

Nudging Health Behavior Change Among Home-Based Cardiac Rehabilitation Patients: A Scoping Review

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Background: In home-based cardiac rehabilitation practices, nudging has emerged and was actively explored to promote health behavior change among patients with heart disease. The literature on nudging strategy is fragmented and lacks comprehensive reviews.

Objective: This study aimed to identify nudging interventions to promote health behavior change among patients undergoing home-based cardiac rehabilitation, focusing on the scope, characteristics and delivery.

Methods: A scoping review was conducted from July to September 2023, during which databases including PubMed, Web of Science, and OVID (Embase, Cochrane Library, JBI) were searched. Search terms were constructed based on population-concept-context mnemonics approach. Reviewers screened articles independently and reviewed the included articles to extract key information about each nudge intervention.

Results: In included 25 studies, the majority (n=21) with the nudging strategy had positive results. 14 nudge strategies were identified and coded with the primary objective of changing health behaviors. The most common nudging strategy was goal setting, followed by feedback, and reminders and alerts. To capture the heterogeneity of nudging strategies, two independent dimensions were introduced to further classify them into four quadrants (active vs passive and synchronous vs passive). For example, some nudging strategies usually occur when the target behavior must be performed (synchronization) and requires the immediate participation of the home-based cardiac rehabilitation patients (active). In addition, digital nudging technology with gamification elements may become the mainstream in future research.

Conclusion: These studies reflected different objectives and implement nudging strategies in different ways. Despite the multiple nudging strategies are widely adopted, identifying the contributing components remains challenging.

Keywords: nudge, cardiac rehabilitation, decision architecture, health behavior, intervention

Introduction

Cardiac rehabilitation (CR) represents a multifaceted regimen aimed at ensuring the optimal physical, mental, and social functions of individuals suffering from heart diseases.¹ The objective is for patients to regain their societal roles to the greatest extent possible through personal effort, thereby leading active and productive lives.¹ As a Level 1A recommendation by clinical guidelines,^{2,3} CR is an essential component in the standardized care of those with cardiovascular conditions, offering marked improvements in clinical outcomes and quality of life. Nevertheless, the persistent nature of heart diseases, combined with logistical challenges such as transportation barriers, means that institution-based CR may be financially taxing and time-consuming for patients.⁴ As a solution, home-based cardiac rehabilitation (HBCR) provides a cost-effective and accessible alternative model that brings similar improvements in reducing cardiovascular

risk, promoting mental and spiritual well-being, enhancing cardiac function and prognosis, and improving the quality of life for patients.^{5–9}

However, these benefits depend on the patient's long-term and regular HBCR practice. Unfortunately, this remains suboptimal on a global scale.^{10,11} Only a minority of patients with heart disease rigorously maintain exercise-based HBCR practices after institutional rehabilitation.¹² Due to limited exercise endurance and knowledge, patients have poor self-efficacy and exercise motivation towards HBCR practices.^{13,14} Despite rigorous interventions, long-term and regular adherence to HBCR practices is relatively challenging,^{15,16} thereby potentially elevating cardiovascular risks and adversely impacting quality of life and clinical prognoses. In light of these considerations, it becomes imperative to develop and implement cost-effective intervention strategies designed to enhance health behaviors during HBCR, thereby improving clinical outcomes and quality of life.¹⁷

Increasingly, insights from behavioral economics are being applied to address this resistance and promote health behavior change.^{18,19} It explains the mechanisms underpinning individual judgment and decision-making in innovative ways.²⁰ Nudging is defined as any element of the choice architecture that consistently influences individual behavior without restricting choices or significantly changing economic incentives.²¹ This means that limitations on choice, such as bans or information withholding, as well as modifications to incentive structures such as financial rewards or taxes, do not qualify as nudging.^{22,23} Nudging, as a novel complementary strategy, has been widely adopted to promote individual health behaviors. Examples of its application include sending text-based reminders to encourage vaccination and self-management of chronic diseases in patients,^{24,25} facilitating physician-patient discussions about serious illnesses through reminders and alerts,²⁶ and promoting hand hygiene among healthcare professionals through goal setting and feedback.²⁷

The term “nudge” later gave birth to the concept of nudge theory, which emphasizes understanding the complexity of behavior and rejects the assumption that individuals will inherently make the best choice when provided with the right information.²⁸ Nudge theory, rooted in the dual-system theory,²⁹ proposes two modes of thought (System 1 and System 2).³⁰ In System 1, thoughts, associations, feelings, and actions occur effortlessly and rapidly, while System 2 involves slow, laborious, and deliberate thinking.³⁰ This dual-system theory forms the basis of nudging as it elucidates our unconscious decision-making processes and presents us with the option to either consciously analyze our behavior (System 2) or alter the environment to guide us toward better choices without conscious effort (System 1).³⁰ Nudge theory introduces fresh perspectives on individual behavior and provides new methodologies for nudging individuals toward making improved decisions.

In cardiovascular healthcare, especially in HBCR practices, nudging strategies have emerged and are actively investigated to promote health behavior change in patients.^{31–33} In many studies, HBCR practices for patients with heart disease benefited from a series of nudge strategies. However, the research and development of nudging strategies to promote HBCR practices is fragmented, and it is difficult to provide meta-knowledge to guide the selection of the most effective approaches or to comprehensively identify the characteristics, expected outcomes, and weaknesses of each strategy. Therefore, this study, using a systematic scoping review approach, aimed to identify studies of nudging strategies used to promote HBCR practices and to comprehensively understand how to construct measures based on the appropriateness or effectiveness of each strategy according to its purpose. Specifically, our research reviewed the trends in publications on nudging strategies for HBCR practices and evaluated literature related to HBCR and individual nudging strategies, analyzing their distinct characteristics and considerations. Additionally, we delved into the prospects of utilizing digital nudge strategies to enhance the advancement of HBCR practices.

Methods

Based on the methodological framework of the Joanna Briggs Institute (JBI)³⁴ and the Preferred Reporting Items for Systematic Review and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR),³⁵ this scoping review focused on mapping the current knowledge landscape and identifying gaps in supporting HBCR practices and defines key concepts. A scoping review is a widely embraced research method tailored for areas of study that have not been thoroughly explored previously. This pioneering scoping review concentrates on strategies for enhancing HBCR practices, offering vital insights and recommendations to steer future research in this domain.

Research Questions

The aim of this study was to use nudge theory to identify interventions to promote health behavior change among patients undergoing HBCR, focusing on nudge strategies, delivery systems, and empirical evidence. To address these knowledge gaps, this study sought to answer three questions: (1) What is the scope of nudging strategies in the existing literature to promote health behavior in patients with HBCR. (2) How nudging strategies to promote health behavior change in patients are delivered in the HBCR settings. (3) Whether these nudging strategies to promote health behavior change in HBCR patients provide sufficient empirical evidence of success.

Inclusion Criteria

The inclusion criteria of this study were developed based on the population-concept-context criteria recommended by the Joanna Briggs Institute for scoping reviews.³⁴ (1) Population: patients aged ≥ 18 years with heart disease. (2) Concept: Interventions using any nudge strategy to promote health behavior change. There is no requirement that the interventions necessarily be labeled as a choice architecture or nudging, but it needs to meet the definitions of nudging.²¹ (3) Context: The patient is in a home-based, supervised or unsupervised cardiac rehabilitation environment. (4) Type of evidence: Empirical studies published in English within international peer-reviewed journals. Only randomized controlled trials, quasi-randomized controlled trial, and longitudinal (before and after) studies were considered. Additionally, if a preprint version is retrieved, the original research associated with the preprint will be retroactively incorporated. Studies were excluded if they were duplicates, lacked full-text access, or were conference abstracts.

Information Sources and Search Strategy

An iterative approach was adopted to develop the search strategy in collaboration with a librarian. Another librarian was invited to review the search strategy using the Peer Review of Electronic Search Strategies (PRESS) checklist.³⁶ Firstly, a preliminary search was conducted on the librarian-recommended database (PubMed), and the results were briefly analyzed to assess the effectiveness of the search strategy. Subsequently, the first author (Y.Z.) conducted searches across three librarian-recommended databases - PubMed, Web of Science, and OVID (Embase, Cochrane Library, JBI) - to identify relevant topics in the title and abstract fields. The search strategies employed across all databases are presented in [Additional file 1](#) of this scope review.

Screening and Selection Process

The search and selection process was conducted by the first author (Y.Z.), with consultation from the second author (Z.X.) throughout the review. Firstly, all the search results in the database were imported into the literature management software, NoteExpress (<http://www.inoteexpress.com/>), and the duplicate search results were automatically identified and deleted. In addition, all remaining results were screened by the first author (Y.Z.) by title and abstract according to pre-determined inclusion criteria, in consultation with the second author (Z.X.). The search results identified as “probable” were discussed between the two authors. In case of disagreement, the third and fourth authors (H.H. and L.S.) were invited to discuss until consensus was reached. Finally, the preliminarily selected literature was reviewed by reviewing the full text to determine the final studies to be included. In this process, in order to ensure the consistency among reviewers, we randomly selected 25 search results, and the reviewers screened them according to the established criteria. When the consistency reached 75%, the formal literature screening began.

Data Coding and Charting

A data extraction table was collaboratively developed by two authors (Y.Z. and Z.X.) to determine the variables for extraction. Each author created a data chart, discussed the results, and iteratively updated the data chart format. In cases of disagreement during the production of the data chart, the third and fourth authors (H.H. and L.S.) were invited to discuss and decide on the final content. We used Microsoft Excel to construct evidence summary tables covering the following data elements: title, author, years, objective, design, study population, nudge strategy, nudge medium, and statistically positive results. An identified challenge in considering the System 1 and System 2 categories is their failure to capture whether the intervention is present at the time of the decision. To address this limitation, based on the classification method proposed by Sant’Anna et al³⁷ and Wolf et al,³⁸ we drew two independent dimensions and four quadrants for more accurate classification as defined by System 1 and System 2 ([Figure 1](#)).

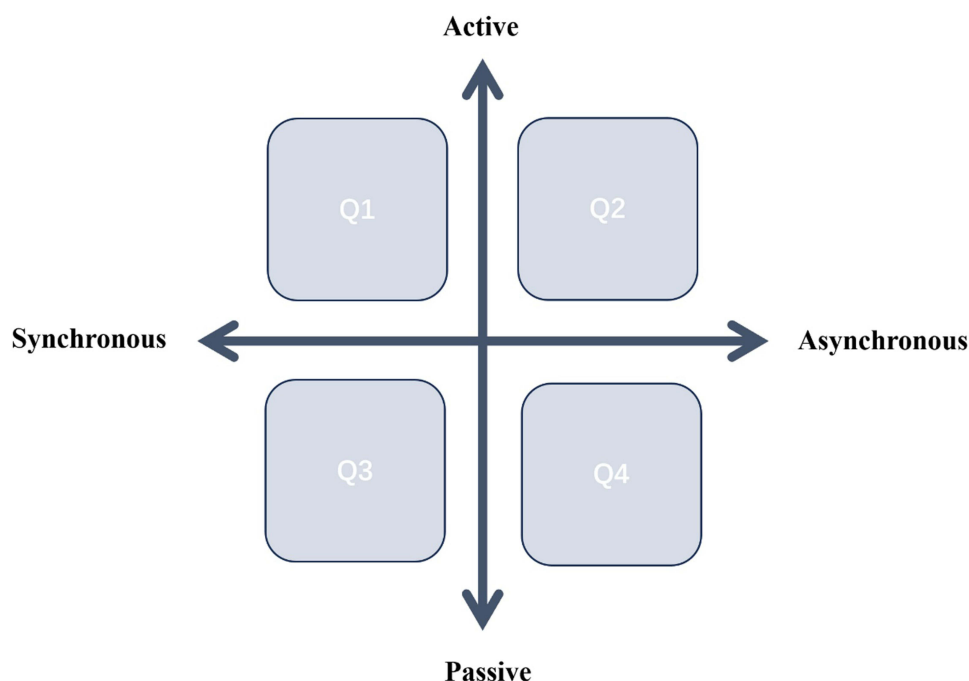


Figure 1 A two-dimensional view of nudging.

Notes: Reproduced from Sant'Anna A, Vilhelmsson A, Wolf A. Nudging healthcare professionals in clinical settings: a scoping review of the literature. *BMC Health Serv Res.* 2021;21(1):543.³⁷

Synchronous vs Asynchronous: An intervention strategy is synchronous if its delivery is consistent with the decision or behavior it is intended to influence, while an asynchronous strategy can be executed at any time. **Active vs Passive:** An active strategy cannot be completed without the action of the target patient, while a passive strategy requires no action. These four quadrants are practical in describing how and when HBCR patients receive nudge interventions.

Results

Article Selection

A total of 5975 studies were generated by this search strategy, and 4926 studies were screened after 1049 studies were eliminated. Based on inclusion criteria, 4670 studies were excluded by two authors at the title and abstract level. Of the remaining 256 studies, 231 studies were subsequently excluded after the authors read the full text, and 25 studies with a total of 8746 patients were retained, covering 3 drafts.^{39–41} (Figure 2). We went back and included the original research related to the three drafts.^{42–44}

Summary of Included Studies

Figure 3 shows the trends and regional distribution of publications across time for the 25 included studies. In this study, the years of the included studies range from 2009 to 2023, with the highest number of publications in 2022 (n=6). Some of the included studies (n=5) were conducted in the United States,^{45–49} and one study spanned across three countries, covering Spain, Netherlands, and China.⁵⁰ Of the 25 studies, the majority employed randomized controls, including 23 randomised controlled clinical trials^{42–64} and one randomised controlled pilot study.⁶⁵ Additionally, one study was classified as a quasi-experimental study.⁶⁶ See Table 1 for details.

Nudging Strategies and Objectives

In total, 55 instances of nudging were incorporated in the 25 studies, as the majority of studies (n=19) involved two or more nudgings.^{42–51,53,55,56,58,60,61,63,64,66} As shown in Table 2, we identified and coded 14 nudging strategies. Prominent strategies for nudging health behaviors encompassed goal setting, feedback, as well as alerts and reminders. Among the

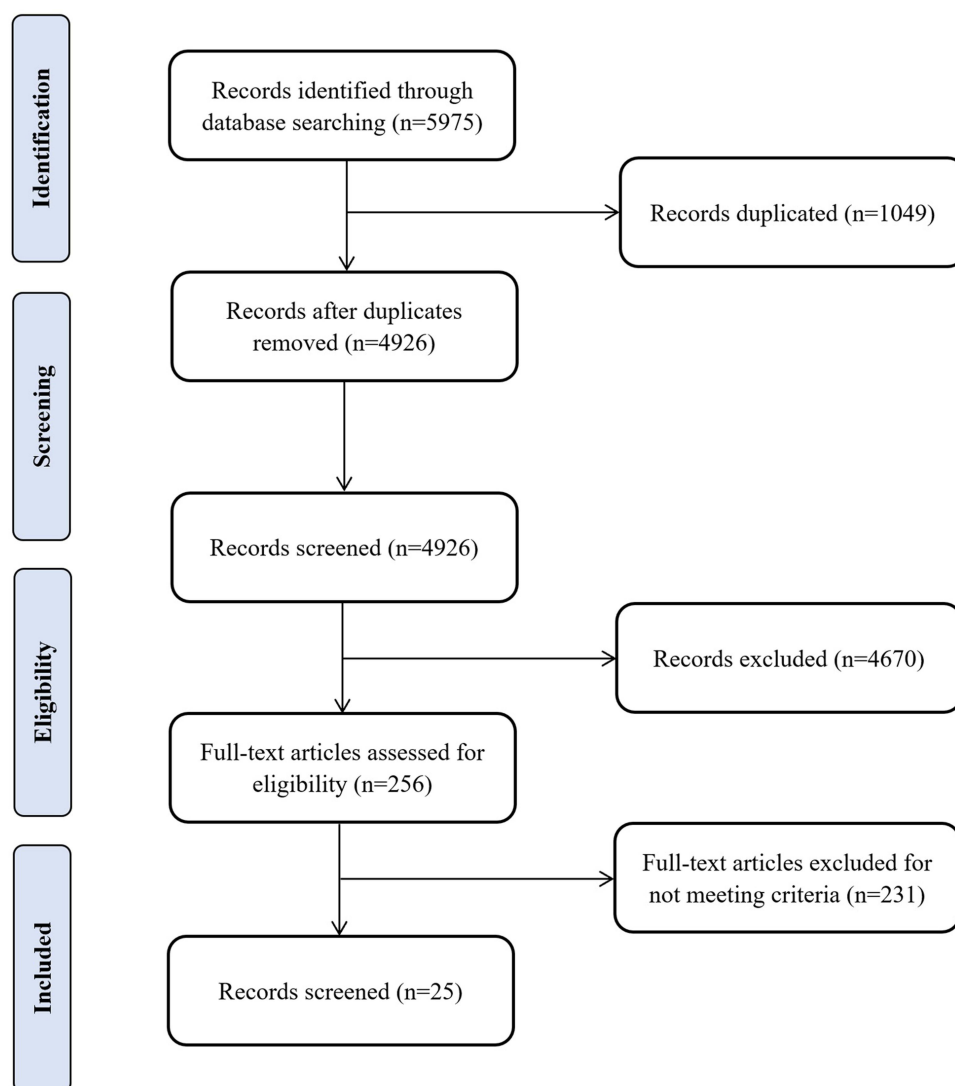


Figure 2 PRISMA flow diagram.

studies employing nudging strategies, the majority ($n=21$) reported positive results, while three studies yielded partially positive results^{54,58,64} and one study noted no positive results.⁴⁹

Out of the 25 studies, seven employed a nudging strategy with System 1,^{52,54,55,57,59,62,65} whereas five used a nudging strategy with System 2.^{44,50,60,61,63} System 1 nudging strategies predominantly involved alerts and reminders, followed by environmental cues/priming. Conversely, System 2 nudging strategies were predominantly labeled goal setting and feedback. Significantly, 13 studies integrated both System 1 and System 2 nudging strategies (multi-nudge strategies) in their interventions,^{42,43,45–49,51,53,56,58,64,66} with the most employed nudging strategy being goal setting, combined with various System 1 nudges such as alerts and reminders and loss aversion.

Based on the heterogeneity of outcomes, we clustered the studies into four different objectives for easy comparison. The primary objective of most studies is to increase physical activity among patients with heart disease in a HBCR setting.^{42,44–48,51,53,56,57,60,61,63–65} The second objective aims to nudge health promotion behaviors among patients with heart disease, including self-care and management and healthy lifestyles.^{50,55,58,59,66} Additionally, ensuring cardiovascular medication compliance among patients with heart disease is also concerned.^{49,52,54} The fourth objective focuses on improving home diet management behavior in patients with heart disease.^{43,62}

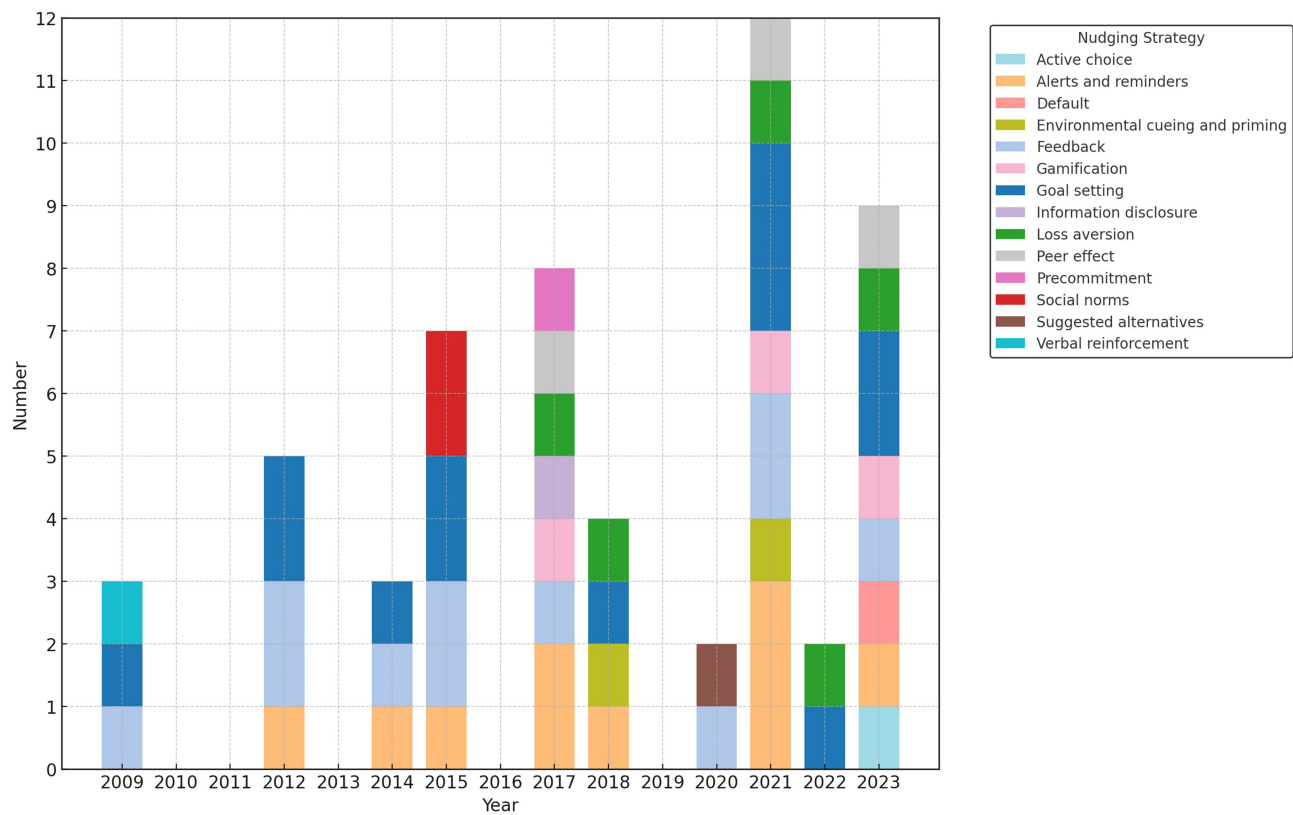


Figure 3 Intervention strategies over time, 2009–2023.

Types of Nudging Strategies

The nudging strategies associated with System 2 will have an impact on health behaviors in HBCR only if participants choose to pay attention and there is a need for it. For example, a specific food nutrition label is displayed at a time when the food is not purchased (information disclosure). However, the participant may completely ignore it, failing to engage their analytical thinking. This is defined as an active nudging strategy. Additionally, some nudging strategies, such as setting the target option as the default option or working the power of the role model (default/social norm), can also occur without the knowledge and awareness of the participant. This is referred to as a passive nudging strategy. In addition,

Table 1 Characteristics of the Articles Included in the Review

Author/year	Country	Design	Objective	Nudging strategies	Nudging medium	Statistically significant
Golbus et al, 2022 ⁴⁶	USA	RCT	Physical activity	Goal setting / Loss aversion	Smartphone / Email	Yes
Sangster et al, 2015 ⁴⁴	Australia	RCT	Physical activity	Goal setting / Feedback	Telephone	Yes
Maddison et al, 2015 ⁵⁷	New Zealand	RCT	Physical activity	Social norms	Mobile phone text message / Website	Yes
Eyles et al, 2017 ⁴³	New Zealand	RCT	Lower-salt food choices	Alerts and reminders / Information disclosure	SaltSwitch smartphone app	Yes
Antypas & Wangberg, 2014 ⁵¹	Norway	RCT	Physical activity	Goal setting / Feedback / Alerts and reminders	Email / Smartphone	Yes
Alsaleh et al, 2016 ⁴²	Jordan	RCT	Physical activity	Goal setting / Feedback / Alerts and reminders	Mobile phone text message	Yes

(Continued)

Table 1 (Continued).

Author/year	Country	Design	Objective	Nudging strategies	Nudging medium	Statistically significant
Piera-Jiménez et al, 2020 ⁵⁰	Spain / China / Netherlands	RCT	Lifestyle and quality of life	Suggested alternatives / Feedback	Text messages / Medical device	Yes
Patel et al, 2017 ⁴⁷	USA	RCT	Physical activity	Precommitment / Loss aversion / Gamification	Text message / Email	Yes
Saleh et al, 2023 ⁶¹	Jordan	RCT	Physical activity	Goal setting / Active choice	Mobile health app / Multimedia message	Yes
Volpp et al, 2017 ⁴⁹	USA	RCT	Medication compliance	Alerts and reminders / Feedback / Peer effect	Text message / Medical device	No
Patel et al, 2021 ⁴⁸	USA	RCT	Physical activity	Gamification / Goal setting / Feedback / Loss aversion	Wearable device / Text message	Yes
Chokshi et al, 2018 ⁴⁵	USA	RCT	Physical activity	Loss aversion / Goal setting	Wearable device / Smartphone	Yes
Cheung et al, 2023 ⁵⁴	Australian	RCT	Medication compliance	Environmental cueing and priming	SMS text messages	Partially
Chew et al, 2021 ⁵⁵	Singapore	RCT	Self-care behaviours and automaticity	Goal setting / Environmental cueing and priming	Telephone / Print booklet	Yes
Poggio et al, 2021 ⁵⁹	Argentina	RCT	Risk screening and management	Alerts and reminders	Text messages / Web-based platform	Yes
Foccardi et al, 2021 ⁶⁵	Italy	RCT pilot	Physical activity	Alerts and reminders	Smartphone	Yes
Su & Yu, 2021 ⁶³	China	RCT	Physical activity and health lifestyle	Goal setting / Feedback / Peer effect	Online platforms	Yes
Butler et al, 2009 ⁵³	Australia	RCT	Physical activity	Goal setting / Feedback / Verbal reinforcement	Pedometer / Telephone	Yes
Bermon et al, 2021 ⁵²	Colombia	RCT	Medication compliance	Alerts and reminders	SMS text messaging	Yes
Frederix et al, 2015 ⁵⁶	Belgium	RCT	Physical activity	Alerts and reminders / Goal setting	Motion sensor / Text message	Yes
Reid et al, 2012 ⁶⁰	England	RCT	Physical activity	Feedback / Goal setting	Email	Yes
Xu et al, 2023 ⁶⁴	China	RCT	Physical activity	Gamification / Feedback / Loss aversion / Peer effect	Smartphone	Partially
Pfäeffli Dale et al, 2015 ⁵⁸	New Zealand	RCT	Adherence to recommended lifestyle behaviors	Feedback / Social norms	Text message / Website	Partially
Son et al, 2023 ⁶⁶	Korea	Quasi-RCT	Self-care behaviours	Goal setting / Default / Alerts and reminders	Smartphone	Yes
Santo et al, 2018 ⁶²	Australia	RCT	Adherence to the dietary guideline recommendations	Alerts and reminders	Text messages	Yes

some nudging interventions are delivered inconsistently with the participant's decisions or behaviors, which we define as asynchronous nudging strategies. For example, some nudging interventions send emails with feedback that can be read at any time, not just when healthy behavior changes. The aim of this nudging strategy is to change health beliefs, ultimately influencing the transformation of health behaviors. In contrast, during HBCR, participants received immediate just-in-time adaptive nudging interventions that did not hesitate to bring about immediate changes in their health behaviors. We coded these interventions as synchronous nudging strategies.

Table 2 Description of Nudging Strategies

Nudging strategy	Description	Connotation	N
Goal setting	Encouraging individuals to establish clear and attainable objectives.	Empowerment and focus. Implies that individuals taking an active role in setting their own goals are more likely to feel committed and take necessary steps to achieve them. Fosters a sense of personal responsibility and progress.	13
Feedback	Providing individuals with information about their actions or behaviors.	Support and growth. Assumes individuals are receptive to insights about their performance and motivated to improve. Implies a relationship where guidance is provided to foster development.	11
Alerts and reminders	Notifications reminding individuals of tasks or important information.	Responsiveness and timely action. Suggests a supportive push to help individuals stay on track with their obligations or goals. Aims to prevent forgetfulness or procrastination.	10
Loss aversion	Leveraging the avoidance of losses over equivalent gains.	Strong motivation through fear of losing. Plays on individuals' natural tendency to protect what they already have. Assumes the fear of losing can be a more powerful motivator than the prospect of gaining.	5
Social norms	Influencing individual actions by tapping into collective behaviors.	Conformity and fitting in. Assumes individuals want to align with typical or approved behavior within their group. Discourages deviations from social norms by implying that conformity is desirable.	2
Default	Pre-selecting the most desired option as a default choice.	Gentle guidance and simplicity of decision-making. Suggests that individuals tend to go with pre-set choices due to a bias toward the status quo. Assumes the default option is recommended or beneficial.	1
Information disclosure	Providing individuals with all relevant information for making informed choices.	Empowerment and respect for autonomy. Assumes individuals can make the best decisions for themselves when given complete transparency. Values personal judgment and decision-making.	1
Suggested alternatives	Offering options aligned with an individual's goals or intentions.	Helpfulness and facilitation of choice. Implies that decision-making can be improved with guidance. Simplifies the process by presenting a curated set of alternatives.	1
Precommitment	Requiring individuals to commit in advance to a future action.	Commitment and forethought. Suggests securing future behavior is crucial to overcoming potential lapses in willpower or motivation. Assumes commitment made in advance increases follow-through.	1
Gamification	Adding game elements to non-game activities for increased engagement.	Playfulness and stimulation. Implies that introducing fun and competition into mundane tasks can make them more enjoyable. Aims to increase participation through game-like elements.	3
Peer effect	Influence of individuals' behaviors on one another.	Social influence and conformity. Assumes individuals look to peers for cues on how to think and behave. Suggests that peers can serve as powerful role models for behavior change.	3
Environmental cueing and priming	Altering physical or social cues in the environment to subconsciously influence behavior.	Subtle manipulation. Implies that people can be guided toward specific behaviors based on environmental design. Assumes triggering instinctive reactions through cues can direct behavior.	2
Verbal reinforcement	Using positive language to encourage desired behaviors.	Affirmation and encouragement. Suggests that reinforcing desired behaviors through verbal praise can strengthen them and motivate continued positive actions. Assumes verbal encouragement has a positive impact.	1
Active choice	Requiring individuals to make explicit decisions.	Deliberateness and personal responsibility. Implies that when individuals are forced to make an active decision, they make more thoughtful choices. Disrupts automatic patterns of behavior and values personal agency in decision-making.	1

In order to capture the heterogeneity of nudging strategies, we adopted the method introduced by Sant'Anna et al³⁷ to classify nudging strategies (Figure 4). In this review, four nudging strategies were assigned to more than one quadrant, including reminders and alerts, feedback, peer effects, and environmental cueing and priming. Reminders and alerts usually occur when the target behavior must be performed (synchronous) and requires the participation of the HBCR patients (active). However, three reminders and alerts were divided into passive and asynchronous nudge strategies. In these cases, text messages were sent to remind participants about their daily healthy eating management, which could be read at any time and did not necessitate immediate action. Feedback, on the other hand, generally does not require active participation from home cardiac rehabilitation patients and is therefore classified as a passive nudging strategy. Nonetheless, there was heterogeneity observed, with feedback identified as synchronous five times and asynchronous six times, depending on whether the feedback information was consistent with the target behavior. Peer effects were consistently categorized as simultaneous nudging strategies since the priming object (peer connection) aligns with the target behavior (physical activity). However, two instances were classified as active, requiring active participation from patients in peer interactions and connections, while one instance was considered passive, employing anonymous peer comparison strategies without the participant's awareness or knowledge. Among the 25 studies included, two environmental cueing and priming were adopted.^{54,55} One instance was classified as an active and asynchronous nudging strategy, as patients were exposed to relevant contexts through interviews that triggered reflection but did not result in immediate engagement in health-promoting behaviors. The other instance was classified as a passive and synchronous nudging strategy, as patients received carefully crafted messages and pictures during HBCR.

Digital Nudging Strategies

For nudging medium, none focused solely on the physical environment, and 16 involved informatization media, including email, smartphones, and pedometers.^{42,44,46,47,51–55,57,58,60,62,64–66} Frequently, smartphones were used to send text messages with reminders to improve participants' physical activity level. As an advanced stage of informatization, there were nine studies involving digital nudging medium, covering smart health applications, digital medical devices, and online internet platforms.^{43,45,48–50,56,59,61,63} The digital wearables and platforms were used to collect and feedback participants' behavioral characteristics to implement just-in-time adaptive behavioral nudging. In addition, gamification

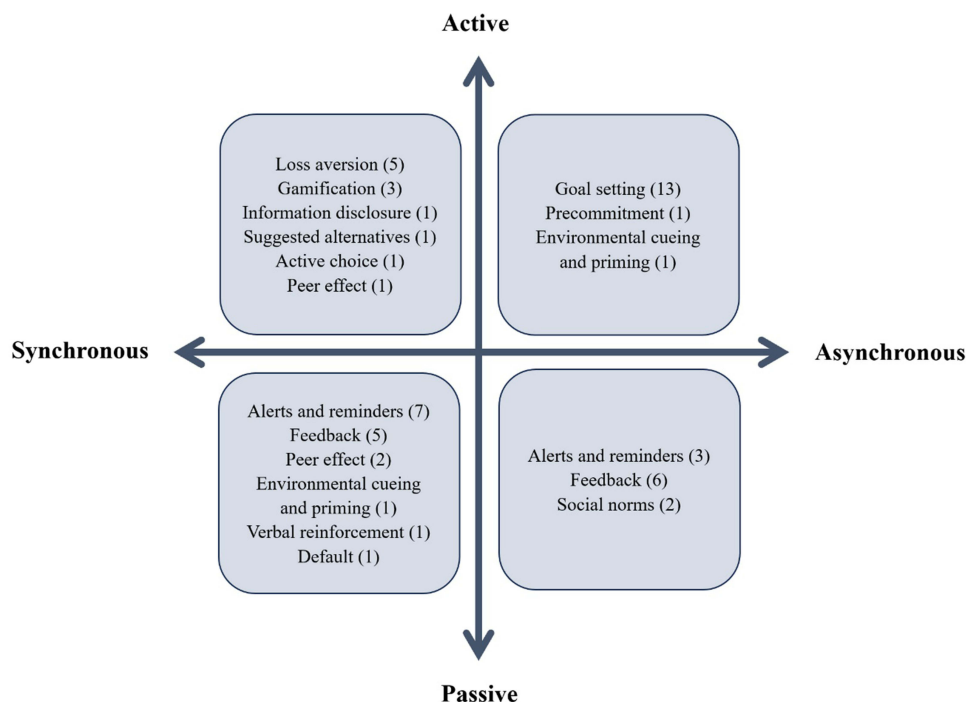


Figure 4 Nudging strategies across quadrants.

has become a crucial component of digital nudging strategies. Interestingly, among the nine studies employing digital nudging strategies, three specifically incorporated gamification, all of which demonstrated a positive impact on the primary outcome.^{47,48,64}

Discussion

The aim of this study was to review the literature on nudging health behavior change in HBCR patients to clarify the scope and delivery of nudging strategies. A total of 25 studies from the database were eventually included, and we identified and coded 14 nudging strategies. The most nudging strategies aimed to increase physical activity levels among patients undergoing HBCR. 14 nudging strategies were divided into four quadrants to capture their heterogeneity. In terms of form and content, it has changed from single nudging strategy to multiple ones, and from information nudging strategies to digital nudging strategies. Notably, the incorporation of gamification as a prominent nudging element yielded positive outcomes in the studies. This scope review clarified the scope and delivery of nudging strategies for health behavior change among HBCR patients, completed practical and meaningful classification and explanation, and provided a new digital nudging perspective and trend for understanding the role of nudging strategies in promoting HBCR practice.

HBCR holds significant importance in improving disease prognosis and quality of life for patients with heart disease.^{5–8} It is especially necessary for patients with heart disease to nudge healthy behavior change during routine HBCR. Nudging has received a lot of attention since 2008 as a simple, low-cost, and easy-to-implement behavior change strategy,²¹ and surprisingly, only 25 studies were included in this scope review. Most studies focused on the last 4 years, suggesting that nudging is becoming popular in health behavior interventions for HBCR. Of the 25 studies included, a total of 55 nudgings were used, as the vast majority of studies used the multi-nudge strategies. All but one of the studies with multiple nudging strategies had positive results in whole or in part. Although the multi-nudge strategies seems to increase the likelihood that an intervention will be effective, it is difficult to determine which elements are the effective components of an intervention success. In addition, adding an educational element to nudge interventions may be one way to make them sustainable. This study found that the multi-nudge interventions often included an education element, although education has not traditionally been seen as a nudging strategy,²¹ which could partly explain their long-term positive effects.

Considering two challenges of System 1 and System 2, one is that they ignore whether nudging intervention occurs with the knowledge and awareness of the participants, and the other is that they do not capture whether nudging intervention occurs at the time of decision-making. Therefore, based on a novel classification proposed by Sant'Anna et al,³⁷ a matrix with two dimensions and four quadrants was plotted to capture the heterogeneity of nudging strategies for health behavior change among HBCR patients. Reminders and alerts have been widely recognized as convenient and low-cost nudging strategies to influence individual health promotion behavior.^{67–69} However, its long-term effect on the primary outcome remains controversial, potentially due to their categorization as passive nudging interventions. Similarly, default, feedback, and social norms were also classified as passive nudging strategies because they often occur without the patient's knowledge and awareness. It is worth noting that when nudging interventions cease, patients may struggle to maintain the desired health-promoting behavior, indirectly highlighting the limitations of System 1 within the nudging theory.^{70–72} However, in all but one study in this review, the passive nudging strategies had a partial or full positive effect on the outcome of the studies. This could be attributed to the utilization of multiple nudging strategies and the inclusion of educational elements as supplementary components.

In this review, active and synchronized nudging strategies showed superiority in terms of both quantity and impact on primary outcomes. The main nudging strategies concentrated in this quadrant were loss aversion and gamification. Loss aversion is a cognitive bias that refers to the tendency of individuals to strongly prefer avoiding losses over acquiring equivalent gains. In other words, people tend to feel the pain of losing something more strongly than the pleasure of gaining something of equal value.^{73,74} Encouragingly, the review revealed that all the nudging strategies incorporating loss aversion had positive impacts on the research outcomes, further validating the effectiveness of this approach.^{45–48,64} In addition, we were surprised to find that gamified intervention strategies were always combined with loss aversion theory to promote health behavior change in patients with HBCR. The efficacy of gamification interventions in improving primary outcomes and enhancing patient adherence to interventions has been well-established.^{75,76} In this review, the gamification nudges with loss aversion theory had a positive effects on the primary outcomes of the studies.^{47,48,64} This could be attributed to the active

participation and synchronization with health promotion behaviors that both gamification and loss aversion require from patients. This combination ensures not only participants' enthusiasm but also the immediate occurrence of target behaviors, thus substantiating the rationale behind merging these two strategies.

In addition, the first quadrant (active and asynchronous) focuses on three nudging strategies, including goal setting, precommitment, and environmental cueing and priming. Of the 25 studies included, goal-setting was the most commonly adopted motivational strategy, with a focus on nudging physical activity levels among HBCR patients. The goal behavior requires the active participation of the patient, but goal setting is asynchronous with the patient's efforts. In this review, goal-setting nudging strategies had a positive impact on the results. According to goal setting theory,^{77,78} goals possess an inherent motivational quality that can convert an individual's needs into effective efforts. Motivated by the goal, patients' needs for HBCR will be transformed into intrinsic motivation to promote health behavior change. As a self-control strategy, precommitment is an effective way to help individuals ensure long-term benefits in intertemporal decision-making.⁷⁹ Similar to goal setting, precommitted behaviors are generated by the patient but are not required to be synchronized with health behavior change. Despite being asynchronous, precommitment as an effective nudging strategy had a positive impact on the findings in this review.⁴⁷ However, limited research exists on the application of precommitment to promote health behavior change among HBCR patients, and its effectiveness should be further demonstrated in future studies.

In this review, two key trends of nudging strategies were found, one is that multiple nudging strategies have become the mainstream, and the other is that nudging strategies have changed from informatization to digitalization. Of the 25 studies included, the majority covered multi-nudge strategies, and all but one multi-nudge interventions had a positive impact on the primary outcome. Multi-nudge strategies can address various dimensions of patients' fundamental psychological needs, thereby fostering intrinsic motivation and facilitating its internalization, which ultimately drives behavior change. Although combining multiple nudging strategies seems to increase the likelihood of an intervention being effective, the contributing nudging components remains challenging to identify. Therefore, a systematic integration of intervention strategies is recommended to promote health behavior change in HBCR patients, ensuring a balance between complexity and burden. In addition, the use of digital technology increases the convenience of the implementation of the nudging strategy and greatly reduces the nudging cost.^{80,81} This review revealed that email, smartphones, and pedometers were commonly used as informatization medium. As a higher stage, especially in recent years, digital nudging medium, covering smart health applications, digital medical devices, and online internet platforms, enable nudging interventions have a positive impact on the primary outcomes of studies with their advantages of convenience, novelty, diversity, and acceptability.^{43,45,48–50,56,59,61,63} It should be further verified in the future research. Additionally, gamification can enhance participants' intrinsic motivation by increasing engagement and immersion, providing real-time feedback and goal orientation, fostering social interaction and competition, and improving acceptability and adherence, all of which contribute to sustained behavior change. A key barrier to implementation is participants' acceptance of digital tools, particularly in populations with limited access to technology or lower digital literacy. Furthermore, privacy concerns and the complexity of integrating multiple strategies may present challenges during implementation. Therefore, future research should focus on overcoming these obstacles by improving accessibility, personalizing nudging strategies, and ensuring user-friendly design to enhance the scalability and effectiveness of nudging interventions.

Limitations

This scoping review has several limitations that should be acknowledged. Firstly, databases outside of medicine and healthcare were not searched in this scope review because we wanted to focus on using nudging strategies to influence health behavior change among HBCR patients. The disadvantage of this decision is that there are potentially important studies not indexed by PubMed, Web of Science, OVID (Embase, Cochrane Library, JBI). Secondly, due to the internal heterogeneity of nudging strategies, although we have identified a series of nudge-related search terms and strategies based on rigorous expert discussions, it is still inevitable that some relevant articles will be missed. Therefore, relevant nudging terms and strategies will be continuously updated and improved in future research. Thirdly, due to the lack of consensus on the theoretical framework of nudging and the heterogeneity of nudging strategies, a challenge arose in classifying and coding the nudging strategies. To address this, we employed a classification method based on Sant'Anna et al,³⁷ which offers a practical way for non-experts to comprehend the nudge strategies influencing health behavior change among HBCR patients. However, future studies should further investigate and validate the terms used in this classification.

Conclusion

In HBCR procedures, health behaviors, such as physical activity, medication compliance, and diet management, play a critical role in the clinical prognosis and quality of life of patients with heart disease, which depends on the patient's long-term compliance. However, health behavior decisions can be influenced by emotional and cognitive biases. Nudging strategies offer a valuable approach to addressing these biases. This review provides the latest insights on how nudging strategies can be applied and implemented in HBCR settings to promote health behavior change among patients with heart disease.

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