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"Let me recommend…. " – Use of digital nudges and recommender systems for obesity prevention – a scoping review protocol

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Abstract

Introduction: Recommender systems and digital nudges increasingly determine our lives. The combination of digital nudges and recommender systems is very attractive for its application for overweight and obesity prevention. However, linking recommender systems with personalised digital nudges has a potential that has not yet been fully exploited. Therefore, the scoping review aims to identify which digital nudges and recommender systems have been used in obesity prevention and whether they have been combined and to map the tools according to target group, behaviour targeted, nudge classification, mechanisms utilised, delivery channel, personalisation, interconnection, used combination, and implementation.

Methods and analysis: The PRISMA-P guidelines for protocol development and the PRISMA-ScR guidelines for scoping reviews were. The eligibility criteria are linked to our scoping reviews' objectives and informed by the PCC framework. MEDLINE, PsycINFO, Web of Science, CINHAL, Scopus, ACM Digital Library, and IEEE Xplore will be searched until September 2023. Primary studies with any design published in peer-reviewed academic journals and peer-reviewed conference papers in ACM Digital and IEEE will be included. Data will be extracted into a pre-tested extraction sheet. To assess the quality of the included studies, the CASP Appraisal checklist will be used. Results will be synthesised descriptively and narratively.

Ethics and dissemination: No ethical approval for the scoping review is required, as data will be obtained from publicly available materials. The results of this scoping review will be published in a peer-reviewed journal, presented at conferences and inform the co-creation process and intervention adaptation of the HealthyW8 project.

Keywords

Digital nudges, recommender systems, obesity prevention, diet, nutrition, physical activity, healthy lifestyle

Article Summary: Strengths and limitations

- The Scoping review systematically maps digital nudges and recommender systems currently used in overweight and obesity prevention.
- The work uses a rigorous interdisciplinary approach, combining social and natural sciences, economics, engineering and computer science expertise.
- Studies that do not name digital nudges or recommender systems in titles, abstracts, or keywords will not be located in the database search.

Background

Recommender systems increasingly determine our lives. Whether it's shopping online, series watching on streaming platforms, music selections, or recipes for the next family meal - recommendation systems suggest products, make recommendations and show new ideas.
Based on Jesse et al. 2021 [3], recommendation systems can be classified as digital nudges because the algorithm allows, for example, to emphasise or hide information, simplify the presentation of information, enable social influence, suggest alternatives, have an ordering effect or increase the salience of incentives. These systems determine different aspects of the choice architecture for users, serving as information filters or providing suggestions for relevant content [3 4]. They significantly impact the online user experience by influencing which information is easily accessible and affecting decision-making processes [5]. Although recommender systems and digital nudging have been investigated separately, there is a vast potential to integrate further nudging mechanisms into recommender systems to influence user decision-making. By leveraging the power of digital nudging, recommender systems can enhance their ability to guide users' choices and preferences.

Nudges and digital nudges are similar in that they both aim to guide people's behaviour towards desirable choices. However, the main difference lies in the context in which they are applied. Nudges refer to any form of choice architecture that triggers behaviour, while digital nudges specifically focus on choice architecture in digital environments [6]. Following the literature, we define digital nudges as events where digital artefacts steer people in particular directions while allowing them to go their way. They differ mainly from conventional nudges because they target choice architectures in virtual environments, can be highly personalised and interconnected, and provide immediate feedback on choices [7-9]. The concept of digital nudging addresses the limitations of bounded rationality in virtual environments and aims to nudge users digitally toward preferential choices. They leverage user interface and design elements to influence decision-making processes in online environments [10]. They can be used in various digital contexts such as social media, mobile apps, e-commerce, or online food retail. Digital nudges can help users make more conscious decisions, whether it is reducing online news consumption [11], increasing physical activity levels [9], or promoting climate-friendly food choices [12].

Digital nudges have become increasingly relevant as more decisions are made in digital contexts [13]. Due to the possibility of personalising digital nudges based on real-time data (e.g., sensor data) and using interconnectivity, digital nudges are highly interesting for health research. They are particularly valuable for tracking individual behaviour over time to detect behaviour change as they combine various data sources. Firstly, they enable real-time data collection by multiple systems (e.g. GPS, sensors, shopping data, user actions). The data can be combined with the system's recommendations on already known data (e.g. age, preferences). This combination of real-time data with preferences allows for dynamic personalisation of each user's decision architecture, including feedback, monitoring and more. Furthermore, interconnectivity allows one user's decision to influence another user's decisions directly.

This makes the combination of digital nudges and recommender systems very attractive for its application for obesity prevention [8] as wearable technology, chatbots, and gamification can be combined to provide personalised feedback to prevent weight gain and maintain a healthy weight [14]. Linking recommender systems with personalised digital nudges is a potential that has not yet been fully exploited and should be used in obesity prevention. Obesity prevention is a highly important topic

as currently obesity, defined by the WHO as having a body mass index greater than 30, was linked to 5.02 million deaths globally in 2019, according to the Global Burden of Disease study [15].

Several review articles have shed light on various aspects of digital nudging, such as categorisation [3 16], psychological underpinning [17-19], and the use and application of digital nudges in specific areas [3 7 8 20-22].

Bergram et al. (2022) reviewed types of digital nudges. The different digital nudges were analysed based on, e.g., digital nudge patterns, outcome, context, evaluation, but also personalisation, interconnectivity and mode of delivery [8]. However, the context domain is only labelled as health (n=3 studies) and recommender system (n=4 studies) without giving specific context on the behaviour targeted with these studies. Further, Jesse et al. developed a taxonomy to code digital nudges, combining the work of others based on the category and the included nudging mechanism [16 23-25]. However, the context of the system was not specified in this work either [3].

Aims and Objectives

Therefore, the scoping review aims to identify which digital nudges and recommender systems have been used in obesity prevention and whether they have been combined. (Figure 1).

Obesity prevention is defined broadly as overweight and obesity prevention, covering weight reduction and weight management, preventing weight gain or stabilising treatment effects. Further, while the development and treatment of overweight and obesity are multifactorial, decreased energy expenditure is considered one of the most important determinants of reduced body weight [26]. Physical activity (PA) is the most modifiable factor in energy expenditure; it represents approximately 25% of total spending and, as such, is a powerful lever to improve the energy balance equation [27] in combination with a healthy diet. This is why having a high level of PA is associated with a lower BMI and measured body fat, even after controlling for genetic factors and, e.g., childhood environment [28 29]. Therefore, we included physical activity promotion and sedentary behaviour reduction in the overall definition of overweight/obesity prevention.

The detailed objectives of this scoping review are therefore:

1) to identify digital nudges and recommender systems for obesity prevention and PA promotion or sedentary behaviour (SB) reduction
2) to map the digital nudges and recommender systems according to target group, behaviour (diet/PA/SB), nudge classification, mechanisms utilised, delivery channel, personalisation, interconnection, used combination of nudges, and implementation

Methods

The scoping review method is used to map the literature to synthesise existing knowledge, identify key characteristics from the body of literature, and identify gaps [30]. As we aim for a broader overview of digital nudges and recommender systems, e.g., for which target group they are used in what way, our research question is not as targeted for feasibility, appropriateness, meaningfulness or effectiveness as in systematic reviews [30].

Study design

The protocol follows the PRISMA-P checklist for developing and reporting review protocols [31 32]. The scoping review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA): Extension for Scoping Reviews (PRISMA-SCR and flowchart) [33]. We use a flow diagram for a transparent report of the information flow in the scoping review. The flow diagram depicts the flow of information through the different phases of our review. It maps out the number of records identified, included and excluded and the reasons for exclusions.

Protocol and Registration

This protocol was written before the study commenced (before the screening process was performed). The study was registered at the Open Science Framework[34].

Eligibility Criteria

The eligibility criteria are directly linked to our scoping review objectives and informed by the PCC framework [2]. PCC is defined as P: population or target group, C: concept and C: context [30] (Fig. 1). Table 1 provides an overview and example of the eligibility and exclusion criteria (Table 1).

Figure 1: Relationship between research objectives, question and eligibility criteria (adopted from Feo et al. (2020), Pollock et al. (2021) [1 2]

Table 1: Eligibility and exclusion criteria for the scoping review

PCC	Inclusion Criteria	Exclusion Criteria
Population	Any population groups (children or adults; healthy, at risk for chronic diseases, clinical samples)	If overweight/obesity/PA/SB, as defined above, is not the primary aim of the target group
Concept	Digital nudges or recommender systems	Studies that use digital nudges or rely on recommender systems but do not name them accordingly in the title, abstract or full-text
Context	Any geographical setting Obesity prevention (e.g., nutrition, food recipes, grocery stores, meal preparation, PA promotion, SB prevention)	Digital nudges/recommender systems, e.g., blockchain, finances, security, privacy, agriculture, service, e-commerce

We will include all study designs as we aim to identify primary studies with any design (randomised or nonrandomised with quantitative or qualitative data).

All languages will be included in the initial search as English titles and abstracts are available for journals that publish in the national language due to the specifications of the literature databases for

indexing articles. During the full-text screening, we will exclude studies not published in English unless the language expertise is available in the review team. We will mark them accordingly to record the number of publications excluded due to language constraints.

We will also include peer-reviewed conference papers from ACM Digital Library and IEEE Xplore due to the different publication traditions in computer science and engineering.

Books, reports, pre-prints, project reports, unpublished work and grey literature (non-peer reviews work) will not be included.

Search strategy

MEDLINE and PsycINFOS via Ovid, Web of Science, CINHAL via Ebsco, Scopus, ACM Digital Library, and IEEE Xplore are searched for the scoping review up to September 2023. The search strategy for MEDLINE is available in Supplementary File 1. The electronic search strategy was developed and tested with feedback from all authors based on their specific expertise in collaboration with an experienced librarian on our team who also performed the search and deduplicated the results.

An iterative technique adapted from JBIs' three-step approach was used to develop the search strategy [35 36]. A preliminary search has been done in MEDLINE based on an initial set of key terms. The retrieved papers were reviewed regarding their topical fit. Keywords, synonyms and index terms were identified from the retrieved papers and used to revise the search strategy. The revised search strategy was discussed with all the experts involved to ensure that the content was fitting and that the specifics of the disciplines were considered. A second search was undertaken across all included databases using all identified keywords and index terms. Retrieved papers were tested according to their topical fit. A third step will be screening the reference lists with all included full-text papers.

Our research librarian implemented the following aspects of the search syntax development: (1) quality of translation of the research question into search terms done by inspecting the number of hits per syntax line, (2) appropriate use of adjacency proximity operators done by comparing the number of hits following different adjacency limits, (3) choice of subject headings done by inspecting the number of hits per syntax line, (4) text word searching done by inspecting the truncation and inclusion of British and American spellings, and (5) spelling and any syntax errors done by reading the syntax strategy line by line and inspecting the use of Boolean operators and brackets. We adhered to the PRESS guideline (Peer Review of Electronic Search Strategies) [37].

Keywords used for the search strategy include variations of digital nudges, recommender systems combined with aspects of weight management, physical activity, sedentary behaviour, diet, food, nutrition and their synonyms. Keywords were combined with the following subject terms (Table 2):

Table 2: Subject terms used

MeSH	PsycInfo subject headings	CINAHL subject headings
overweight	overweight	
obesity	obesity	obesity
physical activity	physical activity	physical activity

sedentary behavior	sedentary behavior	life style, sedentary
food	food	food
diet	diets	diet

Bibliographies of included studies will be manually screened for additional studies.

Engagement with Experts

A "crowd-sourced" element will be used to expand the search for suitable articles by posting the search on the Twitter and LinkedIn accounts of the involved institutions (e.g., BIPS, EE) and on the HealthyW8 website, Twitter and LinkedIn accounts to raise awareness and ask for suggestions for articles that may need to be included in the screening process.

Study selection process

The resources located in the search will be imported into Endnote 20 for deduplication. In EndNote, duplicate entries will be eliminated, first within each database and then across databases. The deduplicated dataset is subsequently imported into Rayyan. The software will be used for managing the title/abstract and the full-text screening. Titles, abstracts, and full texts will be screened independently according to the inclusion and exclusion criteria by at least two researchers. All conflicts are discussed. If no agreement can be reached, another researcher not involved in the screening process will be consulted.

A summary of the study selection will be reported on the PRISMA flowchart. A list of included and excluded studies and reasons for exclusion after the full-text assessment will be reported.

Data Items

Independent reviewers will systematically extract data from eligible articles. A data extraction sheet will be developed to address our scoping review questions. A first overview of the items and their characteristic is shown in Table 3. The data extraction sheet in Excel will be pre-tested beforehand based on three randomly selected studies from the included studies to standardise data extraction. The qualitative information on the data items will be extracted from the articles into Excel. In the next step, these data will be processed by quantifying them into categories developed deductively from the scoping review objectives or inductively from the date. The processed data will be checked and discussed by another researcher.

Table 3: Preliminary data items to be extracted

Data items	Characteristics
Meta-Data	First author, year of publication, country, application domain (nutrition/PA/SB) [16 38], nudge, recommender system, combination
Intervention characteristics	Study design, population, sample size, dose, nudge combination
Delivery channel	Mode of delivery (delivery channels (visual, audio, haptic) and delivery devices (e.g., desktop, mobile, wearable, ambient) [8]

Classification of nudges	Social nudges (guide the user's behaviour by providing references to how other users behave), reinforcement nudges (reinforce behaviours and choices by increasing their salience in the mind of the user), disclosure nudges (adding information that is accessible, clear, and relevant to the choice that the user is about to make), friction nudges (encouraging or discouraging behaviour by removing or adding friction), feedback nudges (information about a past or current behaviour of a user), default nudges (assumed desired behaviour), warning nudges (different kinds of warnings and graphics to grab attention), scarcity nudges (information that something is difficult to acquire), deception nudges (affect how users perceive choice alternatives), commitment nudges (to motivate the user to behave) [8 38 39]
Nudging mechanisms	Decision information (Translate information, increase the salience of information, make information visible, change phrasing of information) Decision structure (change range of composition, change choice defaults, change option consequences, change option-related effort) Decision assistance (provide reminders, facilitate commitment) Social decision appeal (increase the reputation of the messenger, provide a social reference point, instigate empathy) [3]
Personalisation	No, partial (study gathers user data (e.g., location, user demographics, user actions) to infer the potential influence of the nudge on user behaviour), full (such information is used to personalise the choice architecture of individual users dynamically) [8]
Interconnection	No, partial (study investigates how information from other users affects user behaviour), full (study investigates how actions of one user, in turn, dynamically modify the choice architecture of other users) [8]
Implementation information	Any information about implementation and user engagement
Effects	Primary outcome: outcomes related to weight, weight management, PA/SB Secondary outcome: outcomes related to mental health, user engagement, user satisfaction

Study Quality Assessment

We expect to find studies with different study designs. To assess the quality of the included studies, the CASP Appraisal checklist will be used (CASP) 2023). CASP is available for various study designs so that we don't have to select different tools for different study designs. The CASP appraisal checklists will cover questions about the validity of the study design, the methodology and results [40].

Data Synthesis

Results will be synthesised using descriptive statistics to address the scoping review objectives. A narrative synthesis will be used to describe gaps in the literature.

Various forms of visualisation, such as tables and charts, will be used to group the results based on the data we have found. Boundaries for the visualisation depend on the actual extracted evidence.

To increase the usability of the results, the data synthesis includes two further steps if the data allows it. (1) SciModeler will be used to analyse the results and to link the theoretical constructs with empirical data by (a) recording study findings and contexts in a knowledge representation that facilitates querying, (b) mapping study outcomes with theoretical constructs to refine scientific theory, and (c) making replicable predictions on the impact of a particular intervention strategy in a specific context, based on actual empirical data [41 42]. The annotators will use the SciModeler web interface to annotate

the included articles with highlights in terms of the data items listed in Table 3 (marking in the articles those terms that relate to the classification of nudges, the nudging mechanisms, the personalisation mechanisms, the delivery channel). Some elements link to theories/techniques, while others relate to the study design (e.g., intervention characteristics). The items will be labelled, and a graph-based database (based on the types used while annotating the articles) will be generated. From the graph-based database, (2) results can be exported to JSON, an open standard file and data interchange format, to be imported into the digital application (e.g., GameBus [43]) or tabular views.

Ethics and dissemination

No ethical approval for the scoping review is required, as data will be obtained from publicly available materials. The results of this scoping review will be published in a peer-reviewed journal and presented at conferences. We will provide recommendations and conclusions based on the findings from the synthesis. The results will further inform the co-creation process with target group representatives and stakeholders and provide information on how the intervention used in the HealthyW8 project can be adapted to the target groups.

Declarations

Ethics approval and consent to participate

Not applicable

Availability of data and materials

Not applicable

Competing interests

None

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Author contributions

All authors (SF, LR, PvG, ChS, LC, KdS, JH, TdM, LM, TB) contributed to the idea and outline of the protocol. SF, KDS, and LC discussed the first version of the search strategy and key terms. LR, PvG, ChS, JH, TdM, LM, and TB commented on the search strategy and terms, SF developed the first paper draft, and all authors commented and revised the paper draft and the final version of the protocol.

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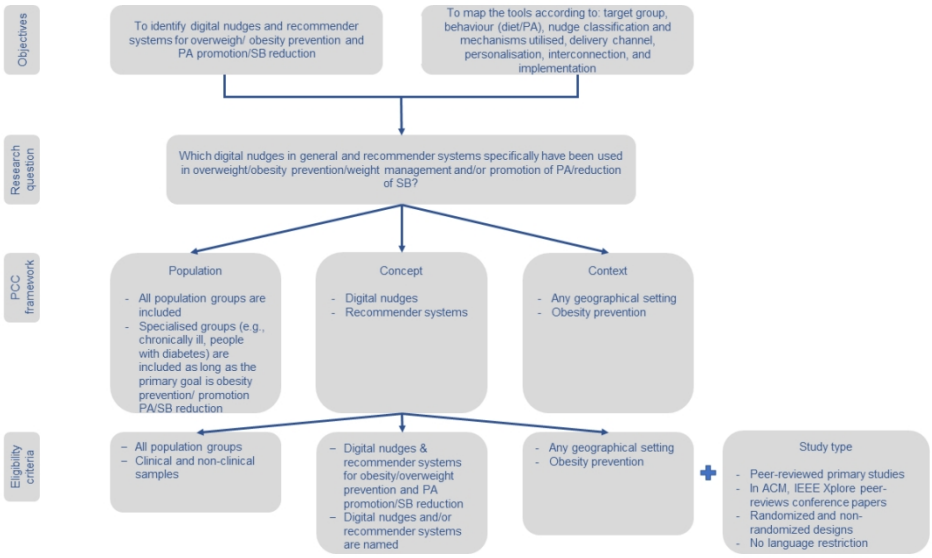

Relationship between research objectives, question and eligibility criteria (adopted from Feo et al. (2020), Pollock et al. (2021) 1 2

855x481mm (38 x 38 DPI)

Supplement 1

Search Strategy Medline via Ovid

Date: 15.9.2023

Search line	Search terms	Results
1	"recommend* system?".mp.	1.090
2	(digital adj2 nudg*).mp.	23
3	overweight.ti,ab.	87.939
4	obes*.ti,ab.	377.274
5	adipos*.ti,ab.	132.556
6	(weight adj3 (bod* or health* or unhealth* or gain* or chang* or retention or loss* or management)).ti,ab.	416.275
7	(physical adj3 (activit* or exertion? or training or inactivit*)).ti,ab.	170.098
8	(sedentary adj2 (behavior* or behaviour*)).ti,ab.	9.791
9	exp obesity/	262.485
10	exp overweight/	273905
11	exp "physical activity"/	248.339
12	exp "sedentary behavior"/	13.682
13	or/1-2	1.113
14	or/3-12	1.132.253
15	(food* or nutrition* or diet*).ti,ab.	1.374.138
16	exp food/	1.480.179
17	exp diet/	330.485
18	or/15-17	2.538.857
19	13 and (14 or 18)	86

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Not applicable (scoping review)
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	4
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	5-6
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	6
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Suppl. 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	7-8
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	8
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	8
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	8
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Not applicable
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Not applicable
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	9
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Not applicable
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Not applicable
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Not applicable
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Not applicable

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Not applicable
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Not applicable
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Not applicable
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Not applicable
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Not applicable
Study characteristics	17	Cite each included study and present its characteristics.	Not applicable
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Not applicable
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Not applicable
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Not applicable
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Not applicable
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Not applicable
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Not applicable
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Not applicable
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Not applicable
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Not applicable
	23b	Discuss any limitations of the evidence included in the review.	Not applicable
	23c	Discuss any limitations of the review processes used.	Not applicable
	23d	Discuss implications of the results for practice, policy, and future research.	Not applicable

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	5
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	5
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Not applicable
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	10
Competing interests	26	Declare any competing interests of review authors.	10
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Not applicable

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71
For more information, visit: http://www.prisma-statement.org/

BMJ Open

"Let me recommend.... " – Use of digital nudges or recommender systems for overweight and obesity prevention – a scoping review protocol

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Keywords:	Obesity, NUTRITION & DIETETICS, Overweight

"Let me recommend…." – Use of digital nudges or recommender systems for overweight and obesity prevention – a scoping review protocol

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Abstract

Introduction: Recommender systems i.e. digital tools providing suggestions and digital nudges increasingly affect our lives. The combination of digital nudges and recommender systems is very attractive for its application in preventing overweight and obesity. However, linking recommender systems with personalised digital nudges has a potential yet to be fully exploited. Therefore, this study aims to conduct a scoping review to identify which digital nudges or recommender systems or their combinations have been used in obesity prevention and to map these systems according to target population, health behaviour, system classification (e.g., mechanisms for developing recommendations, delivery channels, personalisation, interconnection, used combination of nudges), and system implementation.

Methods and analysis: The PRISMA-ScR guideline for scoping reviews was used to inform protocol development. The eligibility criteria are based on the PCC framework (Population: any human; Concept: recommender systems or digital nudges; Context: obesity prevention). MEDLINE, PsycINFO, Web of Science, CINHAL, Scopus, ACM Digital Library, and IEEE Xplore were searched from inception until September 2023. Primary studies with any design published in peer-reviewed academic journals and peer-reviewed conference papers will be included. Data will be extracted into a self-developed extraction sheet. Results will be synthesised descriptively and narratively.

Ethics and dissemination: No ethical approval is required for the scoping review, as data will be obtained from publicly available sources. The results of this scoping review will be published in a peer-reviewed journal, presented at conferences, and used to inform the co-creation process and intervention adaptation in the context of a HealthyW8 project (www.healthyw8.eu).

Keywords

nudges, recommender systems, obesity, overweight, diet, nutrition, physical activity, healthy lifestyle

Article Summary: Strengths and limitations

- This scoping review systematically maps digital nudges and recommender systems explicitly focusing on health behaviour (diet, physical activity, sedentary behaviour).
- The work uses a rigorous methodological approach with an interdisciplinary team of experts from health, social and natural sciences, economics, engineering and computer science.
- A limitation is that the database search will miss studies that do not name digital nudges or recommender systems in titles, abstracts, or keywords.

Background

Recommender systems, i.e., digital data filtering engines that employ deep learning concepts and algorithms to make suggestions for their users increasingly affect our lives. Whether shopping online, watching series on streaming platforms, listening to music, or preparing the next meal, recommender systems suggest products, make recommendations, and offer new ideas.
Based on Jesse et al. 2021 [1], recommendation systems can be categorised as a form of digital nudges, as the algorithms enable various actions, such as highlighting or hiding information, simplifying information presentation, facilitating social influence, proposing alternatives, having an ordering effect or increasing the salience of incentives. These systems determine different aspects of the choice architecture for users, serving as information filters or providing suggestions for relevant content [1 2]. They significantly impact the online user experience by influencing which information is easily accessible and affecting decision-making processes [3]. Although recommender systems and digital nudges have been investigated separately, there is a vast potential to integrate further nudging mechanisms into recommender systems to influence user decision-making. By leveraging the power of digital nudges, recommender systems can enhance their ability to guide users' choices and preferences.

Nudges and digital nudges are similar in that they both aim to guide people's behaviour towards desirable choices. However, the main difference lies in the context in which they are applied. Nudges refer to any form of choice architecture that triggers behaviour, while digital nudges focus on choice architecture in digital environments [4]. Digital nudges can be highly personalised and interconnected, and provide immediate feedback on choices [5-8]. They can be used in various digital contexts, such as social media, mobile apps, e-commerce, or online retail. Digital nudges can help users make more conscious decisions, whether reducing online news consumption [9], increasing physical activity levels [7], or promoting climate-friendly food choices [10].

Both forms of nudges are employed in interventions for overweight and obesity prevention. Given the complexity of the interplay of various behaviours required for obesity prevention (for example, physical activity[11 12], dietary habits[13 14], purchasing decisions and food choice[15-18] or active transportation[19 20]), the field is correspondingly vast and highly dynamic. For example, one systematic review showed that most nudging interventions focused on diet or nutrition, most were conducted as single experiments, and the majority achieved the intended effects. Specific nudging techniques were classified within broader categories, including accessibility, presentation, utilisation of messages and images, technology-supported information, financial incentives, sensory manipulation, and cognitive loading; several studies incorporated more than one nudging technique. However, they also mentioned that the effect of nudging is unclear outside the study setting[21]. Others found that nudges resulted in an average 15.3% increase in healthier dietary or nutritional choices, as measured by a change in the frequency of healthy choices or overall caloric consumption [22]. Another systematic review of nudge strategies for weight loss in adults with obesity and overweight showed significant effects of nudging strategies on weight loss, reduction of body mass index, and waist circumference. Subgroup analysis indicated that the reduction in body weight associated with nudge interventions was significant in younger and more obese individuals. However, the effect of nudge interventions on weight loss weakened over time[23]. A study of a specific type of nudging, the so-called Typology of Proximal Physical Micro-Environments (TIPPME[24]), found that the evidence to date predominantly focused on the effectiveness of information nudges (56%) and position nudges (13%), while less

evidence is available on the effectiveness of other types of TIPPME nudging interventions[25]. TIPPME is a framework for classifying and describing ways in which interventions can alter proximal physical micro-environments to change selection, purchase and consumption of food.

Technological development of apps and sensors has led to the transfer of nudges into the digital environment as more decisions are made in digital contexts [26]. Due to the possibility of personalising digital nudges based on real-time data (e.g., sensor data) and using interconnectivity, digital nudges are highly interesting for health research, including obesity prevention. They are particularly valuable for tracking individual behaviour over time to detect behaviour change as they combine various data sources. Firstly, they enable real-time data collection by multiple systems (e.g., GPS, sensors, shopping data, or user actions). Such data can be combined with the system recommendations based on already known data (e.g., age, weight, height, and eating preferences). This combination of real-time data with preferences allows for dynamic personalisation of the user's decision architecture, including feedback and monitoring. Furthermore, interconnectivity allows one user's decision to influence another user's decisions directly, such as by applying different (already established) labels, suggesting healthier swaps, default options, increasing salience, or a combination of strategies[27].

These features make the combination of digital nudges and recommender systems very attractive for obesity prevention [6] because wearable technology, chatbots, and nudges involving priming, promoting, social norms or gamification can be combined to provide personalised feedback to prevent weight gain and maintain healthy weight [28]. Linking recommender systems with personalised digital nudges represents an untapped potential that should be tested in obesity prevention. Obesity prevention is a highly important topic as currently obesity, defined by the WHO as having a body mass index greater than 30, was linked to 5.02 million deaths globally in 2019, according to the Global Burden of Disease study [29].

Several reviews have shed light on various aspects of digital nudgings, such as categorisation [1 30], psychological underpinning [31-33], and the use and application of digital nudges in specific areas, such as privacy/security, E-commerce, marketing, sustainability or crowdfunding, online food choice [1 5 6 34-36]. For example, Bergram et al. [6] described different types of digital nudges based on digital nudge patterns, outcome, context, evaluation, personalisation, interconnectivity and mode of delivery [6]. However, the context domain was labelled as health without a specific focus on the behaviour targeted by these digital nudges. Jesse et al. developed a taxonomy to code digital nudges, combining the work of others based on the category and the included nudging mechanism [30 37-39]. However, the health context of the system was not specified in this work either [1].

Aims and Objectives

Therefore, this study aims to conduct a scoping review to identify which digital nudges or recommender systems have been used in overweight and obesity prevention and whether they have been combined. (Figure 1).

Obesity prevention is defined broadly as preventing overweight and obesity, including weight reduction and weight management, preventing weight gain or stabilising treatment effects targeting weight loss. While the development and treatment of overweight and obesity are multifactorial, increased energy expenditure is considered one of the most important determinants for reducing body weight [40]. Physical activity (PA) is one of the most modifiable factor in energy expenditure; it represents approximately 25% of total energy spending and, as such, is a powerful requirement to improve the

energy balance equation [41] in combination with a healthy diet. Generally, a higher level of PA is associated with a lower BMI and measured body fat, even after controlling for genetic and environmental factors, such as childhood environment [42 43]. Therefore, we include PA promotion and sedentary behaviour (SB) reduction in the overall definition of obesity prevention.

The detailed objectives of this scoping review are:

1) to identify digital nudges or recommender systems for overweight and obesity prevention, PA promotion or SB reduction
2) to map the digital nudges and recommender systems according to target population, health behaviour (diet, PA, or SB), system classification (e.g., mechanisms for developing recommendations, delivery channels, personalisation, interconnection, used combination of nudges) and system implementation.

Methods

The scoping review method maps the literature to synthesise existing knowledge, identify key characteristics from the body of literature, and identify evidence gaps [44]. Our aim to identify a broad scope of literature on digital nudges or recommender systems for obesity prevention can be addressed using a scoping review rather than a systematic review because it is more suitable for reviews targeting interventions' feasibility, appropriateness, meaningfulness or effectiveness [44].

Study design

The scoping review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guideline [45]. The PRISMA-ScR checklist will be reported as part of the scoping review.

Protocol and Registration

The work on this study began in July 2023, and the database searches were conducted in September 2023. This protocol was written in August-September 2023 (i.e., before the screening process started), submitted for peer review and registered at the Open Science Framework (OSF)[46] in October 2023. Screening and study selection are scheduled for October 2023 until March 2024, data extraction for April-June 2024, and data synthesis for July 2024.

Eligibility Criteria

The eligibility criteria were based on the PCC (Population, Concept, Context) framework [47] (Figure 1, Table 1).

Figure 1: Relationship between research objectives, question and eligibility criteria (adopted from Feo et al. (2020), Pollock et al. (2021) [47 48]

Table 1: Eligibility for the scoping review

PCC	Inclusion Criteria	Exclusion Criteria

Population	Any human population groups (children or adults; healthy, at risk for chronic diseases, or clinical samples)	No human population
Concept	Digital nudges or recommender systems (stated in the title, abstract or full-text of a study)	Digital nudges or recommender systems not used or studies that use digital nudges or rely on recommender systems but do not name them in the title, abstract or full-text
Context	Any geographical setting Overweight and obesity prevention (e.g., nutrition, food recipes, grocery stores, meal preparation, PA promotion, SB prevention)	Digital nudges or recommender systems that are used in e.g., blockchain, finances, security, privacy, agriculture, service, and e-commerce, and not used for overweight and obesity prevention

We aim to identify and include primary studies with any design (randomised or nonrandomised studies with quantitative or qualitative data). All languages will be included in the initial search. During the full-text screening, we will exclude studies not published in English or German unless the language expertise is available in the review team. We will also include peer-reviewed conference papers from ACM Digital Library and IEEE Xplore due to the different publication traditions in computer science and engineering. Books, reports, dissertations, pre-prints, project reports, unpublished work and grey literature (non-peer-reviewed work) will be excluded.

Search strategy

The electronic search strategy was developed and calibrated within the team in collaboration with an experienced librarian (LC). MEDLINE and PsycINFO via Ovid, Web of Science, CINHAL via Ebsco, Scopus, ACM Digital Library, and IEEE Xplore were searched (by LC) from inception until September 2023. The search strategy for MEDLINE is reported in Supplementary File 1.

An iterative technique adapted from JBIs' three-step approach was used to develop the search strategy [49 50]. First, a preliminary search was done in MEDLINE based on an initial set of key terms. The retrieved papers were reviewed regarding their eligibility. Keywords, synonyms and index terms were identified from the retrieved papers and used to revise the search strategy. The revised search strategy was discussed with the team to ensure that the terminology from different disciplines (e.g., health, economics, engineering, and computer science) was considered. Second, the main search was undertaken across all seven databases using all identified keywords and index terms. Third, the search results will be screened following deduplication (done by LC).

The search syntax development was based on the PRESS (Peer Review of Electronic Search Strategies) guideline [51]. Our research librarian (LC) implemented the following aspects of the search syntax development: (1) quality of translation of the research question into search terms done by inspecting the number of hits per syntax line, (2) appropriate use of adjacency proximity operators done by comparing the number of hits following different adjacency limits, (3) choice of subject headings done by inspecting the number of hits per syntax line, (4) text word searching done by inspecting the

truncation and inclusion of British and American spelling, and (5) spelling and any syntax errors done by reading the syntax strategy line by line and inspecting the use of Boolean operators and brackets.

Subject terms used for the search strategy included digital nudges or recommender systems combined with aspects of obesity prevention (e.g., weight management, physical activity, sedentary behaviour, diet, food, nutrition and their synonyms; Table 2).

Table 2: Subject terms used

MeSH	PsycInfo subject headings	CINAHL subject headings
overweight	overweight	
obesity	obesity	obesity
physical activity	physical activity	physical activity
sedentary behaviour	sedentary behavior	life style, sedentary
food	food	food
diet	diets	diet

Bibliographies of included studies will be manually screened for additional studies.

Engagement with experts

A "crowd-sourced" element will expand the search for suitable articles by posting the search on the X/Twitter and LinkedIn accounts of the involved institutions (e.g., BIPS, EE) and on the HealthyW8 website (www.healthyw8.eu). This strategy aims to raise awareness of the project and obtain suggestions for additional studies relevant to the scoping review.

Study selection process

The resources located in the search will be imported into Endnote 20 for deduplication. The deduplicated library will be imported into software COVIDENCE. The software will be used for title/abstract and full-text screening. Titles, abstracts, and full texts will be screened independently according to the eligibility criteria by at least two researchers. All conflicts will be discussed. If no agreement can be reached, a third researcher will be consulted. A final decision will be made by consensus during discussion.

The PRISMA flowchart will be reported to show the study selection procedure. After the full-text assessment, a list of included and excluded studies with individual reasons for exclusion will be reported.

Data Items

Two researchers will independently extract data from eligible studies. A data extraction sheet will be self-developed in Excel to address our scoping review objectives. A preliminary list of data items and their characteristics is shown in Table 3. The data extraction sheet will be pre-tested based on three randomly selected studies from the included studies to standardise data extraction. The qualitative information on the data items will be extracted as author statements from the articles. In the next step, these data will be processed by quantifying them into categories developed deductively from the

scoping review objectives or inductively from the data by one researcher (SF). The processed data will be checked and discussed within a team to reach a category consensus.

Table 3: Preliminary list of data items to be extracted from included studies

Data items	Characteristics
Bibliographic data	First author, year of publication, author country, health domain (nutrition/PA/SB) [30 52], digital nudge, recommender system, or a combination
Intervention characteristics	Study design, population, sample size, dose, digital nudge combination
Recommender system delivery channel	Mode of delivery (delivery channels: e.g., visual, audio, haptic) and delivery devices (e.g., desktop, mobile, wearable, ambient) [6]
Recommender system methods	Hybrid methods, content-based filtering, collaborative filtering, graph-based methods
Classification of digital nudges	Social nudges (guide the user's behaviour by providing references to how other users behave), reinforcement nudges (reinforce behaviours and choices by increasing their salience in the mind of the user), disclosure nudges (adding information that is accessible, clear, and relevant to the choice that the user is about to make), friction nudges (encouraging or discouraging behaviour by removing or adding friction), feedback nudges (information about a past or current behaviour of a user), default nudges (assumed desired behaviour), warning nudges (different kinds of warnings and graphics to grab attention), scarcity nudges (information that something is difficult to acquire), deception nudges (affect how users perceive choice alternatives), commitment nudges (to motivate the user to behave) [6 52 53]
Digital nudge mechanisms	Decision information (translate information, increase the salience of information, make information visible, or change the phrasing of information) Decision structure (change range of composition, change choice defaults, change option consequences, change option-related effort) Decision assistance (provide reminders or facilitate commitment) Social decision appeal (increase the reputation of the messenger, provide a social reference point, instigate empathy) [1]
Personalisation	None, partial (study gathers user data (e.g., location, user demographics, user actions) to infer the potential influence of the nudge on user behaviour), full (such information is used to personalise the choice architecture of individual users dynamically) [6]
Interconnection	None, partial (study investigates how information from other users affects user behaviour), full (study investigates how actions of one user, in turn, dynamically modify the choice architecture of other users) [6]
Implementation information	Any information about implementation and user engagement
Effects	Primary outcome: outcomes related to weight, weight management, PA/SB Secondary outcome: outcomes related to mental health, user engagement, user satisfaction

Data Synthesis

Results will be synthesised using descriptive statistics (e.g., relative frequencies) to address the scoping review objectives. A narrative synthesis will be used to describe evidence gaps in the literature. Various forms of visualisation, such as tables and charts, will be used to report the data synthesis.

To increase the usability of the results, the data synthesis includes two steps, if applicable. First, SciModeler will be used to analyse the results and to link the theoretical constructs with empirical data

by (a) recording study findings and contexts in a knowledge representation that facilitates querying, (b) mapping study outcomes with theoretical constructs to refine scientific theory, and (c) making replicable predictions on the impact of a particular intervention strategy in a specific context, based on actual empirical data [54 55]. The annotators will use the SciModeler web interface to annotate the included articles with highlights in terms of data items listed in Table 3 (e.g., marking those terms that relate to the classification of nudges, the nudging mechanisms, the personalisation mechanisms, and the delivery channels). Some elements link to theories/techniques, while others relate to the study design (e.g., intervention characteristics). The items will be labelled, and a graph-based database will be generated based on the types used while annotating the articles. Second, results can be exported from the graph-based database to JSON, an open standard file and data interchange format, to be imported into the digital application (e.g., GameBus [56]) or tabular views.

Ethics and dissemination

No ethical approval for the scoping review is required, as data will be obtained from publicly available materials. The results of this scoping review will be submitted for publication in a peer-reviewed journal and presented at conferences. They will further inform the co-creation process with target group representatives and stakeholders and provide information on how the intervention developed within the HealthyW8 project (www.healthyw8.eu) can be adapted to different target groups.

Declarations

Ethics approval and consent to participate

Not applicable

Availability of data and materials

Not applicable

Patient and Public Involvement

None

Competing interests

None

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Author contributions

All authors (SF, LR, PvG, ChS, LC, KKDS, JH, TdM, LM, TB) contributed to the development of this manuscript. SF, KKDS, and LC discussed the first version of the search strategy. LR, PvG, ChS, JH, TdM, LM, and TB commented on the search strategy. SF wrote the first draft of this manuscript, SF and KKDS revised the manuscript, and all authors commented on the revised draft. All authors approved the final version of the manuscript. SF acted as guarantor.

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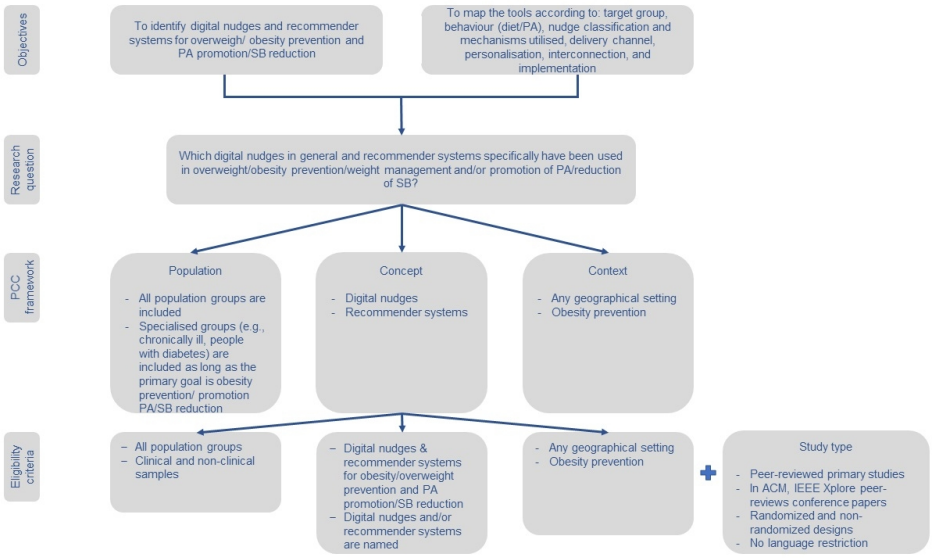

Figure 1: Relationship between research objectives, question and eligibility criteria (adopted from Feo et al. (2020), Pollock et al. (2021)

338x190mm (96 x 96 DPI)

Supplement 1

Search Strategy Medline via Ovid

Date: 15.9.2023

Search line	Search terms	Results
1	"recommend* system?".mp.	1.090
2	(digital adj2 nudg*).mp.	23
3	overweight.ti,ab.	87.939
4	obes*.ti,ab.	377.274
5	adipos*.ti,ab.	132.556
6	(weight adj3 (bod* or health* or unhealth* or gain* or chang* or retention or loss* or management)).ti,ab.	416.275
7	(physical adj3 (activit* or exertion? or training or inactivit*)).ti,ab.	170.098
8	(sedentary adj2 (behavior* or behaviour*)).ti,ab.	9.791
9	exp obesity/	262.485
10	exp overweight/	273905
11	exp "physical activity"/	248.339
12	exp "sedentary behavior"/	13.682
13	or/1-2	1.113
14	or/3-12	1.132.253
15	(food* or nutrition* or diet*).ti,ab.	1.374.138
16	exp food/	1.480.179
17	exp diet/	330.485
18	or/15-17	2.538.857
19	13 and (14 or 18)	86

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	3-5
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	5,6
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	5
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	5-6
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	6-7
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	File 1
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	7
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	7
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	8
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	n.a.

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	8-9
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	n.a
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	n.a
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	n.a.
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	n.a.
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	n.a.
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	n.a.
Limitations	20	Discuss the limitations of the scoping review process.	n.a.
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	n.a.
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	9

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.