REVIEW

CURRENT DEVELOPMENTS IN NUTRITION

Nutritional Epidemiology and Public Health

Eating for 2: A Systematic Review of Dutch App Stores for Apps Promoting a Healthy Diet during Pregnancy

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ABSTRACT

A healthy diet during pregnancy has been associated with beneficial child and maternal health outcomes but is challenging to achieve. Recent technological advances offer new opportunities to support pregnant women in their food choices—for instance, via apps. This is already reflected by a wide availability of pregnancy-related apps, but health care professionals feel unsure about their potential. Therefore, the Dutch Google Play Store and Apple App Store were reviewed to identify existing apps on diet and pregnancy. App quality was assessed using the *1*) Mobile App Rating Scale (MARS; i.e., assessing functionality, aesthetics, engagement, information quality), *2*) Dutch dietary guidelines for pregnant women, and *3*) App Behavior Change Scale (ABACUS). Fifty-seven unique apps were identified with an average star rating of 4.2 ± 0.6 and MARS quality score of 3.2 ± 0.3, indicating a moderate quality. Most apps scored best in terms of functionality and aesthetics (4.0 ± 0.4 and 3.3 ± 0.6), but lowest in terms of engagement (2.5 ± 0.6). Regarding nutrition information provision, most apps were incomplete or deviated from the Dutch guidelines. Folic acid supplementation (91%), hygiene (81%), caffeine (79%), and alcohol (77%) were the most commonly addressed nutrition aspects, whereas licorice (11%), iodine (19%), and soy (18%) were only addressed in a few apps. Moreover, a median of 2 out of 21 ABACUS behavior change items were identified per app, which were predominantly related to the category "knowledge and information." Thus, despite the abundance of apps supporting a healthy diet during pregnancy in the Dutch app stores, there is an urgent need for apps with complete and scientifically sound dietary information that is supported by effective behavior change techniques. *Curr Dev Nutr* 2022;6:nzac087.

Keywords: diet during pregnancy, mHealth, dietary assistance, mobile applications, apps, periconceptional diet, quality assessment, behavior change techniques, pregnancy

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Introduction

A balanced food intake during pregnancy is important for the mother as well as her unborn child (1). Despite multiple lifestyle interventions aiming to support women on health-related issues throughout pregnancy (2), approximately 70% of women worldwide gain either too much or too little weight during pregnancy (3). Thus, there is an urgent need for more effective strategies to support women towards healthier dietary choices, including the formulation of clear and scientifically based information on a healthy diet, and effective tool(s) to transfer the information. As a first step, the Dutch Health Council recently formulated dietary guidelines to reduce the risk of diet-related health problems in mothers and their newborns (4, 5). These guidelines are rather similar to the guidelines for the general adult population but include additional recommendations on vitamin A (liver products), isoflavones (soy products), fish (contaminants), vitamin D, folic acid, iodine, iron, and calcium (4).

In the Netherlands, midwives play a pivotal role in monitoring the health and well-being of mother and child in both primary and secondary care and are, as such, also often the first point of contact for pregnant women in case of nutritional concerns (6–8). Unfortunately, midwives have limited time and knowledge to address the aspect of healthy food choices, and, as such, nutritional counseling usually involves referral to websites, a brochure, an app developed by the Dutch Nutrition Centre (ZwangerHap), and minimal verbal counseling (9). As health care professionals, including midwives, are increasingly open towards digital innovations, mHealth is becoming more and more part of standard health care services (9, 10). Midwives in the Netherlands point out

TABLE 1 Inclusion criteria for apps

Inclusion criteria
Freely available in Dutch Google Play Store and/or Apple App Store (can contain in app-purchases or premium versions)
Targeted to pregnant women or women with a pregnancy wish
Contain dietary advice
In Dutch or English language
Compatible with current operating systems
App store rating of at least 2
At least 10 reviews
Not targeted to a specific group of pregnant women (e.g., specific cultures, comorbidities)

that apps need to be trustworthy, accessible, user-friendly, personalized, scientifically sound, and contain easily digestible information to be used in the health care system (9).

In recent years, various mHealth apps have been developed to support women throughout their pregnancy, which has proven to positively affect self-management (11, 12). In fact, of all health topics, most health apps on the market relate to pregnancy (13). An Australian study indicates that 73% of pregnant women use 1 or more pregnancy-related lifestyle apps (14), which were particularly effective in increasing fruit and vegetable intake and reducing gestational weight gain (15). Furthermore, a small Singaporean randomized controlled trial indicated that an mHealth intervention supported by dietitians beneficially affected gestational weight gain (16). Next to this, a Dutch intervention study using a mobile application proved effective in empowering women to improve their diet before and during early pregnancy (17). In contrast, an Australian study did not observe any added benefits of a nutritional mHealth tool on top of face-to-face consultation and printed materials (18). Thus, the effectiveness of apps seems to vary across studies, which may relate to different functionalities, information quality, target groups, study designs, and/or incorporated behavior change techniques (15, 16, 18–20).

Therefore, the aim of this study was to review available apps, in the Dutch Google Play Store and Apple App Store, focusing on promoting a healthy food intake before and during pregnancy with respect to their quality, accuracy, and effectiveness, in order to guide further innovation of currently available apps as well as newly developed apps. While similar studies have been performed in other countries (21–24), no such study has been performed in the Dutch app stores.

Methods

App identification

To identify apps providing dietary information for Dutch pregnant women and/or women who wish to have a child, a systematic review within the Dutch Google Play Store and Apple App Store was conducted between November 2020 and February 2021. Dutch and English search terms were used (i.e., pregnant, pregnancy, mother, food, diet, and nutrition), and apps in both the Dutch and English language were included. As the aim was to identify apps that are accessible to Dutch women, apps did not have to be specifically designed for Dutch women. Furthermore, apps needed to be compatible with current operating systems and freely available to all Dutch women; in app-purchases, such as premium versions, were allowed (**Table 1**). Apps were excluded if they received fewer than 10 ratings and/or the rating score was below 2 (25), to exclude apps that are likely rarely used and/or have very low quality. Apps focusing on specific cultural customs or diseases (e.g., gestational diabetes, stated Indian pregnancy advice) were excluded as these require specific dietary advice. Initial app screening was performed by 2 researchers (JPMF and MECB) based on the *1*) app title and *2*) app description. Next, selected apps were downloaded and screened again based on the inclusion criteria.

App evaluation

JPMF and MECB independently reviewed app quality, potential for behavior change, and implementation of Dutch dietary guidelines for pregnant women for all Dutch and English apps. Additionally, apps in Dutch were separately evaluated from English apps to specifically investigate apps more targeted to Dutch women. Characteristics of apps that were reported are as follows: app name, version, scope app, language, store rating, in-app purchases, affiliations, developer, country of developer, expert involvement, performed scientific evaluation, and possibility for diet registration. Expert involvement was determined based on app store description, information in app, or information on related webpage and was defined as involvement of scientific or health care experts in the field of nutrition or maternity care. App descriptions, information in app, and related webpages, if available, were screened to obtain information on whether an app was scientifically evaluated.

App quality was assessed using the Mobile App Rating Scale (MARS) (26), which assesses apps on 4 main components—"Engagement," "Functionality," "Aesthetics," and "Information quality"—by answering a variety of questions related to subtopics as stated in **Table 2**. Questions are scored on a 5-point scale. Following scoring for each component, an average was calculated, which resulted in a final score between 1 and 5. Major discrepancies between JPMF and MECB were discussed to identify the source of difference in judgment, and to further align the screening process, average scores were calculated based on scoring by the 2 researchers. The overall MARS quality score was calculated based on the mean of the 4 components.

Implementation of the Dutch dietary guidelines for pregnant women was evaluated according to the recently published guidelines by the Dutch Health Council (4), where dietary recommendations for pregnant women apply to women who wish to become pregnant as well (4, 5). For each app, the provided diet-related information was assessed based on completeness and correctness compared with the Dutch dietary guidelines. We scored for each component whether information was present [yes (1)/no (0)] and, if present, whether the information was complete [yes (1)/no (0)]. Completeness was defined based on

TABLE 2 Overview of MARS components and subcomponents[1]

MARS component	Subcomponent	Explanation
Engagement	- Entertainment	Fun, strategies to increase engagement
	- Interest	Presenting content in interesting way
	- Customization	Provide necessary settings for features
	- Interactivity	User input, provide feedback, prompts
	- Target group	Appropriateness for target group
Functionality	- Performance	Accurate/fast features app
	- Ease of use	Clear how to use the app
	- Navigation	Moving logical/appropriate between screens
	- Gestural design	Interactions consistent and intuitive
Aesthetics	- Layout	Arrangement and size appropriate
	- Graphics	Quality/resolution of graphics
	- Visual appeal	How appealing the app looks
Information quality	- Accuracy of app description	Does app contain what is described
	- Goals	Specific, achievable goals for app
	- Credibility	Legitimate source
	- Evidence base	Has app been trialed/tested
	- Quantity of information	Comprehensive but concise
	- Quality of information	Content correct, relevant, well written
	- Visual information	Explanation clear, logical, correct

[1] MARS, Mobile App Rating Scale.

important aspects of the guideline—for example, folic acid intake of 400 μg was recommended from time of wishing to become pregnant up until 10 weeks of pregnancy (see **Supplemental Table 1** for overview). If time periods or intake levels in the app were missing or different, the item was rated as "not completely in agreement with Dutch dietary guideline for pregnant women."

The potential for behavior change was assessed with the App Behavior Change Scale (ABACUS) (27, 28). The ABACUS contains items related to behavior change based on multiple other existing scales, with a particular focus on its suitability for use in apps. Main topics in the scale are "Actions," "Feedback and monitoring," "Goals and planning," and "Knowledge and information." The scale includes items such as "Distraction or avoidance," "Restructuring environment," and "Opportunities to plan for barriers." Items of the ABACUS are rated 0/1 whether they are not (0) or are (1) included in the app. The total number of items present in an app was calculated as well as the number of items per main topic (e.g., 5 items on ABACUS gives a score of 5). A higher ABACUS score theoretically reflects a higher potential for behavior change (27). Also, the number of apps that include at least one item per main topic was calculated.

Quality assessment of the apps was performed in June and July 2021. An Apple iPhone SE (iOS 14) was used to search the Apple App Store, while a Huawei P10 Lite (Android 11) and a Samsung Galaxy J3 (Android 11) were used to search the Google Play Store. Subsequent descriptive data analyses of final scores were performed in Excel. Results are displayed as frequencies, percentages, means ± SDs, and medians ± IQRs depending on the data.

Results

Systematic searches in the Google Play Store and Apple App Store yielded 1060 and 714 apps, respectively. All apps were screened on title and description, after which 124 apps were downloaded and screened according to the inclusion criteria. This resulted in 68 apps, of which, after exclusion of duplicates, 57 were included in the review. Of these 57 apps, 10 were available in Dutch and 47 in English (**Figure 1**). Four apps focused on preconception, of which 2 focused on diet. Fifty-three apps focused on pregnancy, of which 11 had a specific focus on diet. The average Google Play Store and Apple App Store rating of the 57 included apps was 4.2 ± 0.6 (scale 1–5). Fourteen apps (25%) offered in-app purchases and 4 apps (7%) an extended paid premium version (**Table 3**). In total, 47 apps (82%) had unknown affiliations, while 8 (14%) had commercial affiliations and 2 (4%) were developed in commission of a nonprofit organization (health education). Six (11%) apps were developed in the Netherlands, 10 (18%) in other European countries, 12 (21%) in Asia, 5 (9%) in North America, and 1 (2%) in Australia. For the remaining 23 apps (40%), no country of development could be determined. A total of 13 apps (23%) were created in consultation with experts in the field (e.g., midwives, gynecologists, nutritional experts, pedagogues, and general practitioners). None of the apps were scientifically evaluated. All apps particularly focused on physical health and information provision related to the pregnancy process and actions that mothers can undertake during all stages of pregnancy. None of the apps facilitated individual food intake registration such as a food diary or recall. The dietary information provision varied between apps, ranging from only mentioning some products to avoid during their pregnancy to providing a detailed diet plan per week. Among apps in the English language, most had unknown affiliations ($n = 44$, 94%) or unknown country ($n = 22$, 47%) of development, compared with Dutch apps ($n = 4$, 33%, and $n = 1$, 8%, respectively). Also, expert involvement was lower for English apps ($n = 6$, 13%) compared with Dutch apps ($n = 7$, 70%). An overview of all included apps can be viewed in **Supplemental Table 2**.

MARS

App quality according to the MARS demonstrated an average quality score of 3.2 ± 0.3 on a scale from 1 to 5, with a range of 2.4 to 4.1 (**Table 4**), indicating moderate quality. In general, apps scored highest on "Functionality" (4.0 ± 0.4), followed by "Aesthetics" (3.3 ± 0.6). The

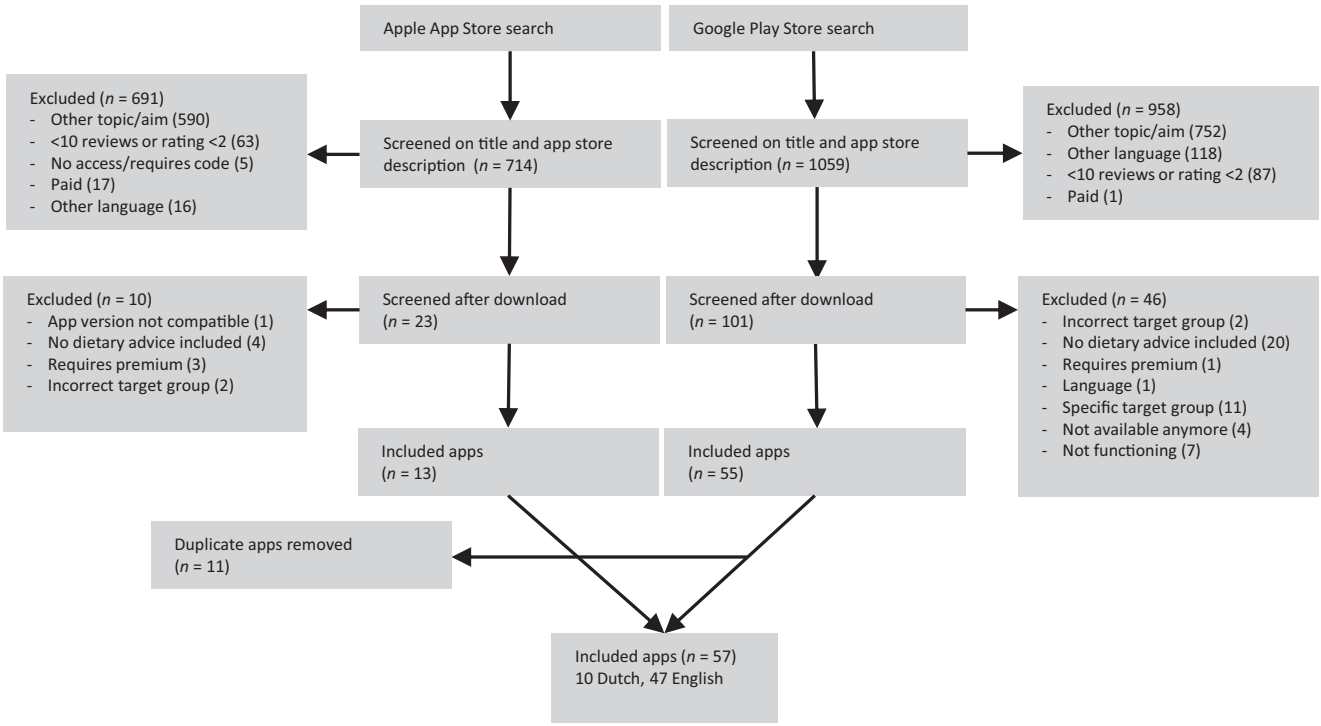

FIGURE 1 Flow diagram on app selection.

lowest average score was on "Engagement" (2.5 ± 0.6). Dutch apps had an average score of 3.6 ± 0.4, while English apps scored 3.1 ± 0.3. The largest difference in scores between Dutch and English apps was observed for "Aesthetics."

Dietary recommendations

All apps provided dietary information mainly through text or videos. Folic acid supplementation (n = 52, 91%), hygiene (n = 46, 81%), caffeine intake (n = 45, 79%), and alcohol consumption (n = 44, 77%) were covered by most apps (**Table 5**). Iodine (n = 11, 19%), soy products (n = 10, 18%), and licorice (n = 6, 11%) were covered by only a few apps. Topics related to food safety were often mentioned, such as hygiene (n = 46, 81%) and contaminants (n = 42, 74%). As expected, Dutch apps were more likely to cover the topics of the Dutch dietary recommendations compared with English apps. To illustrate, the topic of vitamin A was covered by 80% (n = 8) of Dutch apps and 40% (n = 19) of English apps, and the topic of fish was covered by 70% (n = 7) of Dutch apps and 47% (n = 22) of English apps. Conversely, there were also topics that were more often covered by English apps than Dutch apps—that is, caffeine (83% vs. 60%, respectively), calcium (74% vs. 60%, respectively), and iron (68% vs. 60%, respectively).

Most topics mentioned in the apps were incomplete or differed from the Dutch dietary guidelines. For instance, while 52 apps (91%) mentioned folic acid supplementation, only 13 (23%) provided complete information, which predominantly related to deviating from recommended intake levels or time periods to use it. In agreement, iron was mentioned in 38 apps (67%), but only 2 apps (4%) implemented the guidelines correctly. The information on alcohol consumption was quite consistent between apps; 44 apps (77%) addressed this, of which 41 (93%) provided complete and correct information. Strikingly, a small number of apps (n = 3) indicate that (some) alcohol consumption is allowed.

ABACUS

Of the 21 behavior change items of the ABACUS, 13 items were applied in at least 1 of the reviewed apps. Overall, the median number of ABACUS items in the apps was 2 (IQR = 2); the median number of items was 3 (IQR = 2) for Dutch apps and 2 (IQR = 2) for English apps. The addressed behavior change items were particularly related to transferring knowledge or information, including "Instruction on how to perform the behavior" (n = 45, 79%), "Information about the consequences of continuing and/or discontinuing behavior" (n = 30, 53%), "Consistent with national guidelines or created with expertise" (n = 13, 23%), and "Baseline information" (n = 10, 18%). The other 3 main topics—"Goals and planning" (n = 1, 2%), "Feedback" (n = 11, 6%), and "Monitoring and actions" (n = 6, 11%)—were only implemented in a limited number of apps (**Figure 2**). Some items were not used in any of the apps (e.g., "General encouragement" and "Self-monitor behavior").

Discussion

Our systematic review of diet-related pregnancy apps available in Dutch app stores resulted in the identification of 57 unique apps. Evaluation of the apps showed that *1*) apps had a moderate overall quality (i.e., engagement, functionality, aesthetics, information quality), *2*) apps contained basic dietary information with limited details, and *3*) the implementation of behavior change techniques is still limited. Compared with

TABLE 3 Overview of app characteristics

	All apps ($n = 57$)	Apps in Dutch ($n = 10$)	Apps in English ($n = 47$)
App store rating (mean ± SD)[1]	4.2 ± 0.6	4.2 ± 0.8	4.3 ± 0.5
Available store, *n* (%)			
- Apple App Store only	2 (4%)	0 (0%)	2 (4%)
- Google Play Store only	44 (77%)	3 (30%)	41 (87%)
- Both stores	11 (19%)	7 (70%)	4 (9%)
Scope, *n* (%)			
- Preconception	4 (7%)	0 (0%)	4 (9%)
- Diet	2 (4%)	0 (0%)	2 (4%)
- Pregnancy	53 (94%)	10 (100%)	43 (91%)
- Diet	11 (19%)	1 (10%)	10 (21%)
In-app purchases, *n* (%)	14 (25%)	5 (50%)	9 (19%)
Paid premium version, *n* (%)	4 (7%)	4 (40%)	0 (0%)
Affiliations, *n* (%)			
- Unknown	47 (82%)	4 (40%)	43 (91%)
- Commercial	8 (14%)	5 (50%)	3 (6%)
- Nonprofit organization	2 (4%)	1 (10%)	1 (2%)
Place of development, *n* (%)			
- Unknown	23 (40%)	1 (10%)	22 (47%)
- Netherlands	6 (11%)	6 (60%)	0 (0%)
- Europe	10 (18%)	3 (30%)	7 (15%)
- Asia	12 (21%)	0 (0%)	12 (26%)
- North America	5 (9%)	0 (0%)	5 (11%)
- Oceania	1 (2%)	0 (0%)	1 (2%)
Expert involvement, *n* (%)	13 (23%)	7 (70%)	6 (13%)

[1]For apps that were available in both Google Play Store and Apple App Store, the Google Play Store score was used to calculate averages.

English apps, Dutch apps had higher quality scores, more often correctly implemented the Dutch dietary guidelines, and included more behavior change features.

Our findings are in agreement with 2 studies by Brown and colleagues (21, 22), who recently conducted a similar review in pregnancy apps in the Australian Apple App Store and Google Play Store. In their review they reported mean MARS scores of 3.1 ± 0.7 ($n = 51$) for apps identified in the Apple App Store and 3.5 ± 0.6 ($n = 76$) for apps identified in the Google Play Store (21, 22). In agreement with our findings, apps in both Australian app stores scored best on "functionality" (3.3 and 4.1 ± 0.7) (21, 22), and apps in the Australian Google Play Store scored least well on "engagement" (3.3 ± 0.8) and "information" (3.2 ± 0.7) (22). In contrast to our findings, apps in the Australian Apple App Store scored poorest on aesthetics (2.9). In a recent study by Brunelli and colleagues (23), the MARS scores of pregnancy apps in the Italian Apple and Google Play Store were comparable to our study, with the highest median score for functionality (median = 4.0) and the lowest median score for engagement (median = 3.0). Overall, the aspects "engagement," "information," and "aesthetics" require further attention. Co-creating mHealth applications with stakeholders could provide valuable information on users' needs, wishes, and abilities to further develop current tools (29).

Our findings with respect to dietary information quality showed a broad variety of recommendations, which substantially differed over apps in terms of completeness, accuracy, and level of detail. This difference in dietary information quality is also observed for other pregnancy apps from other countries. For example, a review of 29 pregnancy apps, available in the United Kingdom's Google Play and Apple App Store, also concluded that there was a large variability in quality of nutritional information (24). Some of these apps provided conflicting information—for example, encouraged liver consumption to obtain enough iron, but did not stress the risk of an excessive vitamin A intake. Moreover,

TABLE 4 Results from the MARS evaluation, providing overall mean score ± SD[1]

	All apps ($n = 57$)	Apps in Dutch ($n = 10$)	Apps in English ($n = 47$)
MARS scores (mean ± SD)			
1. Engagement	2.5 ± 0.6	3.1 ± 0.4	2.4 ± 0.5
2. Functionality	4.0 ± 0.4	4.1 ± 0.4	4.0 ± 0.4
3. Aesthetics	3.3 ± 0.6	3.8 ± 0.5	3.2 ± 0.6
4. Information	3.0 ± 0.3	3.4 ± 0.5	2.9 ± 0.3
Overall	3.2 ± 0.3	3.6 ± 0.4	3.1 ± 0.3

[1]MARS, Mobile App Rating Scale.

TABLE 5 Results from evaluation of nutritional information provided in apps

	Apps that mention topic, *n* (%)			Apps that include information partly correct/complete,[1,2] *n* (%)			Apps that include topic completely correct,[1,2] *n* (%)		
Dietary advice	**All**	**Dutch**	**English**	**All**	**Dutch**	**English**	**All**	**Dutch**	**English**
Energy intake	35 (61)	8 (80)	27 (57)	32 (91)	7 (88)	25 (93)	3 (9)	1 (12)	2 (7)
Weight gain	35 (61)	7 (70)	28 (60)	22 (63)	4 (57)	18 (64)	13 (37)	3 (43)	10 (36)
Folic acid	52 (91)	9 (90)	43 (91)	39 (75)	4 (44)	35 (81)	13 (25)	5 (56)	8 (19)
Vitamin D	27 (47)	6 (60)	21 (45)	18 (67)	1 (17)	17 (81)	9 (33)	5 (83)	4 (19)
Vitamin A	27 (47)	8 (80)	19 (40)	23 (85)	8 (100)	15 (79)	4 (15)	0 (0)	4 (21)
Iodine	11 (19)	2 (20)	9 (19)	10 (91)	2 (100)	8 (89)	1 (9)	0 (0)	1 (11)
Calcium	41 (72)	6 (60)	35 (74)	29 (71)	4 (67)	25 (71)	12 (29)	2 (33)	10 (29)
Iron	38 (67)	6 (60)	32 (68)	36 (95)	5 (83)	31 (97)	2 (5)	1 (17)	1 (3)
Herbs	23 (40)	7 (70)	16 (34)	8 (35)	1 (14)	7 (44)	15 (65)	6 (86)	9 (56)
Caffeine	45 (79)	6 (60)	39 (83)	25 (61)	3 (50)	22 (56)	20 (44)	3 (50)	17 (44)
Licorice	6 (11)	3 (30)	3 (6)	1 (17)	1 (33)	0 (0)	5 (83)	2 (67)	3 (100)
Alcohol	44 (77)	10 (100)	34 (72)	3 (7)	0 (0)	3 (9)	41 (93)	10 (100)	31 (91)
Fish	29 (51)	7 (70)	22 (47)	25 (86)	4 (57)	21 (95)	4 (14)	3 (43)	1 (5)
Soy products	10 (18)	3 (30)	7 (15)	8 (80)	1 (33)	7 (100)	2 (20)	2 (67)	0 (0)
Hygiene	46 (81)	9 (90)	37 (78)	40 (87)	6 (67)	34 (92)	6 (13)	3 (33)	3 (8)
Contaminants	42 (74)	9 (90)	33 (70)	26 (62)	6 (67)	20 (61)	16 (38)	3 (33)	13 (39)

[1]Percentages are calculated taking as total the number of apps that included this topic.
[2]Completeness was scored based on overview shown in Supplemental Table 2.

multiple apps focused on food safety topics and what you should and should not eat (e.g., alcohol consumption, caffeine consumption and fish and mercury consumption), which has also been indicated in previous reviews (21, 22, 24). Differences in the level of detail may relate to the aim and scope of the app. More specifically, whereas various apps provide information on a broad range of aspects related to pregnancy, other apps are particularly focused on dietary aspects and are already more detailed in terms of dietary advice "by nature." Differences in dietary information quality ratings of the apps in this study may also relate to the implemented national guidelines, as almost half of the reviewed apps were not developed in the Netherlands (30). Moreover, 77% of the reviewed apps in our review lacked expert involvement (i.e., dietitians, nutritionists, midwives, gynecologists) and 47 (82%) apps had unknown affiliations, which may affect the reliability and quality of provided dietary information (10, 21, 24, 31). As dietary guidelines may differ across countries, Dutch pregnant women will benefit most from apps that are specifically developed for them. However, for many apps, the intended target user was unclear (e.g., some apps were translated from another language). The availability of varying dietary information for Dutch pregnant women indicates a need for clear guidelines and regulations for dietary apps available in app stores. Currently, in contrast to medical apps, no (European Union) regulations for health and lifestyle apps exist to stimulate app developers to ensure reliability of provided

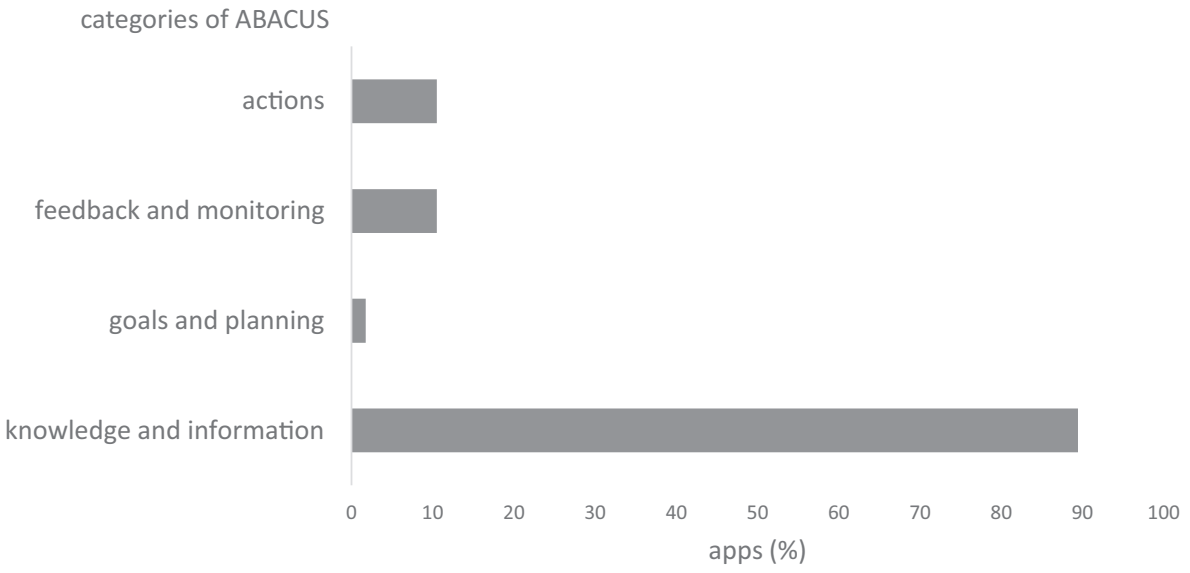

FIGURE 2 Percentage of apps that include behavior change techniques by categories of ABACUS. ABACUS, App Behavior Change Scale.

information; expert involvement, scientific foundation, and indication of app target user are crucial to provide appropriate, trustworthy dietary information of high quality in apps.

Similar to our findings, Brown et al. (21) showed a median of 3 out of 40 behavior change techniques of the CALO-RE taxonomy in 51 iPhone diet-related pregnancy apps. Of note, ABACUS contains specific items focused on apps compared with the CALO-RE taxonomy, which was designed for general lifestyle-related behavior change (27). Similar to Brown and colleagues (21), we observed that "Instruction on how to perform the behavior" and "Information about the consequences of continuing and/or discontinuing behavior" were the most frequently adopted behavior change strategies in pregnancy apps. These are relatively easy-to-implement behavior change techniques with a one-size-fits-all approach. In contrast, interactive and personalized guidance strategies [e.g., self-monitoring, prompts/cues, social support (32)] were hardly implemented, even though these are considered effective strategies to improve dietary behaviors. To illustrate, Celis-Morales and colleagues (33) showed that studies using "barrier identification/problem solving," "plan social support/social change," "goal setting," "use of follow-up prompts," and "provide feedback on performance" were more successful in improving fruit and vegetable consumption compared with studies not using these techniques. Moreover, a recent review of 19 randomized controlled trials showed that personalized web-based nutrition interventions were more effective for improving diet compared with standardized web-based interventions (34). A randomized controlled trial among pregnant women in the Netherlands receiving personalized dietary assistance appeared to be beneficial in improving dietary behavior (17). Goals and planning and feedback and monitoring appeared to be effective strategies to improve diet and physical activity among pregnant women in a systematic review of 11 studies (35), thus highlighting the need for a more personalized and interactive approach towards dietary behavior change among pregnant women.

A strength of this study is that this is the first study to evaluate nutritional pregnancy apps available in the Dutch Google Play and Apple App Store. Furthermore, app assessment was conducted independently by 2 researchers, using the recently published Dutch dietary guidelines and supported by commonly used and validated methods (4, 26, 27). The MARS is a widely used mHealth quality-rating tool developed by an expert multidisciplinary team (26, 36). ABACUS was specifically developed by health promotion experts for the assessment of behavior change potential of apps. A limitation of this study may be that only freely available apps were included, which may have led to the exclusion of apps of higher quality and more expert involvement. Apps with low app store ratings and reviews were excluded from this review. However, due to this exclusion criterion, some recently released—not yet rated—apps of good quality may also have been excluded. App evaluation was performed by 2 researchers from the same institution, potentially resulting in biased results. Furthermore, it should be emphasized that dietary information quality was evaluated using the recently updated guidelines in 2021 (4), which may have resulted in lower dietary information scores as compared with scoring based on former guidelines. However, a large part of the guidelines remained the same and therefore no large differences are expected. To note, as more than half of the apps were not in the Dutch language, the adherence to guidelines might appear low because apps adhered to guidelines from other countries. Another potential limitation of this study is that ABACUS was specifically developed for the assessment of behavior change potential of apps focusing on physical activity and not diet (27), although similar behavior change techniques can and are used in mHealth to target physical activity and dietary behaviors (37). Therefore, the scale is considered to be relevant for the evaluation of diet-related apps as well. Moreover, ABACUS rates behavior change potential on the number of behavior change techniques used, but as correct practical implementation is crucial, this does not necessarily reflect the actual effectiveness of an app (38). Behavior change techniques should fit the target behavior and individual characteristics to be optimally effective (27). Therefore, randomized controlled trials are still essential to evaluate the actual effectiveness of a (dietary) behavior change app (27).

Currently, mHealth is becoming increasingly popular among pregnant women as it is low in cost and easily accessible (10). However, app quality and effectiveness are still suboptimal. Diet-related pregnancy apps from the Dutch Apple App Store and Google Play Store were, in general, of moderate quality, contained limited behavior change features, and provided incomplete dietary information, and only a few were created with nutritional expertise. Use of these freely available apps suboptimally supports pregnant women in their goal to adopt a healthier diet. To optimize trustworthiness and effectiveness of diet-related pregnancy apps, it is crucial to involve pregnancy (care) and nutrition experts in the developmental process from an early stage. Involving the target users in the design steps is important as well to improve engagement and effectiveness by providing information based on needs and abilities of users. Effectiveness could be further enhanced by facilitating personalization of the app—that is, implementing interactive behavior change techniques that can be tailored to the individual. Last, international regulations are required to improve transparency, reliability, and quality of apps including dietary information available in app stores.

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Data Availability

Data described in the manuscript, code book, and analytic code will be made available upon request pending application to and approval from the corresponding author.

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