Dubai Medical Journal
Volume 7, Issue no. 2, DOI 10.18502/dmj.v7i2.17672
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Systematic Review

Transtheoretical Model-based Interventions are Effective in Promoting Healthy Behaviors Related to Modifiable Risk Factors of Noncommunicable Diseases: A Systematic Review

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Abstract

Introduction: Noncommunicable diseases (NCDs) such as heart diseases, type II diabetes mellitus, cancers, and stroke represent significant public health challenges globally. Modifiable risk factors, including insufficient physical activity (PA), overweight or obesity, and smoking, contribute significantly to the prevalence of these diseases. The transtheoretical model (TTM) offers a structured approach to behavior change, identifying stages of readiness and change processes. This systematic review (SR) aims to evaluate the effectiveness of TTM-based interventions in promoting healthy behaviors to mitigate these risk factors.

Methods: This systematic review addresses the PICO question: In adults aged 18 years and older with modifiable risk behaviors related to NCDs, how effective are TTM-based interventions compared to standard care in increasing physical activity levels (PAL), reducing weight or body mass index, improving dietary habits, and promoting smoking cessation (SC)? A comprehensive search of predetermined databases was conducted using nine research strings, adhering to strict inclusion and exclusion criteria. A six-stage process was employed to select studies for inclusion, followed by data extraction and narrative synthesis to identify relevant patterns, trends, and associations.

Results: Of the 259 articles retrieved, eight met the inclusion criteria. Baseline assessments determined participants' readiness for change. TTM-based interventions included feedback or counseling sessions, feedback materials, and reports delivered in-person, online, and by telephone. Follow-up durations varied from 2 weeks to 2 years. Five out of six studies supported the effectiveness of TTM-based interventions in enhancing PAL. Four out of five studies demonstrated their efficacy in weight management and improving dietary habits. However, only two out of five studies confirmed their effectiveness in SC.

Discussion: The findings indicate that TTM-based interventions are promising for improving PAL and, to a lesser extent, for managing weight and promoting healthy dietary behaviors. The limited effectiveness observed in SC interventions suggest a need for further research and possibly tailored strategies within this context.

Conclusion: TTM-based interventions effectively promote PA and weight management, with moderate success in improving dietary habits. However, their effectiveness in SC remains inconclusive, highlighting the necessity for further investigation and potential refinement of intervention strategies.

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Received: July 28, 2024
Accepted: September 16, 2024
Published: November 21, 2024

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OPEN ACCESS

Keywords: noncommunicable diseases (NCDs), transtheoretical model (TTM), behavior change, physical activity levels (PAL), weight management, smoking cessation

How to cite this article: El-Sobkey SB, Fouda BM, Ahmed RS, and El-Sayed DG. Transtheoretical Model-based Interventions are Effective in Promoting Healthy Behaviors Related to Modifiable Risk Factors of Noncommunicable Diseases: A Systematic Review. *Dubai Medical Journal*. 2024;7(2):63–86. DOI 10.18502/dmj.v7i2.17672

1. Introduction

Noncommunicable diseases (NCDs) are of increasing social, economic, and political concern for society and national governments. It has prevailed in many countries and is a major public health challenge globally, contributing to a significant portion of morbidity and mortality rates [1-4]. The NCDs include a variety of conditions such as heart diseases, type II diabetes mellitus, stroke, cancers, chronic respiratory diseases, and mental illnesses [2, 5] and in 2016, it was reported that 71% of global deaths were due to these NCDs [5, 6]. The main risk factors of NCDs can be classified into two main categories modifiable and non-modifiable factors. The non-modifiable risk factors include genetic factors, environmental factors, factors of medical conditions, and socio-demographic factors [1]. Meanwhile, under the umbrella of modifiable risk factors are self-management or lifestyle-related factors or health behaviors that can be modified by the individuals [1, 2]. Insufficient physical activity (PA), unhealthy dietary habits, and smoking are the most important three modifiable health behaviors linked with multiple NCDs [1, 7-9]. Worldwide, 1 in 4 adults do not meet the global recommended levels of PA, and insufficient PA among adults has seen an increase over time and is currently estimated at around 27.5% in 2016 [10, 11]. This lack of PA contributes significantly to the burden of NCDs globally and has been identified as one of the leading risk factors for mortality from such diseases [12]. Insufficiently active people have a 20–30% increased risk of death compared to sufficiently active people [10, 11]. Currently, obesity and overweight are major universal public health problems [13] and in 2016, more than 1.9 billion adults in the world were overweight, and 13% were obese [14]. The Centers for Disease Control and Prevention estimates that tobacco causes 6 million deaths per year and according to the Global Adult Tobacco Survey 2016-2017, nearly 42.4% of men, 14.2% of women, and 28.6% of all adults currently use tobacco [15]. Consequently, the most effective strategy to restore health and well-being along with prevention and control of NCDs, would be the one that promotes health behaviors and leads to lifestyle changes in terms of increased individuals PA, adherence to healthy dietary habits, weight management/loss, and smoking cessation (SC) [1, 2, 8, 16]. Behavior-change theories have been proposed as important tools to enhance individual's achievement of healthier behaviors and to foster addressing their obstacles, thus changing attitudes and contributing to sustainable health behaviors [17-20]. Theories that identify the individual's readiness to change might be helpful since most individuals are not ready to change their behavior; therefore, they will not be able to follow the traditional action-oriented health promotion programs [19, 21]. Additionally, focusing on research that studies the effectiveness of health promotion interventions only on the interventions' outcomes should be shifted to study the theory-based promotion interventions. Doing so would help healthcare practitioners understand the process of behavior change and the underlying mechanism of action contributing to the success of the interventions and to design more effective interventions for health behavior change [22, 23]. The transtheoretical model (TTM) is an integrative model of behavior change [24], and it is a framework that offers a structured approach to behavior change by identifying stages of readiness and processes of change [22, 23]. This TTM (also called the Stages of Change (SoC),

Model), was developed by Prochaska and DiClemente in the late 1970s [25, 26]. This TTM states that changing a behavior is complex and not by chance, instead it is a process as different individuals are in different SoC and readiness [26, 27]. In other words, TTM operates on the assumption that individuals do not change behaviors quickly and decisively. Rather, change in behavior, especially habitual behavior, occurs continuously through a cyclical process and in a sequence of stages [19, 21, 23]. In this TTM process, individuals move through five SoC: 1- Precontemplation: In this stage, individuals are often unaware that their behavior is problematic or produces negative consequences. Additionally, they do not intend to act in the foreseeable future (defined as within the next 6 months). Individuals in this stage often underestimate the pros of changing behavior and emphasize more of its cons. 2- Contemplation: In this stage, individuals intend to start healthy behavior within the next 6 months. They recognize that their behavior may be problematic, and a more thoughtful and practical consideration of the pros and cons of changing their behavior takes place, with equal emphasis on both. Even with this recognition, individuals may still feel ambivalent toward changing their behavior. 3- Preparation (Determination): In this stage, individuals are ready to act within the next 30 days. They start to take small irregular steps toward behavior change, and they believe changing their behavior can lead to a healthier life. 4- Action: In this stage, individuals have recently changed their behavior (defined as within the last 6 months) in regular basis and intend to keep moving forward with that behavior change. 5- Maintenance: In this stage, individuals have sustained their behavior change for a while (defined as more than 6 months) and, going forward, intend to maintain their behavior change. Individuals in this stage work to prevent relapse in earlier stages [19, 21, 23-26]. The TTM framework suggests that intervention programs might be tailored to the individual's stage of readiness [28] which can be assessed through paper-based (onsite or mailed) or online-based assessment [29]. Assessing the readiness for behavioral change is vital, as it determines the real possibilities of this occurring [30]. The SoC provides a substantial challenge for intervention development. Intensity, duration, and type of intervention should be responsive to the SoC of the individual [31]. It means that each SoC has different intervention strategies that are most effective, for instance, for SC, counseling to smokers is recommended for subjects in the preparation or contemplation SoC. On the contrary, it could be sufficient for smokers in the pre-contemplation stage to receive a self-help booklet on smoking cessation [32]. That is why healthcare practitioners' understanding of individuals' readiness to adopt healthier behaviors and tailoring interventions, accordingly, can enhance the effectiveness of health promotion efforts. The TTM-based interventions have the potential to significantly improve these efforts [19, 24, 26] and could help in the prevention and management of NCDs [33]. Considering the increasing burden of NCDs and the necessity to implement effective prevention strategies, this systematic review aims to assess the effectiveness of the TTM-based interventions in promoting healthy behaviors related to modifiable risk factors of NCDs, including insufficient PA, obesity or overweight, and smoking.

2. Methods

The registration number of this SR in PROSPERO International prospective register of systematic reviews is CRD42024518347 and it was received in March 2024. Primary data collection was started in January 2024 and was continued to mid-May 2024. For a better understanding of the methodology employed in this SR, it is provided in detail in the following subsections.

PICO research question: This SR was conducted to answer the following PICO question (Table **1**), in adults aged 18 years and older who exhibit one or more modifiable risk behaviors related to NCDs (such as being underactive, overweight, obese, having unhealthy dietary habits, or smoking)? How effective are TTM-based interventions compared to standard care in increasing physical activity levels (PAL), reducing weight or body mass index (BMI), improving dietary habits, and promoting smoking cessation?

Table 1: Detailed PICO question for a systematic review (SR) of TTM-based interventions addressing NCDs' modifiable risk factors.

Population (P)	Adults aged 18 years and older with a mean age of 40 years or above, who are not medically diagnosed but exhibit at least one unhealthy behavior that constitutes a modifiable risk factor for NCDs. The risk behaviors included are insufficient PA, overweight, obesity, poor dietary habits, or smoking.
Intervention (I)	Health promotion programs or interventions grounded in the principles of the TTM, aim to improve at least one of the unhealthy behaviors included in this SR.
Comparison (C)	No intervention, usual care, or alternative interventions are not based on TTM.
Outcome (O)	**1- Physical activity level (PAL):** Assessed through various means including self-reported or assessor-reported questionnaires, which may be administered on paper, online, or via telephone. Devices such as pedometers or step counters are also utilized to measure PAL. **2. Weight management and healthy dietary habits:** Measured using quantitative indicators such as weight (in kilograms), body mass index (BMI as a percentage), waist circumference (in centimeters), and waist-to-hip ratio. Additionally, adherence to healthy dietary habits was evaluated based on criteria including food portion control, reduced fat intake, and increased consumption of fruits and vegetables. **3- Smoking cessation (SC):** Assessed by measuring either the complete cessation of smoking or the reduction in nicotine dependence levels.

Eligibility criteria: Eligible studies for inclusion in the current SR are based on specifically pre-determined inclusion and exclusion criteria as follows.

Inclusion criteria:

1. *Type of Studies:* Randomized control trials (RCTs) and controlled clinical trials.
2. *Interventions:* Interventions that incorporate or are based on TTM principles and target at least one unhealthy behavior (specified in the PICO research question) are considered as modifiable risk factors for NCDs.
3. *Comparators/Control:* No intervention, usual care, or alternative interventions not based on TTM.
4. *Outcomes:* Outcomes relevant to at least one of the three unhealthy behaviors specified in the PICO research question.

5. *Participants:* Male and/or female aged 18 years or above with a mean age of at least 40 years, exhibiting at least one of the unhealthy behaviors related to the modifiable risk factors of NCDs (specified in PICO research question).

6. *Article Language:* English

7. *Publication Date:* Studies published between 1994 and 2024.

8. *Text Availability:* Online with free full text access.

Exclusion criteria:

1. *Participants:* Subjects with any diagnosed medical condition, post-surgery, cancer survivors, or athletes.

2. *Risk of Bias:* Studies with a high risk of bias as determined by the Cochrane risk of bias tools for non-randomized trials (ROBINS-I) and RCTs (ROB 2). Additionally, studies lack sufficient detail on the TTM intervention components or implementation or those with methodological limitations that could compromise the validity of findings.

Information sources: For this research, various databases were utilized as information sources. PubMed served as the primary source, offering a comprehensive collection of biomedical literature across the globe. APA PsycNet was employed for its critical insights into psychological or behavioral aspects that are essential for reviews in these fields. Scopus was included due to its broad coverage across numerous disciplines. However, gray literature sources such as conference abstracts, dissertations, or non-peer-reviewed publications were excluded from this study.

Search strategy: A comprehensive and systematic search strategy was implemented to identify studies relevant to this SR. Designed to align closely with the SR's objectives and the formulated PICO research question, the strategy encompassed several components: identifying search concepts, combining terms effectively, executing searches, adapting strategies as necessary, applying appropriate filters, and documentation of the process.

Search concepts: *Theoretical Framework (Concept 1):* This concept focuses on the theoretical foundations of health behavior change. The search terms included "Transtheoretical Model", "Stages of Change", "Health Behavior Change", "Health Promotion", "Health Behavior Intervention", and "Behavioral Readiness". *Health Outcomes/Behaviors (Concept 2):* This concept focuses on specific health behaviors and outcomes targeted by the SR. The search terms were organized into three categories:

1- *Physical activity (PA):* Terms such as "Physical activity", "Exercise", "Physical Activity Promotion", and "Physical Engagement".

2- *Weight management:* Terms included “Overweight”, “Obesity”, “Weight Management”, “Body Mass Index Reduction”, “Weight Control”, “Weight Loss”, “Dietary Habits”, “Eating Behavior”, and “Obesity Prevention”.

3- *Smoking cessation (SC):* Included terms like “Smoking Cessation”, “Stop Smoking”, “Quitting Smoking”, “Smoking Reduction”, “Tobacco Use Cessation”, and “Reducing Tobacco Use”.

Combining the terms: The search strategy utilized Boolean operators to effectively combine the identified terms from both Concept 1 and Concept 2. The structure of the search was as follows: (“Transtheoretical Model” OR “Stages of Change” OR “Health Behavior Change” OR “Health Promotion” OR “Health Behavior Intervention” OR “Behavioral Readiness”) AND (“Physical activity” OR “Exercise” OR “Physical Activity Promotion” OR “Physical Engagement” OR “Overweight” OR “Obesity” OR “Weight Management” OR “Body Mass Index Reduction” OR “Weight Control” OR “Weight Loss” OR “Dietary Habits” OR “Eating Behavior” OR “Obesity Prevention” OR “Smoking Cessation” OR “Stop Smoking” OR “Quitting Smoking” OR “Smoking Reduction” OR “Tobacco Use Cessation” OR “Reducing Tobacco Use”).

Search execution: The search strings were formulated using the combined terms previously outlined. For each of the three included outcomes or health behaviors, three distinct search strings were developed, resulting in a total of nine strings. Researchers utilized these nine strings to conduct searches across the predetermined databases. Additionally, to ensure the comprehensiveness of the search strategy and minimize the risk of selection bias, periodic searches were conducted throughout the systematic review, concluding just before the submission for publication. The databases were last accessed on May 11th, 2024, ensuring the most current data were included in the review.

Search strategy adaptation: During the search process, the term “Behavioral Readiness” was found to yield nonrelevant results. Consequently, this term was replaced with an alternative term, as demonstrated in (Table **2**). This adjustment helped refine the search strategy and improve the relevance of the search outcomes.

Documentation: All search activities were meticulously documented, including details of the databases searched, the search terms used, the number of records retrieved, and any adaptation made to the search strategy. This documentation was crucial for ensuring the reproducibility of the search and for adhering to the PRISMA guidelines.

Filters: To align with the SR’s inclusion and exclusion criteria, several filters were applied during the database searches to refine the results. These filters included: *1- Publication date:* Only studies published between 1994 and 2024 were considered, *2- Text availability:* Searches were limited to studies available online as free full-text articles, *3- Article type:* Only RCTs and controlled clinical trials were included, *4- Article language:* The search was restricted to articles published in English, *5- Age:* Focus was placed on studies involving adults specifically 18 years and above with a mean age of a least 40 years, *6- Participants:* The studies selected involved normal or healthy human subjects.

Table 2: Search strings formulated Boolean operators for each health behavior.

Outcomes/Health behaviors	Search strings			
	One	**Two**	**Three**	**Adapted**
Physical activity	("Transtheoretical Model" OR "Stages of Change") AND ("Physical Activity" OR "Exercise")	("Transtheoretical Model" OR "Health Behavior Change") AND ("Physical Activity Promotion" OR "Physical Engagement")	("Transtheoretical Model" OR "Health Behavior Intervention") AND ("Physical Engagement" OR "Physical Activity")	None
Overweight/Obesity	("Transtheoretical Model" OR "Stages of Change") AND ("Overweight" OR "Obesity" OR "Weight Management")	("Transtheoretical Model" OR "Behavioral readiness") AND ("Body Mass Index Reduction" OR "Weight Control" OR "Weight Loss")	("Transtheoretical Model" OR "Health Behavior Intervention") AND ("Dietary Habits" OR "Eating Behavior" OR "Obesity Prevention")	("Transtheoretical Model" OR "Health Behavior Change") AND ("body mass index reduction" OR "weight control" OR "weight loss")
Smoking	("Transtheoretical Model" OR "Stages of Change") AND ("Smoking Cessation" OR "Reducing Tobacco Use")	("Transtheoretical Model" OR "Health Behavior Intervention") AND ("Stop Smoking" OR "Quitting Smoking")	("Transtheoretical Model" OR "Behavioral Readiness") AND ("Smoking Reduction" OR "Tobacco Use Cessation")	("Transtheoretical Model" OR " Health Behavior Change") AND ("smoking reduction" OR "tobacco use cessation")

Selection process: The selection process adhered to the SR aim and research question and followed the predefined SR eligibility criteria. Researchers utilized the nine search strings to query the three predetermined databases, applying the previously mentioned filters. The search results were saved in CSV format. All the researchers set up accounts on the free software Rayyan Intelligent Systematic Review, a tool designed to streamline the SR process by facilitating tasks such as importing data, checking for duplication, and screening. The prime researcher (PR) initiated a new review on Rayyan, imported the CSV documents, and used the platform to check for and resolve any duplications. Meanwhile, the PR invited the other three researchers to join Rayyan as collaborative researchers. To minimize bias, the blind review feature in Rayyan was enabled, allowing each researcher to independently screen studies and see only their decisions. The screening was conducted in three steps:

1- *Title screen:* The researcher made an "include" decision if the study title clearly met the SR eligibility criteria. If the title did not match any of the eligibility criteria, they selected the "exclude" decision. For titles where a decision was not clear, "may be" was chosen.

2- *Abstract screening:* This step was applied to studies marked "include" or "may be" decisions. Based on the abstract screening, studies that were marked as "included" were either continued as "include" or moved to "exclude" or "may be" decisions. The same was applied to the studies marked as "may be" decisions they either remained with the same decision or changed to "exclude" or "include".

3- *Full-article screening:* In this final step, the researcher thoroughly reviewed the full articles for those studies that had been marked "include" or "may be" from the abstract screening. Decisions to "include" or "exclude" were finalized based on a comprehensive review of the full texts.

To provide a transparent and structured review process, reasons for excluding studies were systematically recorded using Rayyan's predefined reasons menu, throughout each screening phase. These reasons and their frequencies were then systematically recorded and tabulated for each screening step.

Risk of bias assessment (ROB): Studies that progressed to the "include" decision following the full-article screening were subject to a thorough ROB. The assessment utilized Cochrane risk of bias tools, ROBINS-I for non-randomized studies, and RoB 2 for RCTs [34]. These domain-based tools qualitatively evaluate the risk of bias across various domains within the studies. Each tool comprises seven domains. Traditionally, the Cochrane ROB tools categorize the risk of bias into three levels (low risk of bias, some concerns, and high risk of bias) for individual domains. However, to better align with the specific context of this SR, the researchers adapted the possible flexibility to categorize the ROB and utilize a modified four-category system to assess bias more precisely as detailed in (Table **3**).

Table 3: Revised judgment categories for Cochrane risk of bias tools in the current systematic review.

Category title	Category description
Low risk of bias	Indicates minimal concerns according to Cochrane ROB tool criteria, suggesting the domain is unlikely to significantly impact study results.
High risk of bias	Significant concerns indicate substantial bias in the domain, affecting the study's validity and results.
Some concerns	Minor issues or uncertainties are noted, which could moderately influence the validity of the study results.
Unclear risk of bias	Insufficient data is available to assess bias in the domain, preventing a definitive risk evaluation.

Use of ChatGPT4 for ROB: ChatGPT4, an Artificial Intelligence (AI) tool, was utilized to assess the risk of bias across the specified domains. The AI was provided with a prompt that included the assessment domains, the judgment categories, and their descriptions. Additionally, PDF documents of the articles under assessed were attached for comprehensive evaluation. The prime researcher meticulously reviewed the ChatGPT4 output to ensure accuracy and checked for any instances of "hallucination", thereby confirming the quality of this ROB assessment. The results of ROB assessment were systematically recorded in an Excel spreadsheet. This spreadsheet included the article title, judgment, and justification for each of the seven assessment domains, along with an overall ROB decision. Despite the initial assessment by ChatGPT4, the final decision to include or exclude an article was made by the researchers, after carefully reviewing each of the seven domains' judgment and its justification. Any study identified with a "high risk" judgment in one or more of the seven domains was excluded from the SR.

Inter-researcher agreement: To address any discrepancies that arose between researchers during the study selection process or ROB assessment, a structured resolution strategy was implemented. This strategy included holding consensus meetings as needed to discuss and resolve differences, ensuring a unified approach to final decisions regarding the inclusion or exclusion of studies. This rigorous method was designed to enhance the reliability and validity of the SR findings by promoting agreement among the research team.

Data extraction and interpretation: Data were extracted from articles that passed the ROB assessment and included in this SR. The extraction process involved recording information in an Excel spreadsheet,

covering key details such as participants characters (age, gender, educational level, and ethnicity), specific unhealthy behavior addressed, intervention details and study groups, outcomes, and results. Additional relevant data were also noted as required. The extracted data were then organized into tables, and narrative data synthesis was applied. This synthesis process involved combining and analyzing the extracted data to draw over-reaching conclusions related to the SR's aim and the research PICO question. Furthermore, this narrative data synthesis was utilized to identify patterns, trends, and associations relevant to the SR's research question and aim, thereby enriching the understanding and implications of the findings.

PRISMA Check list and flow diagram: The report of this SR was structured according to the preferred reporting items of systematic review and meta-analysis (PRISMA) check list. Additionally, the PRISMA flow diagram was employed to visually represent the selection process, detailing the numbers of studies identified, included, and excluded at each stage of the review.

3. Results

The main finding of this SR is that interventions based on the TTM are effective in improving healthy behaviors that are risk factors to NCDs. This is particularly evident in promoting PA and weight management, with moderate success in improving dietary habits. However, the effectiveness of these interventions in SC remains inconclusive.

To achieve the aim of this SR, a rigorous search strategy was applied, and it effectively utilized three main strings, alongside an adapted string, for each of the three investigated outcomes. This approach was executed across the predetermined databases by implementing specific filters, aligned with the study's eligibility criteria. The effectiveness of this strategy is reflected in the retrieval of a significant body of research, with a total of 259 articles identified (144 articles from PubMed, 102 from Scopus, and 13 from APA PsycNet).

As shown in Figure **1**, the number of retrieved articles from the different selection process steps was 8 articles, included in the SR. Because all the articles retrieved from the full-article screening step were RCTs, the Cochrane ROB-2 was used for ROB assessment. As demonstrated in (Table **4**), two articles were excluded because they received a decision of "high risk" in assessment domain six, "Selective Reporting". The remaining eight articles, which had "Included' decision in the overall ROB Judgement had "Low Risk" decisions in nearly all assessment dimensions, except for dimensions three and four. The reasons for article exclusion during the selection process steps were categorized and presented in terms of frequency (Table **5**).

The extracted data from the included studies regarding population characteristics (Table **6**) implies that the included participants were middle-aged as indicated by their ages' range or mean. The table also shows other characteristic such as the number of participants, their ethnicity, and the percentage of female

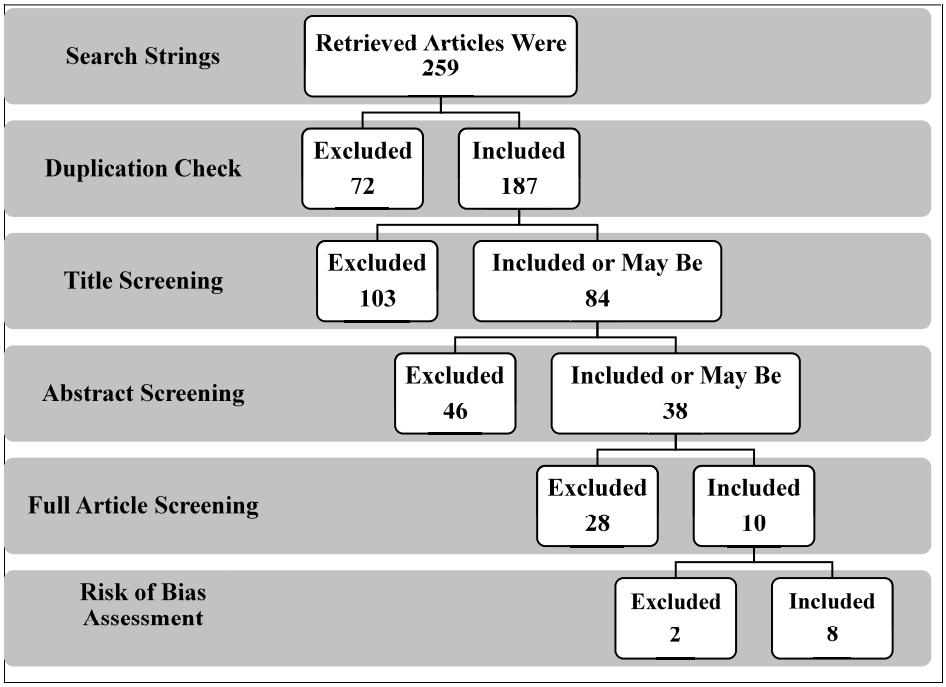

Figure 1: PRISMA flow chart of articles retrieved during selection process steps.

Table 4: Results of risk of bias assessment using Cochrane ROB-2 for randomized control trials.

#	Retrieved article reference number	D1: Random sequence generation	D2: Allocation conceal-ment	D3: Blinding of partici-pants and personnel	D4: Blinding of outcome assessor	D5: In-complete outcome data	D6: Selective reporting	D7: Other sources of bias	Overall, ROB judgement
1	[29]	Low risk	Low risk	Some concerns	Unclear risk	Low risk	Low risk	Low risk	Include
2	[28]	Low risk	Low risk	Some concerns	Unclear risk	Low risk	Low risk	Low risk	Include
3	[22]	Low risk	Low risk	Some concerns	Unclear risk	Low risk	Low risk	Low risk	Include
4	[6]	Low risk	Low risk	Some concerns	Unclear risk	Low risk	High risk	Low risk	Exclude
5	[24]	Low risk	Low risk	Some concerns	Unclear risk	Low risk	Low risk	Low risk	Include
6	[30]	Low risk	Low risk	Some concerns	Unclear risk	Low risk	Low risk	Low risk	Include
7	[33]	Low risk	Low risk	Some concerns	Unclear risk	Low risk	Low risk	Low risk	Include
8	[32]	Low risk	Low risk	Some concerns	Unclear risk	Low risk	Low risk	Low risk	Include
9	[15]	Low risk	Low risk	Some concerns	Unclear risk	Low risk	Low risk	Some concerns	Include
10	[31]	Low risk	Low risk	Some concerns	Unclear risk	Low risk	High risk	Low risk	Exclude

Table 5: Reasons for articles exclusion at different screening steps.

Reason category	Frequency based on screening step			Total
	Title	Abstract	Full text	
Irrelevant study aim	0	18	3	21
Irrelevant study design	29	11	4	44
Irrelevant intervention	17	7	4	28
Irrelevant population	38	10	6	54
Irrelevant outcome	19	0	0	19
Inaccessibility for free full article	0	0	11	11
Total	103	46	28	177

participants. Additionally, the table indicates that the included studies focused on the three predetermined modifiable risk factors of NCDs. Insufficient PA was assessed in six articles, while overweight/obesity and smoking were each studied in five articles. Furthermore, the table indicates that assessing the participants' readiness for behavioral change through the SoC is a common baseline assessment in all the included studies. In addition, at least one of the focused modifiable risk factors of NCDs is included in the baseline assessment. The assessment modes were relied on self-reporting (3 articles), healthcare personnel (3 articles), and the researchers (2 articles). The most frequently used baseline assessment was in-person (5 articles). The participants' groups, interventions implemented, and follow-up assessment are presented in (Table **7**). Participants were divided into one intervention group and one control group in five studies, while two studies included only intervention groups. The total number of intervention groups in eight studies was 14, with 12 of them involving sessions of feedback, behavioral counseling, or motivational interviews, all tailored based on participants' SoC. The remaining intervention groups used printed mailed materials and feedback reports, which were also based on participants' SoC. Six control groups were included, with four of them using the usual intervention or no intervention, while sessions and materials were used in the other 2 groups but were non-tailored. In-person mode of interventions was the most common in intervention groups and less common in the control groups (9 and 2 respectively). Printed materials or telephone mode of intervention were utilized in 3 intervention groups and once in the control group, while the online mode was used twice with intervention groups. Apart from the article in which 48 sessions were applied, the range of sessions ranged from 1-4 sessions in the rest of the 7 studies. Meanwhile, the table determines that in-person follow-up assessment was applied in 4 articles and that the follow-up duration ranged from short duration (2-4 weeks) to long duration, up to 24 months. Results also show that different outcome measures were utilized in the eight included studies. For the PAL, different self-reported questionnaires were used. For overweight/obesity, direct measures such as body weight, BMI, WC, and WHR were employed. Additionally, dietary habit/behavior was assessed using various questionnaires. Meanwhile, SC assessment was mainly based on participants' self-reporting.

Table 6: Summary of population characteristics, modifiable health risk factors of noncommunicable diseases, and baseline assessment extracted from the eight included studies.

Ref.	Age (Year)		Participants' Number	% of Females	Ethnicity/ Nationality	% of Higher Education	MHRF of NCDs			Baseline assessment		
	Range	Mean					IPA	O/O	S	Item	Mode	Assessor
[29]	-	41.6	1401	79	87% Non-Hispanic Caucasian	92	√	√	√	RBC (SoC), BMI, Smoking.	Online health risk assessment and intervention (HRI)	Self-reported
[28]	43.9-51.4	-	883	54	96.2 White	-	√	√	√	RBC (SoC), PAL, dietary fat intake, smoking	In-person	Trained nurses
[22]	-	44.5	239	82	90.3% Caucasian	-	√	-	-	RBC (SoC), PAL.	Mail + Telephone	Self-reported
[24]	-	45.4	1277	49.2	White, not Hispanic: 79.1%, Black, not Hispanic: 6.5%, Hispanic: 7.0%	-	√	√		RBC (SoC), PAL, dietary behavior	Telephone	Self-reported
[30]		IG 43.1, CG 49	33	100	Brazilian	-	-	√	-	RBC (SoC), Anthro-prometric measures	In-person	Researchers
[33]	45-75	49.3	3062	54.9	Spinach	55.8	√	√	√	RBC (SoC), PAL, dietary habit, smoking	In-person	PHC professionals
[32]	25-64	-	1100	100	Italian	-	√	-	√	RBC (SoC), PAL, smoking	In-person	Trained midwives
[15]	18-57	41.3	80	11.2	Indian	-	-	-	√	RBC (SoC), Nicotine dependency	In-person	Researchers

Ref. = Reference of study, IG = Intervention group, CG = Control group, MHRF = Modifiable health risk factors, IPA = Insufficient physical activity, O/O = Overweight/Obesity, S = Smoking, RBC = Readiness for Behavioral change.

Table 7: Summary of extracted data from the eight included studies regarding interventions and follow-up assessments.

Ref.	G	N	Interventions				Follow-up	
			Type	N	Mode	Description	Duration	Mode
[29]	IG	504	Session	3 (at least 30 days in between)	Online	HRI+ Feedback, tailored based on SoC	6 months	Online
	IG	433	Session	3	In-person or Telephone	HRI+ Motivational interview-based health coach	4 and 12 months	In-person
	IG	464	Session	1	Online	HRI only	6 and 12 months	Mail or phone
[28]	IG	316	Session	2 (one risk factor) or 3 (2 risk factors)	In-person	Behavioral counseling, tailored based on SoC	6, 12, 24 months	Mail followed by telephone for non-responders
	CG	567	Session	1	In-person	Usual health promotion methods	4 months	In-person
[22]	IG	80	Materials	-	Printed-mailed	Tailored based on SoC, focused on PA	12 months	In-person
	IG	80	Session	1	Telephone	Behavioral counseling, tailored based on SoC	6 and 12 months	Telephone
	CG	79	Materials	-	Printed-mailed	Non-tailored, standard, focusing on general health and wellness	2 and 4 Weeks	In-person
[24]	IG	628	Feedback reports	4	Printed-mailed	Computer-generated, tailored on SoC, focused on healthy eating, moderate exercise, managing emotional distress without eating	6 months	Online
	CG	649	-	-	-	No intervention	4 and 12 months	In-person
[30]	IG	13	Session	48 exercise, 8 health education, 8 nutrition	In-person	Group guided exercise (3/week) + health education (1/2 weeks) + nutritional guidance (1/2 weeks)	6 and 12 months	Mail or phone
	CG	20	-	-	-	No intervention	6, 12, 24 months	Mail followed by telephone for non-responders
[33]	IG	1481	Session	Individual approach: 2-3+	In-person	Individual approach: Behavioral counseling, tailored based on SoC; Group approach: Health education workshops (gym sessions, cooking workshops, and seasonal menus); Community approach: focused on social prescription of resources and activities offered in the participants' communities	4 months	In-person
	CG	1581	Session	1	In-person	Received usual care: PHC professionals integrated a program of preventive activities and health promotion, mainly brief advice	12 months	In-person
[32]	IG	363+ 366	Session	1	In-person	A self-help booklet + Behavioral counseling, tailored based on SoC focused on PA and Smoking. Precontemplation participants received SC+ PA (N=366), contemplation and preparation received SC (N=363)	6 and 12 months	Telephone
	CG	371	Session	1	In-person	A self-help booklet + usual care without any additional targeted counseling interventions	2 and 4 weeks	In-person

Table 7: Continued.

Ref.	G	N	Interventions				Follow-up	
			Type	N	Mode	Description	Duration	Mode
[15]	IG	20	Session	3	In-person	Behavioral counseling, tailored based on SoC focused on SC	6 months	Online
	IG	20	Session	3	In-person	Behavior counseling and intra oral camera assessment	4 and 12 months	In-person
	IG	20	Session	3	In-person	Behavior counseling and carbon monoxide monitoring	6 and 12 months	Mail or phone
	IG	20	Session	3	In-person	Behavior counseling, intra oral camera assessment and carbon monoxide monitoring	6, 12, 24 months	Mail followed by telephone for non-responders

G = Group, IG = Intervention group, CG = Control group.

The summary of extracted data from the eight included studies regarding their results is demonstrated in (Table **8**). Additionally, Table **9** indicates that five studies support the effectiveness of TTM in improving PAL, while four studies support its effectiveness in weight management and fostering healthy dietary behaviors. Only two studies support the effectiveness of TTM in SC.

Table 8: Summary of extracted data from the eight included studies regarding the results.

Ref.	Results		
[29]	PAL: The MI and TTM groups had significantly ($P < 0.01$) greater percentage than the standalone HRI. No significant differences ($P > 0.05$) were observed between the MI and TTM groups	BMI: No significant differences ($P > 0.05$) between groups	Smoking: A nonsignificant ($P > 0.05$) trend favoring the MI and TTM groups but lacked the sample size to find significant differences
[28]	PAL: The odds for intervention vs control were 1.89 (95% CI = 1.07, 3.36) at 4 months and 1.68 (95% CI = 1.08, 2.61) at 12 months	Dietary fat intake reduction: The odds for intervention vs. control were 1.77 (95% CI = 0.76, 4.14) at 4 months and 1.49 (95% CI = 0.56, 4.00) at 12 months	Smoking: The odds for intervention vs. control were 2.15 (95% CI =1.30, 3.56) at 4 months and 1.26 (95% CI = 0.73, 2.18) at 12 months
[22]	At 6 months: Print-based vs. control P = 0.005 Print-based vs. Phone-based P = 0.005. Phone-based vs. control P = 0.020.	At 12 months: Print-based vs. control and vs Phone-based P = 0.001. Phone-based vs. control P = 0.204	
[24]	PAL (n = 713): IG had greater percentages than the CG progressed to (A/M) at 6, 12, and 24 months $P < 0.050$.	Healthy Eating (n = 1121): IG had greater percentages than the CG progressed to (A/M) at 6, 12, and 24 months $P < 0.001$ Fruit and Vegetable (n = 858): IG had greater percentages than CG and progressed to A/M at 6, 12, and 24 months $P < 0.0001$	Managing stress without eating (n = 458): IG had greater percentages than CG at 6, 12, and 24 months $P < 0.001$ Self-reported weight loss: IG had a greater percentage than CG and lost at least 5% of baseline weight at final follow-up $P < 0.050$
[30]	IG: pre-post reductions in weight (P = 0.004), BMI (P = 0.003), WC (P = 0.001), and WHR (P = 0.002). 6 out of the 13 (about 50%) showed progression in SoC	CG: Pre-post reductions in weight (P = 0.235), BMI (P = 0.111), WC (P = 0.145), and WHR (P = 0.104). All the participants in the CG either remained in the same stage or regressed	
[33]	No difference in PAL positive change between IG and CG (P = 0.737)	IG had a greater percentage of positive change than CG in diet behavior (P = 0.001).	No difference in smoking behavior between IG and CG (P = 0.165)

Table 8: Continued.

Ref.	Results		
[32]	Participants in both SC group and SC + PA group who were in the preparation SoC for SC doubled their likelihood of quitting compared to CG (OR = 2.1 95% CI = 1.0-4.6) P < 0.05. Participants in the contemplation stage were more likely to reduce their daily cigarette consumption after the intervention (OR = 1.8, 95% CI: 1.1-3.0). This is specifically for the 6-month follow-up period, not 12 months	SC Rates showed significant differences (P = 0.010) at 12 months: SC group: 14.1%. SC + PA group: 13.2%. CG: 5.1%.	The increase in PA in the SC + PA group was significant (p < 0.05) compared to the CG
[15]	Percentages of participants showed progression from pre-contemplation stage to contemplation or preparation stages in 2- weeks follow-up showed significant difference (P ≤0.05), IG 4 (37%), IG 3 (28.3%), IG 2 (13%), and IG 1 (21.7%)	In 4-weeks follow-up the percentages showed no significant difference. IG 4 (40%), IG 3 (24%), IG 2 (24%), and IG 1 (12%)	

Ref. = Reference of Study.

Table 9: Summary of effectiveness of the transcortical model on improving the modifiable risk factors of noncommunicable diseases.

Ref.	Physical activity level improvement	Weight management/ healthy dietary behavior	Smoking cessation
Prochaska et al. [29]	*	X	X
Steptoe et al. [28]	*	*	*
Papandonatos et al. [22]	*	NA	NA
Johnson et al. [24]	*	*	NA
Bevilaqua et al. [30]	NA	*	NA
Zabaleta-del-Olmo [33]	X	*	X
Gorini et al. [32]	*	NA	*
Das [15]	NA	NA	?

* = Significant improvement, X = Nonsignificant improvement, NA = Not applicable (the risk factor was not included in this study), ? = No concluded decision (no explicit decision if significant or not significant).

4. Discussion

Improving the modifiable risk factors of NCDs can have a significant impact on controlling these diseases. The modifiable risk factors included in this SR are focused on improving PAL, managing weight, fostering healthy dietary habits, and smoking cessation. These risk factors are primarily addressed through behavioral changes, which makes the TTM an ideal intervention to tailor the participants through their behavioral change journey based on their SoC. Therefore, this SR aimed to assess the effectiveness of the TTM-based interventions in promoting healthy behaviors related to modifiable risk factors of NCDs including insufficient PA, obesity or overweight, and smoking.

A combination of rigorous methodology and AI assistance was implemented during the conduction of this SR to guarantee the validity of its results. The commonly practiced screening of articles for titles, abstracts, and full text was applied based on pre-specified eligibility criteria. Regarding the ROB assessment, studies focusing on behavior change interventions, such as the current SR, often face challenges in fully complying with ROB criteria related to blinding either the participants or the outcome assessor. De Freitas PP et al., reported in their study that due to the type of intervention used in TTM for weight management, it was impossible to blind the participants and investigators to the intervention [13]. They added that one of the strategies used in TTM intervention group was the agreement on the treatment goals and clarification of the proposed objectives, which precluded blinding [13]. This challenge is particularly pronounced in interventions based on the TTM, which often involve providing individualized feedback to the participants. Unlike studies involving interventions like medications, where blinding is more feasible, behavior studies, especially those employing TTM are inherently struggling to implement blinding effectively. Additionally, during the preliminary review conducted for this SR, it was observed that information regarding blinding domains (domains 3 and 4) was frequently missing from the reviewed studies. Consequently, the researchers decided on “some concern” whenever participants’ blindness was not followed and “unclear risk” for cases of insufficient data. For these reasons, this SR included studies with “low ROB” or “some concerns” or “unclear risk” decisions, and only studies with “high ROB” decisions were excluded. Eight articles were included in the current SR and the results of these articles will be discussed based on each modifiable risk factors of NCDs.

4.1. Effectiveness of TTM-based Interventions on PAL

Out of the eight articles included in the SR, six articles assessed the effectiveness of TTM-based interventions on improving PAL. Five of these studies supported the effectiveness of these interventions for participants with insufficient PAL [22, 24, 28, 29, 32].

The TTM-based intervention was shown to be effective regardless of its type, mode, or number. In the five studies indicating significant effectiveness, various methods were used, including feedback and counseling sessions (in-person, online, telephone), printed materials, and printed feedback reports. The number of sessions ranged from one to four. The commonality among all interventions was that they were tailored to participants’ SoC. This strongly supports the concept that individual health promotion programs based on participants’ readiness to change their health behaviors are more effective and should be the preferred practice for modifying health risk factors related to NCDs, including PAL. The effectiveness of computer-generated materials and online sessions also suggests that TTM-based interventions are cost-effective. In addition, these TTM-based interventions were implemented by different health professionals, indicating their wide applicability and that no specialized specialist is needed. This fosters its broader application. It is to be noted that the follow-up for the effectiveness of TTM-based interventions on PAL

was assessed over durations ranging from 6 months to 24 months. This evidence of the effectiveness of TTM-based interventions in maintaining the change in participants' PA behavior for up to 24 months.

Only one study [33] showed no significant difference between the intervention group and the control group. The older age of participants in this study might explain this non-significant result. The age range for participants in this study was 45-75 years, while the reported age range in studies that showed significant improvement in PAL was 25-64 years in one study [32] and 43.9-51.4 years in another study [28]. Additionally, the mean age in this study was 49.3 years, whereas the mean age in other studies were lower 41.6 years [29], 44.5 years [22], and 45.4 years [24]. Younger participants might be more likely to have the motivation, willingness, and health opportunities to change their PA behavior than older participants. With aging, people experience normal physiological structural brain changes, such as a decrease in brain volume, particularly in the frontal lobe, which is critical for higher cognitive functions like planning, decision-making, and adapting to new situations [35]. These changes can make behavior change more challenging for older adults. Another possible reason for non-significance is the low percentage of participants in this study who received a high level of education (55.8%). Although the percentage of participants with a high level of education was mentioned in only one of the studies that showed significance, and it was high percentage (92%), the low percentage of participants with a high level of education is still considered a factor for no significance. This is due to the relationship between the educational level and behavior change. Studies have demonstrated a strong relationship between educational level and behavior change. Higher educational attainment is associated with better health behaviors, including increased PA, healthier diets, and reduced smoking rates. This correlation is often mediated by health literacy, where individuals with higher education levels tend to have a better understanding of health information and a greater ability to apply it effectively to make positive behavioral changes [36]. In this study of non- significant results for PA, participants received not only an individually tailored intervention based on their SoC but also group health education workshops in the form of gym sessions. Additionally, they engaged in a community approach focused on the social prescription of resources and activities available in their communities. This triple-fold program was supposed to have a greater effect than the other studies that received only the individual approach. However, this was not the case, emphasizing the dominant effect of old age and lower educational levels.

4.2. Effectiveness of TTM-based Interventions on Weight Management and Healthy Dietary Behavior

This SR included five studies that assessed the participants' weight management and improvement in healthy dietary behavior. Four of these studies showed that TTM-based interventions are effective. Interestingly, the study [24] that included younger participants (mean age 41.6 years) with a high percentage of highly educated individuals (92%) demonstrated a non-significant effect. In addition, this study showed significant improvement in PAL. These results highlight that the effectiveness of TTM-based interventions

might be selective to one health behavior rather than another. This proposed concept is like what was mentioned by de Freitas et al., that interventions targeting PA using TTM have shown considerable success in increasing activity levels among participants. In contrast, dietary interventions using TTM have produced variable outcomes, highlighting the complexity and potential selectivity of the model's effectiveness depending on the specific health behavior being addressed [13]. This variability could be attributed to differences in how individuals perceive and engage with these behaviors, the specific challenges associated with each behavior, and the contexts in which interventions are implemented. An example of the context of intervention implementation is the study that showed a non-significant effect, which included three online sessions with at least 30 days in between each session. This time gap might have affected and interrupted the participants' motivation and focus on behavior change, leading to a loss of their readiness for this change, particularly with the online mode of sessions. It should be noted that online sessions with this time gap showed effectiveness in improving PAL, which again highlights the complexity and variability of the TTM. This necessitates careful consideration from health professionals when selecting TTM to promote healthy behaviors.

4.3. Effectiveness of TTM-based Interventions on Smoking Cessation

Five studies assessed the effectiveness of TTM on SC. No specific consensus about this effectiveness can be claimed, as two studies supported the effectiveness while another two studies did not. The remaining study's results are questionable. The small sample size was the accused reason for nonsignificant effectiveness in the two studies [29, 33]. Smaller sample sizes often lead to higher variability and less power to detect a true effect [29]. Additionally, the intervention included three online sessions with at least 30 days in between. As mentioned earlier, this time gap might have affected participants' motivation and readiness for behavior change, particularly for SC, which often requires more consistent and intensive support [29]. Smoking cessation is a complex behavior that might be more resistant to change compared to other health behaviors like PA or dietary changes. The combination of a small sample size, time gap in intervention application, and the complexity of SC behavior might have collectively resulted in the non-significant effectiveness of TTM for SC. The fifth study's results are questionable due to the nature of the interventions implemented. This study included four intervention groups. The first group received behavioral counseling, tailored based on SoC focused on SC. In the other three intervention groups, this behavioral counseling was included in addition to other motivational interventions. The outcome measure was the percentage of participants who showed progression from the pre-contemplation stage to contemplation or preparation stages. This progression was reported to 21.7% of participants in the first group, 13% in the second group, 28.3% in the third group, and 37% in the fourth group, with significant differences among the groups. Several reasons contribute to the uncertainty of this study's results: 1- While a considerable percentage of participants in the first group showed progression, the highest percentage was in the fourth group. It is unclear whether this progression is due to the TTM-based counseling alone

or the additional interventions. 2- The results were significant at the 2-week follow-up assessment but not at the 4-week follow-up, casting doubt on the sustained effectiveness of TTM-based intervention. 3- The study included four intervention groups and no control group, which made it difficult to draw clear conclusions about the effectiveness of the TTM-based intervention. 4- The study included only 80 participants, with 20 in each intervention group. This small sample size limits the ability to confirm the effectiveness of the tested intervention. These factors collectively hinder the ability to make definitive conclusions regarding the effectiveness of the TTM-based intervention in this study, in SC.

4.4. Recommended Dose of TTM-based Interventions in Promoting Healthy Behaviors Related to NCDs

Based on the previous discussion, the following key recommendations can be considered by health professionals to optimize the design, delivery, and effectiveness of TTM-based interventions in promoting healthy behaviors related to NCDs: 1- Tailored interventions: Interventions (sessions-materials-feedback reports) should be tailored to the participant's SoC to enhance motivation and effectiveness. 2- Number of sessions: The reviewed studies suggest that the optimal range is between one and four sessions. This range can be effective for promoting PAL and managing weight and dietary behaviors. 3- Follow-up duration: Interventions should include follow-ups over a period ranging from 6 to 24 months to ensure sustained behavior change. 4- Mode of interventions: A combination of in-person, online, and telephone-based interventions can enhance accessibility and engagement. 5- Target age group: TTM-based interventions have shown higher effectiveness in younger to middle-aged adults. These age groups tend to have higher motivation and capacity for behavior change.

5. Conclusion

Transtheoretical model-based interventions promise to improve PAL and, to a lesser extent, weight management and healthy dietary behaviors. However, their effectiveness in SC remains uncertain. Given that these behaviors are closely related to the prevention and control of NCDs, integrating TTM-based interventions into clinical practice can be a valuable strategy for reducing the incidence and impact of NCDs. By targeting and modifying these key risk factors, health professionals can leverage TTM-based interventions to promote healthier lifestyles and contribute to the overall management and prevention of NCDs. Health professionals should tailor these interventions to individual client's needs, ensure long-term follow-up, and use the appropriate delivery methods to maximize effectiveness.

Clinical Implication

The findings of this SR have several important clinical implications for health professionals aiming to promote healthy behaviors and manage modifiable risk factors of NCDs. Firstly, the demonstrated effectiveness of TTM-based interventions in improving PAL suggests that personalized, stage-based strategies can be successfully integrated into clinical practice to enhance PA among clients. Health professionals should consider assessing the SoC of their clients and tailoring interventions accordingly to maximize engagement and effectiveness. Secondly, the mixed results regarding weight management and healthy dietary behavior indicate that while TTM-based interventions can be effective, their success may vary depending on individual characteristics such as age and educational level. Clinicians should consider these factors when designing and implementing interventions, ensuring that programs are adaptable to the specific needs and readiness levels of different client populations. Moreover, the importance of maintaining long-term engagement and follow-up is underscored by the findings. Clinicians should design intervention programs that include regular follow-ups and support to sustain behavior changes over time. The use of various modalities, including in-person, online, and telephone-based sessions, can provide flexibility and accessibility, which are crucial for maintaining clients' involvement. Finally, the study's emphasis on the necessity of individualized approaches supports the broader application of TTM-based interventions by different health professionals without the need for specialized specialists. This can facilitate the widespread adoption of these interventions across various clinical settings, promoting a more holistic and personalized approach to managing NCDs risk factors.

Future Research Project

Future research should aim to address the limitations identified in this review, such as small sample sizes, the need for control groups, and the challenge of maintaining participant engagement over time. Additionally, tailored interventions that consider individual differences in demographics and behavior change readiness are crucial for optimizing outcomes across various health behaviors. Additionally, more research is needed to assess the effectiveness of TTM-based interventions on SC considering the complexity of smoking behavior.

Declaration of Generative AI and AI-assisted Technologies

The authors disclose the use of Rayyan Intelligent SR tool for importing data, checking for duplication, and screening as well as the generative AI tool, ChatGPT4, for assessing the ROB and for editing purposes to improve the readability and language of the SR. These technologies were employed with human oversight and control, and all work was reviewed carefully. The authors are ultimately responsible and accountable for the contents of the work.

Ethical Statement

Ethical approval and consent are not required because this systematic review research was done exclusively based on published literature.

Disclosure Statement

There is not any financial disclosure, or any non-financial relationship and activities.

Conflict of Interest

The authors declare that there is no conflict of interest.

Artificial Intelligence (AI) Disclosure Statement

Authors disclose their use of artificial intelligence (AI) in the production of submitted work. It was used for writing assistance, data collection, and ROB.

Funding

No funding or support was received from any organization.

Author Contribution

Salwa B. El-Sobkey, Bassem M. Fouda, Radwa S. Ahmed, and Dalia G. El-Sayed: Design of the work, acquisition, analysis, and interpretation of data. In addition, all authors input in drafting the work, reviewing, and final approval of the version to be published. All Authors agreed to be accountable for all aspects of the work.

Data Sharing Statement

Date sets are available publicly at the depository storage at https://figshare.com/s/5dcb5596cdb074cecaad

References

[1] Budreviciute A, Damiati S, Sabir DK, Onder K, Schuller-Goetzburg P, Plakys G, et al. Management and prevention strategies for non-communicable diseases (NCDs) and their risk factors. Front Public Health. 2020;8:574111. doi: 10.3389/fpubh.2020.574111. PMID: 33324597; PMCID: PMC7726193.

[2] Passi SJ. Prevention of non-communicable diseases by balanced nutrition: Population-specific effective public health approaches in developing countries. Curr Diabetes Rev. 2017;13(5):461-476. doi: 10.2174/1573399812666160905105951. PMID: 27593512.

[3] Naja F, Shatila H, Meho L, Alameddine M, Haber S, Nasreddine L, et al. Gaps and opportunities for nutrition research in relation to non-communicable diseases in Arab countries: Call for an informed research agenda. Nutr Res. 2017;47:1-12. doi: 10.1016/j.nutres.2017.07.011. Epub 2017 Aug 3. PMID: 29241573.

[4] Horton R. Non-communicable diseases: 2015 to 2025. Lancet. 2013;381(9866):509-510.

[5] World Health Organization [Internet]. Geneva: World Health Organization; 2019. Global Health Observatory (GHO) data. Deaths from NCDs [Internet]. Available from: https://www.who.int/gho/ncd/mortality_morbidity/ncd_total/en/ Accessed 25 February 2024.

[6] Fahs PS, Pribulick M, Williams IC, James GD, Rovnyak V, Seibold-Simpson SM. Promoting heart health in rural women. J Rural Health. 2013;29(3):248-257. doi: 10.1111/j.1748-0361.2012.00442.x. Epub 2012 Oct 25. Erratum in: J Rural Health. 2014;30(1):120. PMID: 23802927; PMCID: PMC3695442.

[7] World Health Organization. Global status report on noncommunicable diseases 2014. Geneva: World Health Organization; 2014. Available from: https://apps.who.int/iris/bitstream/handle/10665/148114/9789241564854_eng.pdf?sequence=1 Accessed 25 February 2024.

[8] Stenholm S, Head J, Aalto V, Kivimäki M, Kawachi I, Zins M, et al. Body mass index as a predictor of healthy and disease-free life expectancy between ages 50 and 75: A multicohort study. Int J Obes. 2017;41(5):769-775.

[9] Australian Institute of Health and Welfare: Risk Factors Contributing to Chronic Disease. Cat No. PHE 157. Canberra: AIHW; 2012.

[10] World Health Organization. Physical activity [Internet]. Geneva: World Health Organization; 2024. Available from: https://www.who.int/news-room/fact-sheets/detail/physical-activity

[11] World Health Organization. Global Status Report on Physical Activity 2022 [Internet]. Geneva: World Health Organization; 2024. Available from: https://www.who.int/teams/health-promotion/physical-activity/global-status-report-on-physical-activity-2022

[12] Yang X, Sun J, Zhang W. Global trends in burden of type 2 diabetes attributable to physical inactivity across 204 countries and territories, 1990-2019. Front Endocrinol (Lausanne). 2024; 15:1343002. doi: 10.3389/fendo.2024.1343002. PMID: 38469145; PMCID: PMC10925666.

[13] de Freitas PP, de Menezes MC, Dos Santos LC, Pimenta AM, Ferreira AVM, Lopes ACS. The transtheoretical model is an effective weight management intervention: A randomized controlled trial. BMC Public Health. 2020;20(1):652. doi: 10.1186/s12889-020-08796-1. PMID: 32393214; PMCID: PMC7216547.

[14] World Health Organization (WHO). Obesity and overweight [Internet]. Geneva: World Health Organization; 2024. Available from: http://www.who.int/mediacentre/factsheets/fs311/en/ Accessed 3 March 2024.

[15] Das D, Menon I, Gupta R, Sharma A, Ahsan I, Ashraf AA. Comparison of interventional methods to motivate and change the behavioural stage of smokers to quit smoking: A hospital based randomised controlled trial. Asian Pac J Cancer Prev. 2021; 22:711-717.

[16] World Health Organization (WHO). Global action plan for the prevention and control of noncommunicable diseases 2013-2020. Geneva: WHO; 2013. Available from: https://apps.who.int/iris/bitstream/handle/10665/94384/9789241506236_eng.pdf?sequence=1 Accessed 25 February 2024.

[17] Dansinger ML, Gleason JA, Griffith JL, Selker HP, Schaefer EJ. Comparison of the Atkins, Ornish, weight watchers, and zone diets for weight loss and heart disease risk reduction: A randomized trial. JAMA. 2005; 293:43-53.

[18] Katan MB. Weight-loss diets for the prevention and treatment of obesity. N Engl J Med. 2009;360:923-925.

[19] Mastellos N, Gunn LH, Felix LM, Car J, Majeed A. Transtheoretical model stages of change for dietary and physical exercise modification in weight loss management for overweight and obese adults. Cochrane Database Syst Rev. 2014;(2):CD008066. doi: 10.1002/14651858.CD008066.pub3

[20] Hartmann-Boyce J, Johns DJ, Jebb SA, Aveyard P; Behavioural weight management review group. Effect of behavioural techniques and delivery mode on effectiveness of weight management: Systematic review, meta-analysis, and meta-regression. Obes Rev. 2014;15:598-609.

[21] Norcross JC, Krebs PM, Prochaska JO. Stages of change. J Clin Psychol. 2011; 67:143-154.

[22] Papandonatos GD, Williams DM, Jennings EG, Napolitano MA, Bock BC, Dunsiger S, et al. Mediators of physical activity behavior change: Findings from a 12-month randomized controlled trial. Health Psychol. 2012;31(4):512-520. doi: 10.1037/a0026667. Epub 2011 Dec 12. PMID: 22149130; PMCID: PMC5718351.

[23] Behavioral Change Models. Transtheoretical model (Stages of Changes) [Internet]. Available from: https://sphweb.bumc.bu.edu/otlt/mph-modules/sb/behavioralchangetheories/behavioralchangetheories6.html Accessed 29 February 2024.

[24] Johnson SS, Paiva AL, Cummins CO, Johnson JL, Dyment SJ, Wright JA, et al. Transtheoretical model-based multiple behavior intervention for weight management: Effectiveness on a population basis. Prev Med. 2008;46(3):238-246. doi: 10.1016/j.ypmed.2007.09.010. Epub 2007 Oct 23. PMID: 18055007; PMCID: PMC2327253.

[25] Hashemzadeh M, Rahimi A, Zare-Farashbandi F, Alavi-Naeini AM, Daei A. Transtheoretical model of health behavioral change: A systematic review. Iran J Nurs Midwifery Res. 2019;24(2):83-90. doi: 10.4103/ijnmr.IJNMR_94_17. PMID: 30820217; PMCID: PMC6390443.

[26] Prochaska JO, Diclemente CC. Transtheoretical therapy: Toward a more integrative model of change. Psychother Theory Res Pract. 1982;19:276-288.

[27] Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan — a web and mobile app for systematic reviews. Syst Rev. 2016;5:210. doi: 10.1186/s13643-016-0384-4

[28] Steptoe A, Kerry S, Rink E, Hilton S. The impact of behavioral counseling on stage of change in fat intake, physical activity, and cigarette smoking in adults at increased risk of coronary heart disease. Am J Public Health. 2001;91(2):265-269. doi: 10.2105/ajph.91.2.265. PMID: 11211636; PMCID: PMC1446539.

[29] Prochaska JO, Butterworth S, Redding CA, Burden V, Perrin N, Leo M, et al. Initial efficacy of MI, TTM tailoring and HRI's with multiple behaviors for employee health promotion. Prev Med. 2008;46:226-231.

[30] Bevilaqua CA, Pelloso SM, Marcon SS. Stages of change of behavior in women on a multi-professional program for treatment of obesity. Rev Lat Am Enfermagem. 2016 Oct 10;24. doi: 10.1590/1518-8345.0549.2809. PMID: 27737377; PMCID: PMC5068905.

[31] DiClemente CC, Prochaska JO, Fairhurst SK, Velicer WF, Velasquez MM, Rossi JS. The process of smoking cessation: An analysis of precontemplation, contemplation, and preparation stages of change. J Consult Clin Psychol. 1991 Apr;59(2):295-304. doi: 10.1037//0022-006x.59.2.295. PMID: 2030191.

[32] Gorini G, Carreras G, Giordano L, Anghinoni E, Iossa A, Coppo A, et al.; SPRINT Working Group. The Pap smear screening as an occasion for smoking cessation and physical activity counselling: Effectiveness of the SPRINT randomized controlled trial. BMC Public Health. 2012 Sep 5;12:740. doi: 10.1186/1471-2458-12-740. PMID: 22950883; PMCID: PMC3491017.

[33] Zabaleta-del-Olmo E, Casajuana-Closas M, López-Jiménez T, et al. Multiple health behaviour change primary care intervention for smoking cessation, physical activity and healthy diet in adults 45 to 75 years old (EIRA study): A hybrid effectiveness-implementation cluster randomised trial. BMC Public Health. 2021;21:2208. doi: 10.1186/s12889-021-11982-4

[34] Higgins JPT, Savović J, Page MJ, Elbers RG, Sterne JAC. Chapter 8: Assessing risk of bias in a randomized trial. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). Cochrane handbook for systematic reviews of interventions version 6.4 (updated August 2023). Cochrane, 2023. Available from https://training.cochrane.org/handbook/current Accessed 27 February 2024

[35] Garaschuk O. Understanding normal brain aging. Pflugers Arch - Eur J Physiol. 2021;473:711-712. doi: 10.1007/s00424-021-02567-6

[36] Van den Broucke S, Renwart A. Health literacy mediates the relationship between education level and health behaviour. Eur J Public Health. 2014;24(Suppl 2). doi: 10.1093/eurpub/cku164.012