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Existing differences between available lists of FODMAP-containing foods

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ABSTRACT

Background and aim: reduced intake of fermentable oligosaccharides, disaccharides, monosaccharides and polyols (FODMAPs) is useful to treat functional gastrointestinal disorders. However, there is no consensus on which foods should be included in the FODMAP list as FODMAP profile characterization is lacking for many different foods.

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This study aimed to emphasize the need for a unified FODMAP list to prevent patient confusion. We hypothesized that FODMAP lists do not include all products that may contain high levels of FODMAPs.

Methods: PubMed, ScienceDirect, Scielo, and Cochrane were searched to identify food composition tables, reviews, food analysis publications, laboratory analyses, and clinical trials containing FODMAP lists.

Results: of 1,308 articles identified, 10 were selected; 22.6 % of the 204 foods listed were classified differently among studies. This included almonds, avocados, banana, broccoli, soft cheese, eggplant, and walnuts. Nutritional guidance may be taken from existing FODMAP-related literature, but the information given is not always consistent.

Conclusion: Unvarying lists of low FODMAP foods should be compiled to provide patients with accurate information on FODMAP dieting.

Keywords: Oligosaccharides. Disaccharides. Monosaccharides. Polyols. FODMAP diet.

INTRODUCTION

Dietary carbohydrates that are fermented by bacteria in the colon and poorly absorbed in the human intestine are known as fermentable oligosaccharides, disaccharides, monosaccharides and polyols (FODMAPs) (1). These short-chain carbohydrates were discovered in food by researchers in the Department of Gastroenterology at Monash University (2) in 2005. The ingestion of FODMAPs may cause several symptoms such as abdominal pain or bloating. Dietary therapy with a low FODMAP diet has been shown to be helpful in the treatment of those functional gastrointestinal disorders (1).

A FODMAP-poor diet is understood to be one with a low content of fermentable oligosaccharides (fructooligosaccharides (FOS), galactoligosaccharides (GOS)), disaccharides (lactose), monosaccharides (fructose) and polyols (xylitol, mannitol, sorbitol, maltitol) (3). This type of dietary treatment consists of two phases. The first phase consists of severe FODMAP restriction for 4-8 weeks, followed by a second

phase in which the initially withdrawn foods are reintroduced according to each person's tolerance ("top-down" methodology) (4). This approach is usually applied in patients who do not consume large amounts of FODMAPs but are very symptomatic (5). The "top-down" methodology is the most frequently used treatment. However, the amount of FODMAPs in the diet can also be managed in the opposite direction ("bottom-up" methodology). Only foods with fairly high amounts of FODMAP are restricted in the first place, followed by a restriction of foods with lower FODMAP contents until reaching the tolerance level (4). This second approach is usually taken in patients who consume a large amount of FODMAPs or have moderate symptoms (5). In order to ensure that a diet is not deficient despite restrictions, it is necessary that the diet is controlled by experienced dietitians.

Fructans and FOS are found naturally in food such as garlic, onions, rye and wheat; GOS in legumes; lactose in dairy products like milk, soft cheese and yogurt; fructose in honey, corn syrups and some fruits like apple and pear; and polyols in fruits with bones, some vegetables, and artificial sweeteners (6). European legislation lacks definitions and regulations regarding FODMAPs, therefore very few low FODMAP-labeled food products are available in the European market (1).

Most studies related to FODMAP dieting provide lists of allowed foods or foods that should be eliminated in a low FODMAP diet. This frequently cited lists comprise the most abundant nondigestible, osmotically active, and easily fermentable dietary carbohydrates including fructans, FOS, GOS, lactose, fructose in excess of glucose, and polyols (1). However, there is no established consensus on which foods should be included and excluded from the list of FODMAPs, probably due to lack of characterization of the FODMAP profiles of a wide range of raw ingredients and food products. We hypothesized that FODMAP lists do not comprise all products that may contain high levels of FODMAPs. Therefore, the aim of this study was to emphasize the need for unified information on the FODMAP content of foods in order to prevent confusion in both patients and dietitians.

METHODS AND MATERIALS

Data sources and search strategies

A bibliographic search was conducted from June to December 2020. Articles published within the last 10 years were included. The databases used were PubMed, ScienceDirect, Scielo, and Cochrane. The search strategy was performed using MeSH descriptors and Boolean operators (AND and OR) in each database. The keywords used were (("Disaccharides/administration and dosage"[Mesh]) OR ("Disaccharides/analysis"[Mesh]) OR ("Monosaccharides/administration and dosage"[Mesh]) OR ("Monosaccharides/analysis"[Mesh]) OR ("Polymers/administration and dosage"[Mesh]) OR ("Polymers/analysis"[Mesh]) OR ("Dietary Carbohydrates/administration and dosage"[Mesh]) OR ("Dietary Carbohydrates/analysis"[Mesh])) AND "Food Analysis"[Mesh].

Eligibility criteria

The inclusion criteria established for the selection of articles were food composition tables, reviews, food analytical publications, laboratory analyses, and clinical trials. Duplicate titles, conference summaries, editorial papers, and publications not related to the topic were excluded. Languages were limited to English and Spanish. The literature was independently selected by two researchers, and inconsistencies were discussed.

Data collection

All foods mentioned in each study were listed and divided in low, moderate or high FODMAP content.

Most publications used the Monash Institute food database (7) as a reference for their recommendations. Thus, FODMAP content classification is based on serving sizes and considered as such when not specified.

Following Varney et al. (2017) (8), low FODMAP cut-off values in these publications are as follows: 0.3 g oligosaccharides, 0.4 g polyols, 0.15 g excess fructose, and 1 g lactose per serving size. However, food lists from clinical trials did not state their cut-off values (5,9-12).

RESULTS

Search results

Figure 1 shows the article selection flow diagram. A total of 1,308 articles were retrieved from the search. After reading the titles, abstracts, and methods sections, and applying the exclusion criteria, only 10 studies were eligible for this article.

Study characteristics

All of the chosen studies have a low-medium grade of evidence as described by the GRADE system (13). The narrative review of Pensabene et al. (9) synthesized the current information on the role of low FODMAP diet in reducing symptoms related to functional abdominal pain disorders in children. Casellas et al. (5) is a consensus document on the purpose of elimination diets in irritable bowel syndrome (IBS), prepared by different experts representing the major Spanish scientific societies. The study by Baraguán et al. (10) analyzes the implementation of a low FODMAP diet as treatment for functional chronic abdominal pain in a pediatric population at a Mediterranean region, as well as the condition's response. Dieterich et al. (12) studied how a low FODMAP diet affected clinical symptoms, stool microbiota, and intestinal integrity and inflammation versus a gluten-free diet. Pérez y López et al. (11) evaluated clinical response in patients with IBS, in its different clinical variants, to low FODMAP diet. Ispiryan et al. (1) characterized the FODMAP profile of a vast range of cereal-product ingredients in order to develop low FODMAP products. A year afterwards they investigated the impact of malting on the FODMAP content of some cereals and legumes (14). Prichard et al. (15) aimed to quantify the FODMAP content of 20 commonly consumed foods in ethnic minority groups. Tuck et al. (16) focused on measuring FODMAP levels in plant-based foods used in vegetarian/vegan diets, and investigated whether these levels changed after food processing. Latulippe et al. (17) focused on understanding fructose intolerance and malabsorption derived from the consumption of fructose and other carbohydrates.

Table 1 shows a compilation of foods from the different studies (1,5,7,9-12,14-17) indicating their FODMAP content. A total of 204 foods are listed; 67.6 % (n = 138) of the listed foods were classified identically by all authors. In contrast, 22.6 % (n = 46)

were classified differently between studies. These include foods as common as almonds, avocados, banana, broccoli, fresh/soft cheese, eggplant and walnuts, among others. The 9.8 % (n = 20) remaining foods were only cited by one study; therefore, no comparison could be made.

DISCUSSION

FODMAPs are present in a vast number of foods. Current evidence, as summarized in this article, suggests that there is no homogeneous consensus on their levels, and differences between food estimates make it hard for nutritionists and health professionals to accurately advise patients, and patients find it hard to correctly follow a diet based on the current lists. Therefore, the hypothesis was accepted.

This article has shown how three different FODMAP contents (high, moderate and low) were attributed to one and the same food. This was the case of banana, blueberry, broccoli, ice cream, pecan nuts, and walnuts. Furthermore, several foods such as celery, corn, eggplant, grapes and squash were classified at opposite ends (high vs. low FODMAP content) by more than one study in each case, whereas just one study would differ in the classification of foods like avocado, beetroot, bell pepper, wheat-based biscuits, cashews, soft/fresh cheese, sweet corn, grapefruit, and lentils, among others.

Differences in the classification of FODMAP content in foods could be due to different methodologies employed for their analysis. Thus, rigor varies widely between studies, as does between findings. All tools and methods should be standardized to achieve the goal of obtaining reliable information. Each assessed FODMAP must be defined in the same way, the measurement units and the methods used to assign values should be comparable if not the same (18). Other explanations as to why the classifications of FODMAP content may vary may involve ripening degree (e.g., in fruits and vegetables) (19), food preparation, or serving size (20). In ripening bananas fructose concentration changes after the fruit reaches the climacteric stage (19). Fruit dehydration to prepare dried fruits concentrates all the sugars — including FODMAPs — initially present in the fresh fruit. Some dried fruits (cranberries for example) are only high in FODMAP if consumed in larger serving sizes (20). Some saccharides, such as fructans, not found in a fresh fruit have also been detected in its dried counterpart (20). Yeasts

and *Lactobacilli* use fructans during fermentation. Hence, the sourdough fermentation process is known to reduce FODMAP levels. Certain traditionally-fermented sourdough breads made from lower-FODMAP flours, such as spelt and oat, are classed as low or moderate in FODMAP content (20). However, sourdough breads made from high-FODMAP flours (such as rye and wheat) are still considered to be high in FODMAPs (20).

Developing a low FODMAP diet required the establishment of "cutoff values" to classify foods as low in FODMAPs. These cutoff values relate to each particular FODMAP sugar present in a given food (8). Cutoff values were initially derived by considering (based on clinical experience) the FODMAP content and typical serving size of the food, consumed in a single sitting or meal, that potentially triggered symptoms in individuals with IBS. Foods that were generally well tolerated were also considered. This enabled the establishment of threshold levels for each FODMAP, above which most people experience symptoms. Although the reliability of these FODMAP cutoff values has been tested (21,22), not every study may have relied on the same cutoff levels to classify the FODMAP content of foods (8).

The application of a FODMAP diet is limited by the paucity of food composition data available (15), also lacking adaptation to different cultures and gastronomies. FODMAP levels should be incorporated into food composition databases and then updated frequently. New foods and recipes need to be added promptly so that results are precise and accurate also over time. The Spanish Speakers FODMAP Diet Expert Group (23) is an initiative in this respect, proposing a FODMAP diet guide that is culturally adapted to different countries for dietitians-nutritionists and nutrition experts, to facilitate the management of patients who benefit from FODMAP dieting.

Instructing patients on a low FODMAP diet to limit their intake of high FODMAP products would seem a reasonable recommendation. However, following such a recommendation will be challenging for several reasons. First, simply knowing that a product contains FODMAPs does not allow an accurate estimate of their content. Second, FODMAPs are generally not listed in labels, making it difficult to identify the presence of a specific FODMAP. Third, FODMAP-free or -low products may require more effort to identify. The foods listed in the Monash FODMAP App (7) are an

average of a number of products that have been tested, therefore they are unable to name brands in the app. Any action taken by manufacturers (e.g., analyze their products for FODMAP content and make the data available) and policy makers (e.g., mandate to include FODMAP content on the nutrition facts label) will help patients limit their FODMAP intake, will help providers to better instruct patients, and will help researchers to accurately assess dietary intake.

The above can lead patients to assume erroneous or insufficiently verified information, and generates incomplete or ineffective dietetic treatments. Existing FODMAP literature predominantly serves as nutritional guidance for individuals adhering to a low FODMAP diet, but the information given is not always consistent. Consensus and unvarying lists of low FODMAP foods should be elaborated to provide patients with adequate, accurate information on FODMAP diets. Further studies are necessary to provide a dry matter-based characterization of FODMAP profiles for a wider range of foods, to homogenize the current lists of FODMAPs, and to allow patients to handle their FODMAP-associated symptoms in a more accurate way.

Limitations

This is a descriptive analysis of the literature available to date. Data are highly variable and may significantly differ between studies. The classification of FODMAP content in foods is ambiguous due to the sparse details reported in the studies relating to the methodology employed for the analysis, or their failure to describe factors potentially influencing results. In this regard, more attention should be paid to the characterization of FODMAP profiles, and the creation of low FODMAP food databases. Further studies are necessary to establish the safety limits for FODMAPs in food, and the intolerance they may cause.

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Table 1. Compilation of foods indicating their low, medium or high content in FODMAPs

	Monash App (7)	**Pensabene (9)**	**Casellas (5)**	**Pérez y López (11)**	**Dieterich (12)**	**Barangu án (10)**	**Ispiryan (1)**	**Prichard (15)**	**Tuck (16)**	**Latulippe (17)**	**Ispiryan (14)**
Cereal and tubercle											
Barley											H (fn)
Barley (malted)											H (fn)
Barley (sprouted)	L								L		
Biscuits (gluten-free)	L				L	L	L				
Biscuits (wheat-based)	L				H	H	H (g,fn,l)				
Buckwheat	L		L								L
Buckwheat (malted)											L
Cassava	L							L			
Corn	H (s)	L	L		H	L					
Corn pasta		L			L						

Corn (sweet)	H (s)		H (p)			L					
Crackers (gluten-free oat)						L	L				
Crackers (wheat-based plain)	L					H	L				
Crackers (wheat-based garlic)						H	H (f,fn)				
Gluten-free products	L	L			L	L					
Noodles	H (f,fn)	L									
Oat	L	L	L		L					L	
Oat (malted)										L	
Polenta	L	L			L	L					
Potato	L	L	L		L	L					
Rice	L	L	L		L	L					
Rye	H (fn)		H (fn)	H (o)	H	H					
Rye (sprouted)	H (fn)							H (fn)			
Soda bread (brown)						H	H (g,fn,l)				
Soda bread						H	H				

(whole wheat)	(g,fn,l)

Soda bread (whole wheat)						H (g,fn,l)				
Sorghum flour	L						L			
Sourdough		L								
Spaghetti, gluten-free (cooked, uncooked)	L				L	L				
Spaghetti, wheat (cooked, uncooked)	H (fn)		H (fn)		H	H	H (fn)			
Taro	L						L			
Tortilla chips		L			L	L				
Wheat	H (g,fn)		H (fn)	H (o)	H	H				H (fn)
Wheat germ	H (g,fn)							H (g,fn)		
Wheat sourdough bread	L					L				
Wheat (malted)										H (fn)
Wheat	H (fn)							H (fn)		

(sprouted)

Wheat (sprouted)								
White loaf (gluten-free)	L					L		
White loaf (wheat)	H (f,fn)			H	H	L		
Yam (fresh, pounded)	L						L	
Seeds								
Chia seeds	L	L						
Egusi seeds	L						L	
Fenugreek seeds	L						H (g,o)	
Flax seeds	L	L						
Poppy seeds	L						L	
Pumpkin seeds	L	L						
Legumes								
Adzuki beans (canned, dried, cooked)	H (g)		H (g)	H	H			H (g)
Bean sprouts		L	L	L				

Chana dal	H (g)						H (g)			
Chickpeas			H (p)	H (o)	H	H				H (g)
Chickpeas (canned)	M (g)	L								
Chickpeas (malted)										H (g)
Chickpeas (sprouted)	H (g)							H (g)		
Fava beans	H (f)				H					
Kidney beans, red (canned)								L		
Kidney beans, red (dried, cooked)	H (g,fn)		H (g)	H (o)	H	H		H (g,fn)		
Kidney beans, red (sprouted)	H (g,fn)							H (g,fn)		
Lentils	L		H (g)	H (o)	H	H				H (g)
Lentils (canned)	L	L								
Lentils (malted)										H (g)
Lentils (red)	M (g)				H			H (g)		

Mung beans (sprouted)	L										L	
Soy roll											L	
Tempeh	L	L									L	
Tofu (firm)	L	L										
Urid dal	L									L		
Nuts												
Almonds	H (g)	L					H					
Cashews	H (g,fn)	L					H					
Cashews (activated)	H (g)										H (g)	
Macadamia nuts	L	M					H					
Pecan nuts	L	M					H					
Pistachios	H (g,fn)						H					
Pistachios (activated)	H (g,fn)										H (g,fn)	
Walnuts	L	M					H					
Fruit												
Ackee	L									L		
Apple	H (f,s)		H (f)	H (f,p)	H		H					H (f)

Avocado	H (s)		M	H (p)		H					
Blackberry	H (s)		L								
Blueberry	H (fn)	L	L		M	L					
Breadfruit	L							L			
Carambola	L	L			H						
Banana	H (fn)	L	M		L	L				H (f)	
Cherry	H (f,s)		H (p)	H (p)	H	H					
Choko/Chayote	L	L						L			
Coconut	M (s)	L									
Coconut flour	H (f,fn,s)								H (f,fn,s)		
Cranberries		L			L						
Dragon fruit	L										
Durian	L	L									
Grapefruit	H (fn)	L	L		L	L					
Grapes	L	L	L		H	L				H (f)	
Guava (tinned in syrup)	H (f,fn)				H			H (o,fn)			
Kiwi fruit	L	L	L		L	L					
Lemon			L		L						

Lemon juice	L	L								
Lime		L	L		L	L				
Lychee	H (s)				H					
Mango	H (f)		H (f)	H (f)	H	H				
Melon (Cantaloupe)	M	L								
Melon (Honeydew)	H (fn)	L			H					
Nectarine	H (fn,s)				H	H				
Orange	L	L	L		L				H (f)	
Papaya	L	L	L		H	L				
Passion fruit	L	L	L							
Paw paw	H (fn)	L								
Peach	H (s)		H (p)	H (p)	H	H				
Pear	H (f,s)		H (f)	H (p)	H	H			H (f)	
Pineapple	L		L		L					
Plantain	L						L			
Plum	H (fn,s)		H (p)	H (p)	H	H				
Raisin	H (fn)		H (p)	H (f)	H	H				
Raspberry	H (fn)	L	L		L	L				

Strawberries	L	L	L		L	L				
Tamarind	L							H (o,fn)		
Tomato	L	L	L		L	L				
Watermelon	H (f,fn,m)		H (f)	H (p)	H	H			H (f)	
Vegetables										
Asparagus	H (f,fn)		H (fn)	H (o)	H	H				
Bamboo shoot	L	L	L							
Beetroot	H (g,fn)	L	H (fn)		H	H				
Bell pepper	L	L	H (p)		L	L				
Bok choy	L	L								
Broccoli	L	M	H (fn)	H (o)	H	H				
Brussel Sprouts	H (fn)		H (fn)	H (o)		H				
Callaloo	L							L		
Capsicum	L	L								
Carrot	L	L	L		L				L	
Cauliflower	H (m)		H (p)	H (p)	H	H				
Celery	H (m)	L	L		L	H				
Chives	L	L	L		L					
Choy sum	L	L								

Dulse	L								L		
Eggplant	L	L	H (fn)		H	L					
Fennel	H (fn)				H	H					
Fenugreek leaves	L							L			
Garlic	H (fn)		H (fn)	H (o)	H	H					
Green bean	L	L	L		L	L					
Karela	H (g)							H (g)			
Lettuce	L	L	L		L	L					
Mushrooms	H (fn,m)		H (p)	H (p)	H	H					
Onion	H (g,fn)		H (fn)	H (o)	H	H				L	
Parsnip	L	L									
Pickled artichoke	H (f,fn)								H (fn)		
Pickled beetroot	L								L		
Pickled garlic									L		
Pickled onion	L								L		
Pumpkin		L	L	H (p)	L	L					
Pumpkin (canned)	L	L									

Rhubarb	L	L	L									
Silver beet	L	L										
Spinach	L	L			L	L						
Spring onion	H (fn)	L										
Squash	H (g,m)		L	H (p)		L						
Wheat grass									L			
Zucchini	M (fn)	L	L		L	L						
Dairy												
Brie	L	L	L		L	L						
Camembert	L	L	L		L	L						
Cheddar	L	L										
Cheese (fresh)	L		H (l)	H (l)	H	H						
Cheese (soft)	L			H (l)	H	H						
Cheese (hard)		L	L		L	L						
Ice cream	M (l)		H (l)	H (l)	H	H				L		
Lactose free milk	L	L	L		L	L						
Mozzarella	L	L			L							
Parmesan		L			L	L						
Whole milk	H (l)		H (l)	H (l)	H	H						

Yoghurt	H (l)		H (l)	H (l)	H	H			
Dairy substitute									
Coconut milk (canned)	L								L
Coconut milk (UHT)	H (fn)			H (p)					H (fn,s)
Coconut milk (with inulin)	H (fn)								H (fn)
Coconut yoghurt	L								L
Macadamia milk	L								L
Quinoa milk (agave sweetened)									H (f,fn)
Quinoa milk (unsweetened)	L								H (fn)
Rice milk	L	L				L			
Soy cheese	L								L
Soy milk	H	L			L				
Soy yoghurt (plain, vanilla)									H (fn)

Sweeteners, additives and seasonings										
Agar-agar	L							L		
Aspartame		L	L							
Corn syrup			H (f)	H (f)					L	
Fructose syrup			H (f)	H (f)					H (f)	
Garlic infused oil	L	L								
Glucose		L	L		L	L				
Gluten (fresh)								L		
Golden syrup	H (fn)	L				L				
Honey	H (f)		H (f)	H (f)	H	H			H (f)	
Maple syrup	L	L	L		L				L	
Molasses	H (f,fn)	L	L						L	
Stevia	L	L				L				
Sucrose	L	L	L		L	L				
Vegan substitutes										
Egg replacer	L							L		
Egg yolk (vegan)								L		
False bacon								H (g,fn)		
False pork								L		
False chicken								H (g)		

(soybean extract)		
False chicken (soybean)	H (g,fn)	H (g,fn)
False chicken (canned fried gluten)		L
False chicken (soy protein, soybean)		H (fn)
False chicken (gluten, soybean)		H (fn)
Others		
Kelp noodles	L	L
Kombucha	H (fn)	H (fn)
Kvass	L	L
Pea protein isolate	L	L
Rice protein		L

isolate

Rice protein isolate											
Soft drinks (light)				H (p)	H	H					H (f)
Sorbet		L	L			L					
Soy protein (textured)	H (g,fn)									H (g,fn)	
Spirulina	L									L	
Wakame flakes	M (m)									H (m)	
Wasabi (powder)	L							L			
Wheat gluten	L									L	
Yeast (nutritional)	L									L	

L: low FODMAP content; M: medium FODMAP content; H: high FODMAP content; G: galacto-oligosaccharides; o: oligosaccharides; f: fructose; fn: fructan; l: lactose; s: sorbitol; m: mannitol; p: polyols. Red color = disagreement between studies on FODMAP content; blue color = only one reference on FODMAP content; green color = agreement between studies on FODMAP content.

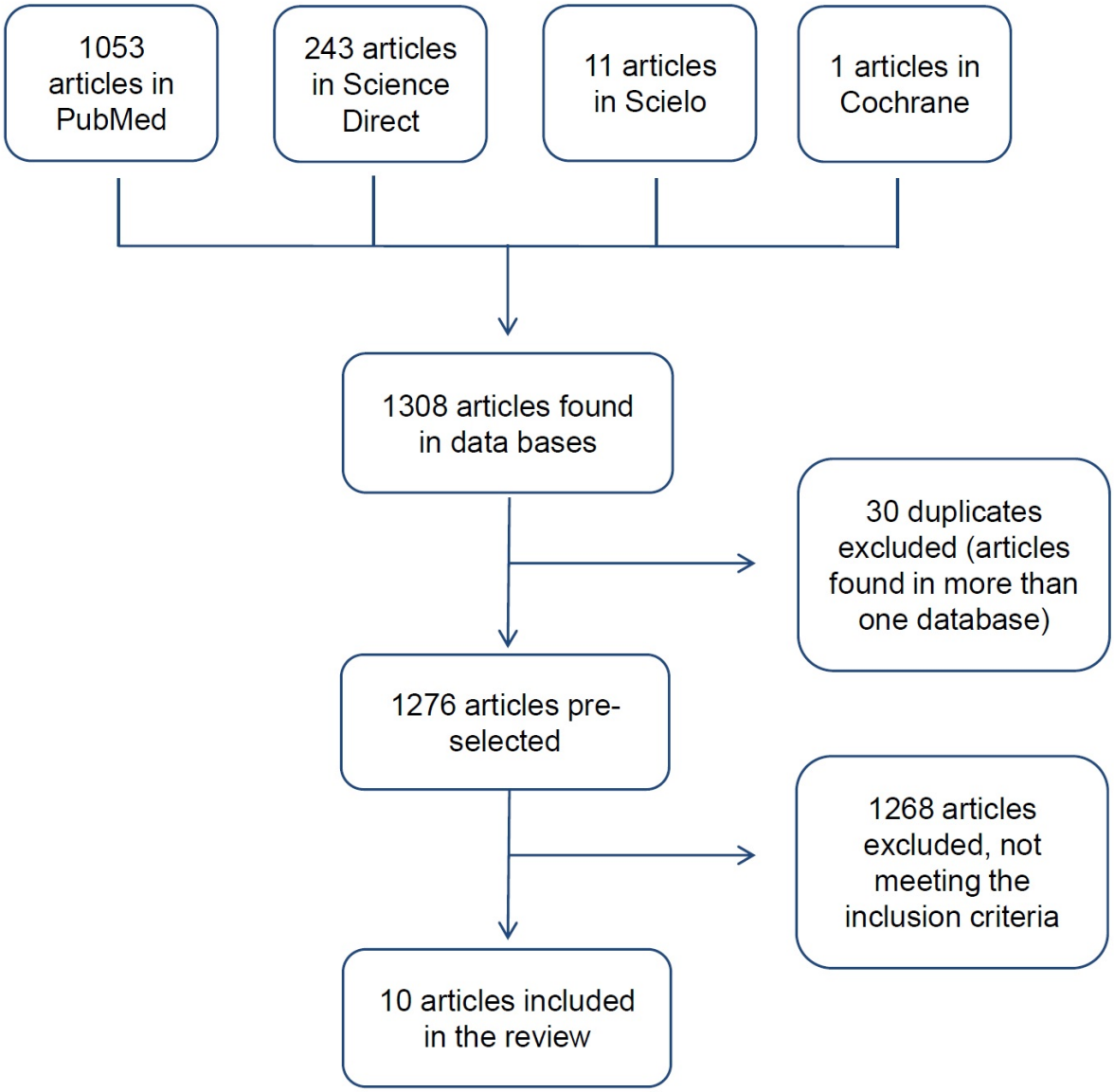

Fig. 1. Flowchart of selected studies.