: 0.1–1.3 g per 10 g serving). The TFA content of three products increased between 2002 and 2006. SFA: the average amount of TFA and MUFA decreased, PUFA levels increased and SFA levels did not change significantly between the two time points. SFA content increased in the 13 products reformulated; in three, the increase equalled or exceeded the TFA decrease. Price: The average price of products labelled TFA-free in 2006 had risen by 28%, compared with a 10% rise in products not labelled TFA-free. Products with low TFA and SFA levels were more expensive than those with high TFA levels.

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Study	Study type[a]	Study population or sample	Aim and main outcomes	Relevant results
Canada, 2009, Ratnayake et al.[25]	Interrupted time series	221 individual manufactured and restaurant foods sold in major grocery stores or restaurants in Canada during 2005–2007 that were likely to contain TFAs (e.g. biscuits, crackers, breakfast bars, frozen potato products and margarines)	Aim: to assess TFA and SFA levels in grocery and restaurant foods that probably contained TFAs in Canada in 2005–2007. Outcomes: number of products containing TFA, number of reformulated products, change in fatty acid and total fat content of reformulated products.	TFA: in the initial assessment, 42% of products contained TFA: 12 had a TFA content of 5–10% and 80 had > 10%. Of products containing TFA, 8 were discontinued, 12 were reformulated but not assessed by the end of the study and 7 were measured for the first time in 2007. Of the remaining products, nearly 75% were reformulated during the study period to decrease TFA content. TFA levels decreased from 26 ± 13% to 2 ± 4%. SFA: of products tested more than once to assess reformulation, none showed an increase in SFA or TFA level and one showed no change but all others had lower TFA and SFA levels and higher cis-unsaturated fat content. The average combined TFA and SFA content was reduced from 53 ± 12% to 30 ± 19%. The average absolute change in total fat content was 0.8 ± 3.0%.
Canada, 2009, Ratnayake et al.[26]	Interrupted time series	1120 samples in 31 different food categories collected from major grocery stores, fast food-chains and cafeterias across Canada during 2005–2009; foods collected had previously been identified as having high quantities of TFA; 2004 Canadian Community Health Survey data on TFA and SFA intake ($n = 33\,000$ participants)	Aim: to report the results of a TFA monitoring programme for the period 2005–2009. Outcome: fatty acid composition of selected foods.	TFA: Of the 1120 samples from 2005–2009 analysed, 76% were within the recommended TFA limits. In 2005–2006, only 58% were within the limits; in 2007, the figure was 68%; in 2008, it was 77%; and in 2009, 78%. Baked goods: after regulation, 45% of brownies, 43% of cakes, 25% of croissants, 45% of Danish pastries, 55% of garlic bread, 36% of pies and 67% of tarts contained < 5% TFA. Only 29% of donuts sampled between 2005 and 2008 contained < 5% TFA. Savoury snacks: after regulation, 100% of pizzas, 79% of French fries, 79% of chicken products, 83% of fish products, 89% of muffins and 75% of onion rings sampled contained < 5% TFA. Margarines and spreads: after regulation, 62% of tub margarines, 0% of print margarines and 50% of vegetable shortenings met the recommended limits. Between 2005–2007, the TFA content of margarines averaged 39.3%. Most (70%) products sold in cafeterias met the limits; exceptions included margarines, onion rings and fish products. SFA: in most products, the TFA level was reduced without an increase in SFA level but MUFA and PUFA levels increased. However, in crackers, biscuits, frozen chicken products and garlic spreads, the reduction in TFA level was associated with an increase in SFA and unsaturated fatty acid levels. The combined TFA and SFA level in these products did not increase. SFA levels in donuts reformulated to reduce TFA content were nearly double those in donuts with a TFA content > 5%. TFA intake: mean TFA intake decreased from 8.4 g per day in the mid 1990s to 3.4 g per day in 2008, which is still above WHO recommendations. On average, there was a 30% decrease in TFA intake between 2004 and 2008. SFA intake did not increase during this period.

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Study	Study type[a]	Study population or sample	Aim and main outcomes	Relevant results
Mandatory limits and local bans				
New York City, USA,[h] 2009, Angell et al.[27]	Interrupted time series	478 restaurants in 2005, 1021 restaurants in 2006, 996 food establishments in 2007 (after passage of the regulations but before the effective date); information on nutritional content of fast foods ($n = 12$) at major chains before and after introduction of the regulations	Aim: to examine the effectiveness of TFA regulation. Outcomes: restaurants' compliance with TFA ban as assessed by inspectors, fatty acid composition of selected foods.	Before regulation in 2005–2007, 50% of restaurants used fats containing TFAs to prepare food. Following an education campaign aimed at restaurants, the 2006 survey found that 51% of restaurants were still using fats containing TFA. In 2007, TFA use had decreased to 43%. After regulation in 2008, 99% of all restaurants were compliant with phase 1; 6 months after phase 2, 92% were compliant. Change in use: 98% of restaurants were not using oils or spreads containing TFAs in November 2008 compared to 50% in 2005. SFA: On average, SFA content in French fries from fast food-chains decreased by 10.5%, TFA content by 97.9% and combined TFA and SFA content by 54%.
New York City, USA, 2012, Angell et al.[28]	Pretest–post-test	6969 purchases in 2007 and 7885 purchases in 2009 at 168 randomly selected restaurants belong to 11 fast food-chains	Aim: to examine the effect of TFA restriction on the TFA and SFA content of fast-food purchases. Outcome: change in quantity of TFA and SFA per purchase and change in quantity of TFA per 1000 kcal energy content, both overall and by fast-food-chain type.	TFA: the mean TFA amount per purchase decreased by 2.4 g (i.e. 2.9 g to 0.5 g, $P < 0.001$) and the mean TFA amount per 1 000 kcal decreased by 2.7 g. The mean TFA amount per purchase decreased significantly in 3 of 5 types of fast food-chain and increased in one (0.2 g to 0.3 g). Purchases containing 0 g of TFA increased by 86%: from 32% to 59%. The maximum TFA amount in a single purchase decreased from 28 g to 5 g. SFA: the mean SFA amount per purchase increased by 0.6 g ($P = 0.011$) and the mean combined TFA and SFA amount decreased by 1.9 g ($P < 0.001$). The maximum TFA and SFA amount in a single purchase decreased from 96 g to 60 g.
Boston, USA,[h] 2009, Boston Public Health Commission[29] (grey literature)	Post-test	2500 food service establishment inspections	Aim: to assess compliance with a TFA ban. Outcome: restaurants' compliance with TFA ban as assessed by inspectors.	In 2008–2009, after regulation, the compliance rate was 98%. There were 11 violations of the ban. On reinspection, 10 of the 11 were compliant.
Seattle and King County, USA,[h] 2010, King County[30] (grey literature)	Post-test	16 218 food inspections in 2008	Aim: to assess compliance with TFA policy. Outcome: restaurants' compliance with TFA ban and labelling regulation as assessed by inspectors.	In 2008, after regulation, 0.5% of food establishments inspected were noncompliant with phase 1 of the regulations. In 2009, 97% of food establishments inspected were compliant with phase 2.
British Columbia, Canada,[i] 2010 and 2012, ActNowBC,[31] (grey literature)	Post-test	8846 health authority onsite inspection reports and 2659 voluntary documentation audits of chain food service establishments carried out between October 2009 and March 2010; follow-up in 2012 of 48 547 food products likely to contain TFA	Aim: to evaluate the effectiveness of a TFA ban. Outcome: restaurants' compliance with TFA ban as assessed by inspectors and self-reported audits.	In 2009–2010, after regulation, 100% of self-reported audits indicated that the 2% TFA limit for oils and spreads had been met; 82% indicated that the 5% TFA limit in foods had been met. In addition, 87% of health inspections indicated that the 2% TFA limit had been met and 81% that the 5% TFA limit had been met. In 2012, after regulation, onsite inspections indicated that there was 95% compliance with the 2% TFA limit and 92% compliance with the 5% TFA limit.

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Study	Study type[a]	Study population or sample	Aim and main outcomes	Relevant results
Mandatory limits and national bans				
Denmark,[j] 2006, Stender et al.[32]	Post-test	43 servings of fast foods from McDonald's and KFC purchased in 20 countries in 2004 and 2005	Aim: to assess the TFA content of chicken nuggets and French fries. Outcome: TFA content of foods.	Comparison with other countries after regulation: TFA content varied from 1 g per serving in Denmark to 24 g per servingin Hungary. Cooking oils in Denmark contained 1% TFA, compared with 23% in the USA, 24% in Peru and around 10% in European countries (excluding Denmark). Content was as high as 30% in some restaurants and varied between establishments, even in the same country.
Denmark, 2006, Stender et al.[33]	Post-test	542 servings of foods (55 servings of French fries and chicken nuggets, 87 packages of microwave popcorn and 393 samples of biscuits, cakes or wafers) with PHVO high on the list of ingredients, sampled between November 2004 and February 2006	Aim: to assess TFA levels in a "high trans menu" in Denmark and 19 other countries. Outcome: TFA content of three categories of food: French fries and chicken nuggets from McDonald's and KFC, packaged microwave popcorn and biscuits, cakes or wafers.	Before regulation in 2001, TFA content in a "high-trans menu" was 30 g in Denmark. Comparison with other countries after regulation: in 2005, TFA content in a Danish "high-trans menu" was < 1 g. In 17 of 18 other countries, a "high-trans menu" provided > 20 g; in Hungary, it was 42 g. 90% of fast foods, 57% of popcorns and 40% of biscuits, cakes and wafers purchased outside Denmark contained fat with > 2% TFA content, which would be illegal to sell in Denmark.
Denmark, 2006, Stender et al.[34]	Post-test	63 fast food items from 30 different countries, 110 bags of popcorn from 29 countries and 476 biscuits, cakes or wafers from 28 countries all of which included PHVO (or a similar term) in the ingredient list and the fat content was > 15%, sampled between November 2004 and July 2006; samples of all three food categories were obtained from 21 countries	Aim: to assess TFA levels in a "high trans menu" in Denmark and in 20 other countries. Outcome: the TFA content of three categories of food: French fries and chicken nuggets from McDonald's and KFC, packaged microwave popcorn and biscuits, cakes or wafers.	Comparison with other countries after regulation: no sample from Denmark exceeded the TFA limits. TFA content in Danish McDonald's outlets was < 1 g compared with 10 g in the USA. TFA content in Danish samples of biscuits, cakes, wafers and popcorn was < 0.5 g/100 g. 83% of fast foods, 50% of popcorns, and 43% of biscuits, cakes and wafers purchased outside Denmark exceeded the Danish limit of 2% TFA content.

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Study	Study type[a]	Study population or sample	Aim and main outcomes	Relevant results
Denmark, 2006, Leth et al.[35]	Pretest–post-test	253 samples of both imported and domestically produced products were collected between the end of 2002 and early 2003 before the ban; 148 samples of both imported and domestically produced products were collected between November 2004 and February 2005 after the ban was introduced	Aim: to assess the effectiveness of Denmark's TFA ban. Outcome: TFA content of food samples known to be high in TFAs, assessed in 2002–2003 and 2004–2005.	TFA intake decreased from 4.5 g per day in 1976 to 1.5 g per day in 1995 and TFAs were virtually eliminated from food in 2005 after the ban. Before regulation, the highest TFA levels were in frying fat in chain restaurants (20% of fat was TFA), popcorn (30% of fat was TFA) and various cakes, biscuits and pastries (10% of fat was TFA). In 25% of samples, > 2% of fat was TFA. Chocolate and confectionary items contained virtually no TFA, with the exception of caramels. Industrial bakery products contained high amounts of TFA; 43% of biscuit products had levels > 2%; 26% of potato products contained > 2%; and 80% of ready-made French fries contained > 2%. After regulation, fewer samples contained > 2% TFA. TFA content ranged from 2–6% in samples with a level > 2%; as some contained milk ingredients, the TFA was probably naturally occurring. High TFA levels were found in a few potato and cake products and steps have been taken by authorities to correct this.

HDL, high-density lipoprotein; LDL, low-density lipoprotein; MUFA, monounsaturated fatty acid; PHVO, partially hydrogenated vegetable oil; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid; USA, United States of America; WHO, World Health Organization.

[a] Study quality was based on National Health and Medical Research Council designations of levels of evidence: case–control studies provide level III-2 evidence, interrupted time series studies provide level III-3 evidence and pretest–post-test, post-test and cross-sectional studies provide level-V evidence.

[b] In 2004, the Netherlands' Product Board for Margarine, Fats and Oils set up the Task Force for Responsible Fatty Acid Composition to reduce the use of PHVOs and set a limit of 5% for TFAs in frying oils.

[c] Voluntary industrial modification of partially hydrogenated soybean oil.

[d] Voluntary reformulation of products: 12 major companies in the Americas signed a declaration of their intention to help achieve "trans-fat-free Americas".

[e] The TFA content of foods labelled TFA-free had to be < 0.2 g per serving.

[f] The TFA content of foods labelled TFA-free had to be < 0.5 g per serving.

[g] The TFA content of foods labelled TFA-free had to contain < 0.2 g TFA per serving and < 2 g TFA and SFA combined per 10-g serving (≤ 15% of energy content). There was a voluntary limit of 2% for TFA as a proportion of total fat in fats, oils and spreads and a limit of 5% as a proportion of total fat in foods.

[h] Artificially produced TFAs banned (i.e. < 0.5 g per serving) in all licensed food establishments. Phase 1 applied to oils and spreads; phase 2 applied to all products, including bakery items.

[i] Ban on TFAs in restaurants and schools. TFA levels must be documented, the maximum TFA content as a proportion of total fat in all oils and soft margarines was 2% and the maximum TFA content as a proportion of total fat in all food items was 5%.

[j] Ban on TFA in all food sold in Denmark; the maximum TFA content as a proportion of total fat was 2%.