UNIVERSIDAD POLITÉCNICA DE MADRID
FACULTAD DE CIENCIAS DE LA ACTIVIDAD FÍSICA Y DEL DEPORTE (INEF)

Optimizing Adherence in Behavioural Weight Loss Programs: An Evidence-Based Approach to Definition, Measurement and Facilitators

DOCTORAL THESIS

Submitted for the degree of Doctor by:

Deng Wang
Máster en Educación Física

Madrid, 2025

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Doctoral Degree in Physical Activity and Sport Sciences

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Dr. Miguel Ángel Rojo Tirado

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Author: Deng Wang

Doctoral Programme: Ciencias de la Actividad Física y del Deporte

Thesis Supervision: Dr. Miguel Ángel Rojo Tirado, Profesor Contratado Doctor, Universidad Politécnica de Madrid.

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"Empty your mind, be formless. Shapeless, like water.

If you put water into a cup, it becomes the cup.

You put water into a bottle, and it becomes the bottle.

You put it in a teapot, it becomes the teapot.

Now, water can flow or it can crash.

Be water, my friend."

— Bruce Lee

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2025 年 4 月

马德里，西班牙

Abstract

Introduction: The prevalence of adults living with obesity is expected to increase from 0.81 billion in 2020 to 1.53 billion in 2035. This represents a significant economic and social burden on public health. The cornerstone of treatment for overweight and obesity is lifestyle-based therapy, which combines a tailored low-calorie diet, physical activity, and behavioural change. Following an early phase of consistent weight loss, individuals attempting to lose weight frequently reach a disheartening plateau where progress halt. Due to the number of behavioural weight-loss interventions used for weight management, one challenge faced is low long-term adherence—with studies reporting only 60.5% adherence rates (95% CI 53.6–67.2), which can ultimately lead to suboptimal outcomes. Previous studies attempted to summarize socio-demographic, patient-related and treatment-related factors, but the lack of standardized definitions often made cross-study comparisons difficult, and it was hard to draw conclusions about selecting optimal adherence facilitators. This substantial attrition highlights the urgent need to optimize adherence-focused strategies.

Objectives: The present Doctoral Thesis aims to investigate adherence to behavioural weight loss intervention. Specifically, the three studies are divided into: Study I, to clarify definitions of adherence, its components, measurements, and facilitating factors in weight loss programs; Study II, to review existing factors of adherence to weight loss interventions and identify factors that facilitate the design of effective intervention programs; and study III, to explore the long-term adherence to physical activity and dietary behaviours during an intensive lifestyle intervention in the PROPEL weight loss study.

Methods: (I)First, a scoping review was conducted to summarize and synthesize the evidence on the definition, measurements, and facilitators. (II) Then, an umbrella review was performed to include all facilitators and barriers to weight loss programs. (III) Finally, a group-based trajectory analysis of physical activity and dietary behaviour adherence was conducted using data from the PROPEL lifestyle weight loss trial.

Results: (I) 182 articles were included. The WHO definition and framework for operationalizing adherence are recommended, with modifications tailored to the specific weight management context and the use of standardized measurement metrics. Regarding behaviour change techniques, self-monitoring and social support were reported as ways to improve adherence. (II) 21 studies were included.

Forty-seven factors in six groups were identified as relevant to adherence. Overall, the factor map can be monitored and modified by researchers and practitioners to improve adherence to weight loss interventions. (III) Trajectory analysis identified five groups of physical activity and dietary fat intake over 24 months. The 5 trajectories show adherence to physical activity and diet during the intervention period. Multinomial regression indicated that participants with diabetes at baseline were more likely to be classified as group 5 with a lower activity level and high dietary fat intake.

Conclusions: This Doctoral Thesis provided comprehensive research on adherence to behavioural weight loss programs and addressed the challenge of obesity management. (I) The findings highlight that adherence to weight management should be aligned with standardized framework, such as the WHO adherence model, with necessary modifications to align with weight loss interventions. The adherence roadmap provided a structured framework for defining adherence and selecting measures. (II) The adherence factor map summarizes facilitators and barriers, which can be used to guide the future studies. Future research should focus on the role of technologies (e.g., self-monitoring) in improving adherence. (III) Trajectory modelling can identify distinct physical activity and diet patterns during weight-loss interventions. Additional strategies may be needed to improve adherence in individuals with low activity and high fat intake pattern. Participants with diabetes were more likely to fall into Group 5 with low activity, high-fat group. Future research should examine objectively measured behavioural trajectories in larger, diverse ethnic participants.

Resumen

Introducción: Se prevé que la prevalencia de adultos con obesidad aumente de 0.81 billones en 2020 a 1.53 billones en 2035. Esto representa una carga económica y social significativa para la salud pública. La piedra angular del tratamiento para el sobrepeso y la obesidad es la terapia basada en el estilo de vida, que combina una dieta baja en calorías personalizada, actividad física y cambio de comportamiento. Después de una fase inicial de pérdida de peso consistente, las personas que intentan perder peso suelen alcanzar una desalentadora meseta en la que el progreso se detiene. Debido a la variedad de intervenciones conductuales para la pérdida de peso utilizadas en el manejo del peso, uno de los principales desafíos es la baja adherencia a largo plazo, con estudios que reportan tasas de adherencia del 60.5% (IC 95% 53.6–67.2), lo que finalmente puede llevar a resultados subóptimos. Estudios previos intentaron resumir factores sociodemográficos, relacionados con el paciente y el tratamiento, pero la falta de definiciones estandarizadas dificultó las comparaciones entre estudios, y fue difícil llegar a conclusiones sobre cómo seleccionar los facilitadores óptimos de la adherencia. Esta importante tasa de deserción resalta la necesidad urgente de optimizar las estrategias centradas en la adherencia.

Objetivos: La presente Tesis Doctoral tiene como objetivo investigar la adherencia a intervenciones conductuales para la pérdida de peso. Específicamente, los tres estudios se dividen en: Estudio I, para aclarar las definiciones de adherencia, sus componentes, mediciones y factores facilitadores en programas de pérdida de peso; Estudio II, para revisar los factores existentes de adherencia a intervenciones de pérdida de peso e identificar factores que faciliten el diseño de programas de intervención eficaces; y Estudio III, para explorar la adherencia a largo plazo en actividad física y comportamiento alimentario durante una intervención intensiva en el estudio PROPEL de pérdida de peso.

Métodos: (I) Primero, se realizó una revisión de alcance para resumir y sintetizar la evidencia sobre la definición, mediciones y facilitadores. (II) Luego, se llevó a cabo una revisión general para incluir todos los facilitadores y barreras de los programas de pérdida de peso. (III) Finalmente, se realizó un análisis de trayectoria basado en grupos de adherencia a la actividad física y comportamiento alimentario utilizando los datos del ensayo PROPEL sobre pérdida de peso mediante un enfoque de estilo de vida.

Resultados: (I) Se incluyeron 182 artículos. Se recomienda la definición y el marco de la OMS para operacionalizar la adherencia, con modificaciones adaptadas al contexto específico del manejo del peso y el uso de métricas de medición estandarizadas. En cuanto a las técnicas de cambio de comportamiento, se informó que el automonitoreo y el apoyo social son formas eficaces para mejorar la adherencia. (II) Se incluyeron 21 estudios. Se identificaron 47 factores a través de seis grupos relevantes para la adherencia. En general, el mapa de factores puede ser monitoreado y modificado por investigadores y profesionales para mejorar la adherencia a las intervenciones de pérdida de peso. (III) El análisis de trayectoria identificó cinco grupos de actividad física y consumo de grasas dietéticas durante 24 meses. Las cinco trayectorias muestran la adherencia a la actividad física y la dieta durante el período de intervención. La regresión multinomial indicó que los participantes con diabetes en la línea base tenían más probabilidades de clasificarse en el grupo 5, con un nivel de actividad bajo y un alto consumo de grasas dietéticas.

Conclusiones: Esta Tesis Doctoral proporciona una investigación integral sobre la adherencia a los programas de pérdida de peso conductuales y aborda el desafío del manejo de la obesidad. (I) Los hallazgos destacan que la adherencia al manejo del peso debe alinearse con un marco estandarizado, como el modelo de adherencia de la OMS, con las modificaciones necesarias para adaptarse a las intervenciones de pérdida de peso. El mapa de adherencia ofrece un marco estructurado para definir la adherencia y seleccionar medidas. (II) El mapa de factores de adherencia resume los facilitadores y barreras, lo que puede utilizarse para orientar futuros estudios. Las investigaciones futuras deberían centrarse en el papel de las tecnologías (por ejemplo, el automonitoreo) en la mejora de la adherencia. (III) El modelado de trayectorias puede identificar patrones distintos de actividad física y dieta durante las intervenciones para la pérdida de peso. Pueden ser necesarias estrategias adicionales para mejorar la adherencia en individuos con patrones de baja actividad y alta ingesta de grasa. Los participantes con diabetes tenían más probabilidades de pertenecer al Grupo 5, con baja actividad y alta ingesta de grasa. La investigación futura debería examinar trayectorias de comportamiento medidas objetivamente en muestras más grandes y diversas en términos étnicos.

Table of Contents

List of Figures

List of Tables

Abbreviations and Acronyms

ACT	Acceptance and Commitment Therapy
AMSTAR-2	Assessment of Multiple Systematic Reviews-2
BCIO	Behavior Change Intervention Ontology
BCTs	Behavior Change Techniques
BMI	Body Mass Index
GBMT	Group-Based Multivariate Trajectory modeling
MVPA	Moderate-to-Vigorous Physical Activity
OSF	Open Science Framework
PICO	Participants, Intervention, Comparators and Outcomes
PRISMA	Preferred Reporting Items for Systematic review and Meta-Analysis
PRISMA-ScR	Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews
PROPEL	Promoting Successful Weight Loss in Primary Care in Louisiana
PROSPERO	International Prospective Register of Systematic Reviews
RCTs	Randomized Controlled Trials
TPA	Total Physical Activity
WHO	World Health Organization

1. Introduction

1.1. Doctoral Thesis Structure

This Doctoral Thesis involved four years of research work. The thesis, which began in October 2021 and continuing until 2025, consists of three articles (Table 1) The Study I addressed adherence definitions, components, measurements, and facilitating factors through a scoping review; The Study II conducted an umbrella review identifying 47 factors across six categories that influence adherence, developing a factor map for researchers and practitioners; The Study III analysed physical activity and dietary behavior adherence trajectory patterns in the PROPEL weight loss trial, identifying five distinct behavioural trajectories and finding baseline predictors.

This Doctoral Thesis structure (As shown in Figure 1) has been developed in accordance with the model and formatting guidelines for doctoral theses of the Universidad Politécnica de Madrid, which, in many respects, follow the formatting standards common to many other national and international academic institutions. The document is divided into three parts (front matter, main matter and end matter), each of which has several subcomponents.

The first section contains the general introduction, research gaps, and the structure of the Doctoral Thesis. The second chapter details the general objectives and each research question. The third section includes the materials and methods of the Doctoral Thesis, including the study design, study protocol, search strategy, eligibility criteria, data extraction and, and analysis methods. The final section

synthesizes the findings of the cross-disciplinary studies, evaluates their disciplinary contributions, and presents evidence-based conclusions that address the research question.

Table 1. Articles included in this Doctoral Thesis.

Article	Reference	Journal/ Impact factor	JCR Quartiles	Status
Study I	Adherence to Behavioural Weight Management Interventions in Population with Overweight and Obesity: A Scoping Review of Definition, Measurements and Facilitators	Obesity Reviews - IF: 8.00	Q1	Under Review
Study II	Wang D, Benito PJ, Rubio-Arias JÁ, Ramos-Campo DJ, Rojo-Tirado MA. Exploring factors of adherence to weight loss interventions in population with overweight/obesity: an umbrella review. Obesity Reviews. 2024; 25(9):e13783. doi:10.1111/obr.13783	Obesity Reviews - IF: 8.00	Q1 14/186 ENDOCRINOLOGY & METABOLISM	Published
Study III	Longitudinal Changes in Physical Activity and Dietary Fat Intake During intensive lifestyle intervention: the PROPEL Trial	Annals of Behavioral Medicine - IF: 3.6	Q1	Under Review

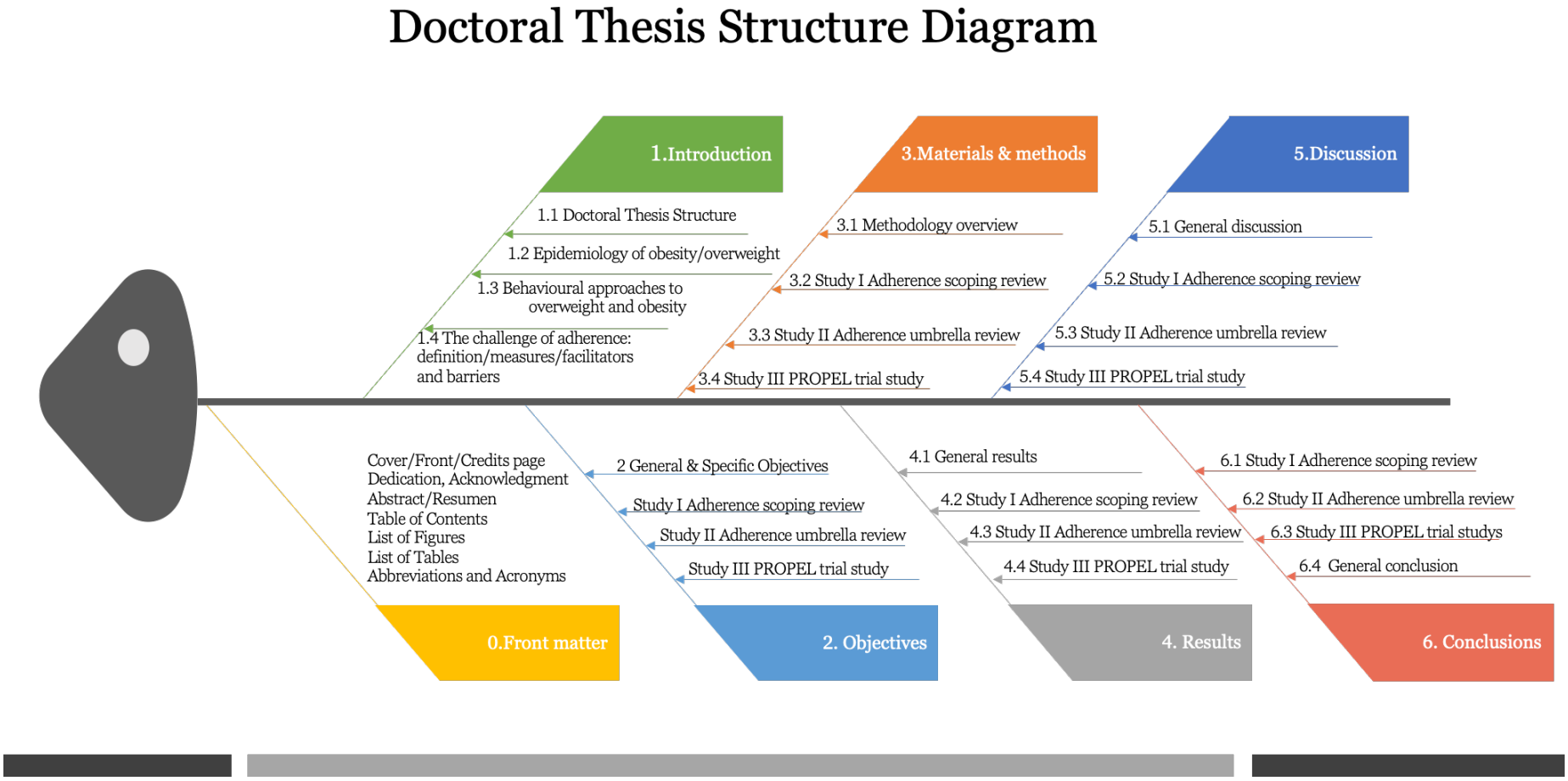

Figure 1. Doctoral Thesis structure diagram.

1.2. Epidemiology of overweight and obesity

Overweight and obesity are major public health concerns today, with an epidemic spreading worldwide. Over the past three decades, the prevalence of obesity has increased significantly, according to a recently published pooled analysis of 222 million people [1]. The health consequences of obesity are profound, with increased risks of cardiovascular disease, type 2 diabetes, and certain cancers. Furthermore, obesity is a leading cause of metabolic syndrome, which exacerbates the risk of chronic conditions [2]. It has been causally linked to diabetes, cardiovascular diseases, and cancer [3]. It also places a significant financial burden on chronic diseases, not only in terms of adverse health outcomes but also places a heavy strain on healthcare budgets. In the United States, severe obesity (body mass index $\geq$35 kg/m^2) is associated with higher healthcare expenditures, costing nearly $3000 per adult [4]. Severe obesity also significantly increases the use of healthcare resources in Spain [5]. Overweight and obesity represent important modifiable risk factors for morbidity and mortality [6].

In a recent study, 42% of adults in the general population were trying to lose weight through exercise and diet, and 22% were trying to maintain it, according to a systematic review and meta-analysis of 72 studies involving over 1 million adults. Moreover, even modest weight reduction (5% of body weight) is associated with significant health benefits in improving various health parameters, including fasting glucose, systolic and diastolic blood pressure, haemoglobin A1c, and high-density lipoprotein cholesterol [7–9]. These improvements can substantially reduce the risk of chronic diseases such as type 2 diabetes [10].

1.3. Behavioural approaches to overweight and obesity

Empirical research has shown that obesity is a complex and multifactorial health problem [11]. However, it is preventable and treatable. An interdisciplinary approach is often required for the treatment of people living with overweight and obesity [12]. Behavioural and lifestyle intervention are central to the treatment of obesity [13], as shown in Figure 2. Current weight management strategies include lifestyle modification programs with diet and exercise interventions, complemented by pharmacotherapy and bariatric procedures that aim to improve weight loss, health status, and quality of life goals [14,15]. Lifestyle modifications successfully aid weight loss of 5% to 10% of initial weight at 6 to 12 months, but long-term weight loss maintenance proves to be quite difficult, and weight gain usually follows [16,17]. It can be challenging, as patients and healthcare professionals have expressed concerns about weight regain and the long-term efficacy of weight loss attempts [18]. Behavioural-based weight loss programs have demonstrated moderate success, with behavioural support encouraging long-term adherence to dietary modifications and improved levels of physical activity [19].

1.4. The Challenge of Adherence

It is widely accepted that attrition and non-adherence are common challenges in weight loss programs, with reported mean attrition rates ranging from 10% to over 80% [10,20–22]. The World Health Organization (WHO) defines adherence as a multidimensional phenomenon. The five dimensions include socioeconomic, patient-related, clinical condition-related, therapy-related, and health system-related factors [23]. This understanding of adherence emphasizes that a systems

approach is needed to address the complex interplay between these factors to improve adherence rates and long-term outcomes. However, inconsistencies in defining adherence, measuring it, and identifying influencing factors have hampered progress despite a growing body of research.

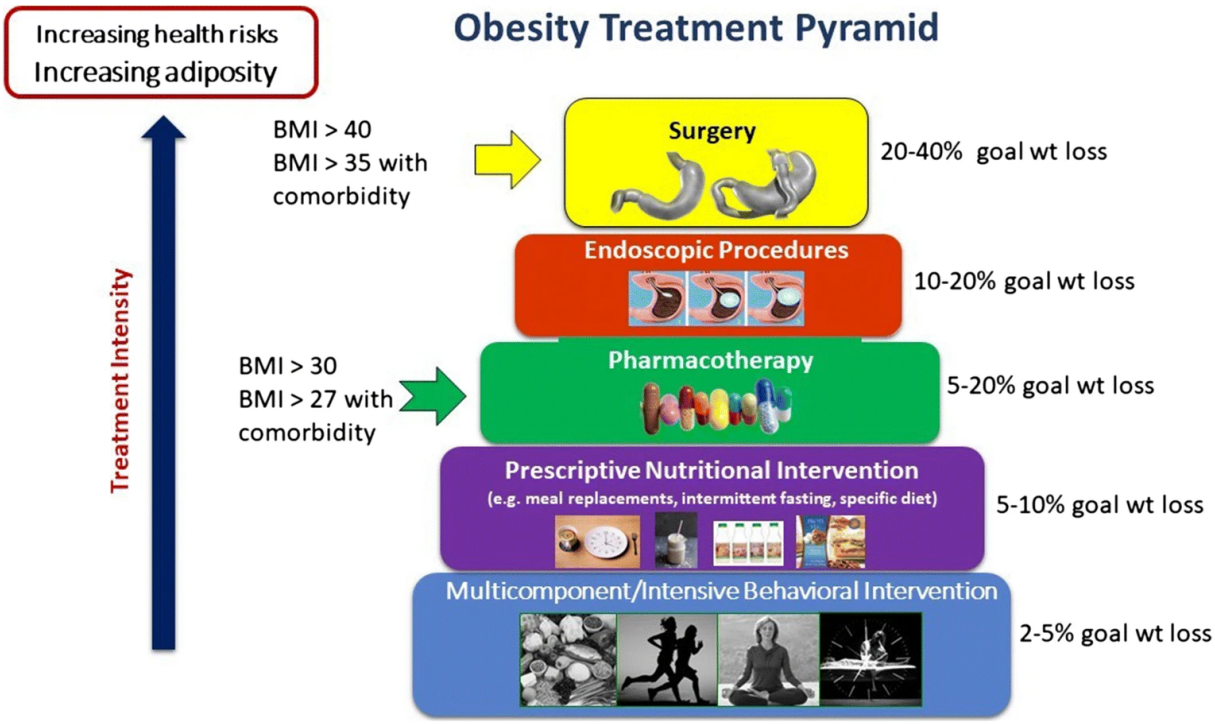

Figure 2. Obesity treatment pyramid.
Note: BMI unit: kg/m^{-2}, Wt: Weight loss. It Adapted from Angela Fitch, MD[24])

1.4.1. Definition of adherence

Since its proposal in the 1970s, adherence has been closely linked to medication treatment. Over the past decade, research on adherence has grown substantially, with a total of over 130,000 studies on the topic [25], as shown in Figure 3. Notably, in 2003, the World Health Organization published its seminal report on adherence to chronic treatments, emphasizing that it is a problem of global importance and

mobilizing policymakers and health managers to improve public health through effective adherence support [23].

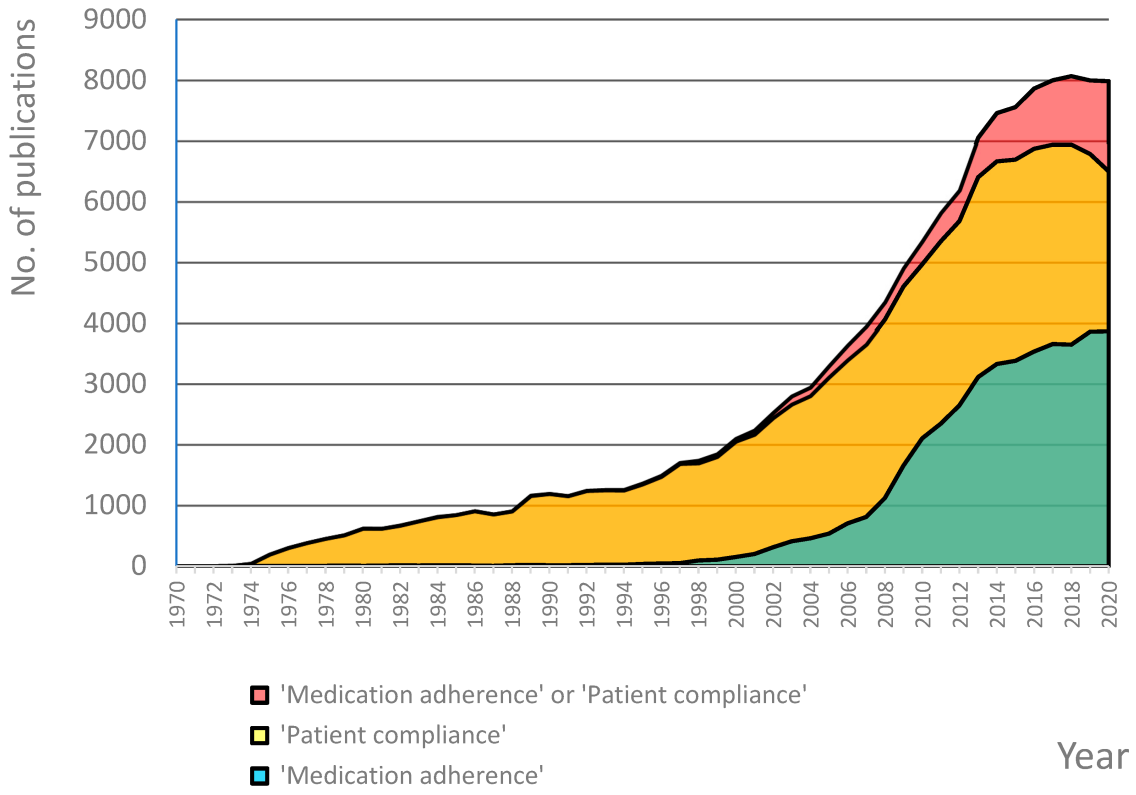

Figure 3. The yearly numbers of scientific publications on medication adherence.

(Retrieved by the PubMed online database for the period 1970–2020, Adapted from Przemysław Kardas[25].)

Regarding the definition of adherence, the WHO defines it as "*the extent to which the person's behavior (including medication-taking) corresponds with agreed recommendations from a healthcare provider*" [23]. The term adherence is often used to describe medication compliance. A recent study defining and describing the taxonomy of medications identified more than 10 different terms through literature review, often with different meanings, that describe medication-taking

behavior [26]. Definitions of adherence and terminology employed in the literature are inconsistent, with terms such as "engagement," "fidelity," and "compliance" being used interchangeably [27]. In weight loss interventions, the terms adherence, attendance, and dropout are frequently used interchangeably [22,28]. Therefore, there is a need for a review of terminology and definitions, with a focus on promoting consistency and quantification of terminology and methodology to assist in conducting, analyzing, and interpreting scientific research on weight loss interventions.

1.4.2. Measurement of adherence

Adherence measurement reveals the extent to which a program's implementation aligns with its predefined aims [28]. While the concept of adherence is frequently included in reports of Randomized Controlled Trials (RCT), there appears to be no consensus and adherence measures and metrics vary widely [29]. However, measuring adherence can be particularly difficult in complex and behaviour change interventions, i.e., those with several interacting components [30,31]. There is a growing need for standardized and validated methods that can measure adherence across different dimensions and types of intervention to ensure reproducibility and comparability. Accurately measuring adherence to medical and behavioural regimens is crucial for clinicians and researchers, as poor adherence can significantly reduce the effectiveness of an intervention [32].

According to a review, significant variation in adherence measurement and metrics was observed [33]. Even under the same concept, approaches and cutoffs for adherence differ [34,35]. Adherence to dietary interventions is predominantly

quantified by assessing group-level mean nutrient intake from 24-hours recalls, food records, or food frequency questionnaires, and less frequently, self-report scores and objective biomarkers are used, as reported in a recent meta-analysis including 47 RCTs [36]. Furthermore, recent research suggests that comparison across studies is difficult due to differences in definition and measurement in weight loss interventions, as adherence can be measured in a variety of ways [22,28,37–40].

1.4.3. Facilitators and barriers to adherence

It is important to note that preventing excessive weight gain or maintaining it long-term remains a challenge. For example, multicomponent behavioural interventions typically result in 5% to 10% weight loss, although weight regain occurs in 25% or more of participants at 2-year follow-up [41]. One potential strategy to address this is to explore how participants perceive themselves as supporting or hindering changing their behaviours [42]. The impact of adherence on weight loss success is substantial [43].

However, less is known about the perspectives of participants living with overweight or obesity regarding the barriers and facilitators that hinder the implementation of lifestyle modifications. Exploring the facilitators and barriers to behavioural weight loss interventions can provide valuable insights into both the conceptual framework (i.e., the "what") and implementation strategies (i.e., the "how") of interventions [44]. This enables researchers to make more practical design decisions by focusing on the most modifiable aspects of an intervention [42] .

2. Objectives

2.1. General objective

The general objective of this thesis is to investigate adherence to a behavioural weight management program in populations with overweight and obesity, examining definitions, measurements, facilitating and inhibiting factors, and longitudinal changes in physical activity and dietary behaviours in intervention.

2.2. Specific objectives

To achieve the overall objective, the following specific objectives are presented, divided into three distinct studies:

Study I

This study aimed to identify: (a) definitions of adherence; (b) components of adherence; (c) methods for measuring adherence; and (d) behaviour change techniques to improve adherence.

Study II

The aim of this study was to review existing factors that influence adherence to weight loss interventions and identify factors that facilitate the design of effective intervention programs.

Study III

This study aimed to evaluate trajectories of physical activity and dietary behaviors in the PROPEL project, a 24-month intensive lifestyle intervention, and to identify baseline characteristics and sociodemographic predictors associated with these behavioural trajectories.

3. Materials and methods

3.1. Methodology overview

The present Doctoral Thesis is composed of three studies: a scoping review (Study I) to map the definitions and measurements of adherence to behavioural weight management interventions; an umbrella review (Study II) to synthesize the evidence on factors influencing adherence to weight-loss interventions; and a secondary analysis (Study III) of a RCT (PROPEL Trial) to examine longitudinal changes in physical activity and dietary behaviors during an intensive lifestyle intervention in individuals living with overweight and obesity.

The methodology used in this Doctoral Thesis is explained below, along with a detailed and specific description of each of the studies.

3.2. Study I Adherence to Behavioural Weight Management: A Scoping Review of Definition, Measurement and Facilitators

To achieve the objectives proposed for the first study, a scoping review was conducted. The protocol was designed according to the Preferred Reporting Items for Systematic Reviews and Meta Analyses Extension for Scoping Reviews (PRISMA-ScR).[45] The final protocol of this scoping review was prospectively registered through the Open Science Framework(OSF): https://osf.io/4mzjg/.[46]

3.2.1. Database and search strategy

Following the PRISMA statement for scoping reviews,[47] a comprehensive and systematic two-step search process was conducted to identify potentially relevant peer-reviewed publications in Web of Science, PubMed/MEDLINE, Scopus and Cochrane database. First, keywords were retrieved by searching for published reviews (three recent reviews served as the basis for article retrieval in this study [48–50]), and then Medical Subject Headings (MeSH), alternative terms and synonyms were used to identify relevant terminology. Final searches and updates were performed on August 1, 2024.

The full search strategy included relevant terms and their synonyms, connected using Boolean operators, including i) population group (i.e., obes* OR overweight), (ii) intervention (i.e., "behav* treatment*" OR "behav* intervention*" OR "behav* therap*"), and (iii) adherence (i.e., adher* OR nonadher* OR non-adher*). The detailed search strategy used in the different databases can be found in the Annexes of Study I.

3.2.2. Inclusion and exclusion criteria

Studies included measured or focused on specific dimensions of behavioural body weight management programs developed within the conceptual framework (e.g., nutrition, physical activity, psychology, etc.). This extends previous research by including peer-reviewed journal articles written in English, which involved human participants living with overweight and/or obesity (overweight, BMI > 25 kg·m^{-2}/ obesity, BMI > 30 kg·m^{-2}), and described a measure for treatment adherence, for example, by including individual measures, measuring and/or incorporating one or

two dimensions of treatment adherence. Quantitative, qualitative, and mixed-methods studies were included to consider different aspects of measuring treatment adherence. Editorials, commentaries, protocols and conference abstracts were excluded if they did not focus on behavioural interventions (e.g., bariatric surgery), focused on other pathologies (e.g., cancer), or other conditions associated with body weight (e.g., pregnancy).

3.2.3. Data extraction and synthesis

For screening, search results were exported to Rayyan software and duplicates were removed (https://www. rayyan.ai). Finally, Deng and Miguel conducted the article selection process. A third author (Marta) resolved disagreements.

Data extraction was performed using a pre-tested data extraction form. The two reviewers independently recorded data, assessed outcomes, and iteratively revised the data recording form. The study characteristics included were: i) study objectives, ii) study design, iii) sample size, iv) gender characteristics, and iv) intervention characteristics (intervention duration, follow-up). In addition, information was extracted on: i) adherence definitions and terminology, ii) adherence components and measures, and iii) BCTs reported to be associated with adherence, identified using the BCT ontology.

In accordance with the recommendations on data presentation[51], key findings from the source publications that answered the study question were described in tables and figures. Initially, a list of all the different terms and definitions used to describe adherence was extracted, and their frequency was summarized in tabular form. Then reviewed adherence across several studies to identify components

commonly associated with adherence in behavioural weight management. Also measurements for each component were summarized and presented the findings in graphical format. In addition, a summary of BCTs that may improve adherence in the accompanying table. Finally, a roadmap was developed to clarify adherence process in weight management, along with practical implications, recommendations, and directions for future research.

3.3. Study II Exploring factors of adherence to weight loss interventions in population with overweight/obesity: an umbrella review

3.3.1. Design

An umbrella review was performed following the recommendations of the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) and the Joanna Briggs Institute manual.[52] All phases of the umbrella review were performed in duplicate. The study protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO) under the following registration number: CRD42022326218.

3.3.2. Search strategy

Two of the authors (Deng and Miguel) independently identified studies dated up to April 13, 2022, in the following 6 electronic databases: Web of Science, PubMed/MEDLINE, Cochrane Library, Scopus, SPORTDiscus, and Embase. To answer the question “What are the factors in current research that contribute to improved treatment adherence in weight loss programs?”, the following

combination of descriptors was used: i) Obese OR Obesity OR Overweight, (ii) Weight OR bodyweight OR "Body Weight Change" OR BMI OR "body composition" OR fatness, (iii) Adhere* OR Nonadher* OR "Non-adhere*" OR complian* OR Noncomplian* OR "Non-complian* Adhere* OR Nonadher* OR "Non-adhere*" OR complian* OR Noncomplian* OR "Non-complian* (iv) "meta-an*" OR "systematic review". A systematic search strategy was developed by collecting key ideas following the PICOS strategy. The search syntax for each database is provided in Annexes of Study II.

3.3.3. Eligibility criteria

Both authors independently checked the titles, abstracts, and (if applicable) full texts of the identified publications. In their review, the two authors compared their lists of included and excluded articles. Any disagreements were resolved through discussion and agreement between the authors. Systematic reviews and systematic reviews with meta-analysis analyzing all types of weight loss interventions (except surgeries) were included. In the Participant-Intervention-Comparison-Outcome (PICO) process, studies that met the following criteria were included: Participants: (i) Population aged 18 years or older (overweight, BMI>25 $kg \cdot m^{-2}$ / obesity, BMI>30 $kg \cdot m^{-2}$); Interventions: (ii) Interventions that included behavioural (exercise and/or nutrition and/or pharmacological and/or psychological and/or any combination over two of them (multi-intervention)) and non-surgical strategies targeting weight loss; Control: at least one control group included; Outcomes: (iii) Aimed at identifying factors associated with adherence to the intervention / barriers identified for lifestyle intervention and/or predictors of

adherence or attrition, (iv) Adherence as an outcome variable, one of the primary outcomes was adherence to the lifestyle intervention or lifestyle intervention programs (measured by objective or self-reported modifications in physical activity and/or diet or by attendance at the lifestyle intervention program session or attrition).

Conversely, studies were excluded if: (i) they included populations with pathologies not associated with metabolic syndrome or obesity, (ii) the article was not a peer-reviewed article published in a scientific journal, (iii) they were reviews written in any language other than English.

3.3.4. Data extraction

Data extraction was performed following previous recommendations for umbrella reviews.[53] Extraction was performed using pre-designed Microsoft Office Excel forms. Two researchers independently extracted the following information from each included study: (1) basic information about the study, including the name of the first author, year of publication, and journal; (2) search date and name of databases searched, number of included studies, total number of participants, designs of included studies, tools used to assess risk of bias, age and sex of included participants, and an overall summary of each outcome. Disagreements were resolved by discussion with a third author.

3.3.5. Methodological quality evaluation

The methodological quality and risk of bias of the selected studies were assessed using The Assessment of Methodological Quality of Systematic Reviews (AMSTAR-2).[54] Two reviewers (Deng and Miguel) independently applied the

methodological quality assessment. Where there was disagreement, consensus was reached through discussion or with the help of a third reviewer. The AMSTAR-2 contains 16 items, and each item on this checklist is answered with a “yes”, “no”, “cannot answer” or “not applicable”. Of these possible answers, only the “yes” answer counts as one point in the total score for the assessed review. Based on the AMSTAR-2 working group criteria, the included reviews were categorized into four levels: high confidence (no defects or only one non-critical defect), medium confidence (more than one non-critical defect), low confidence (critical defects with or without non-critical defects), and critically low confidence (more than one critical defect with or without non-critical defects).

3.3.6. Umbrella review synthesis method

All extracted data were analyzed qualitatively and presented narratively. A meta-analysis was not performed, as most studies were highly heterogeneous in terms of the definition, measurement, and outcomes of adherence (in Annexes of Study II).

3.4. Study III Longitudinal Changes in Physical Activity and Dietary Fat Intake During an Intensive Lifestyle Intervention: the PROPEL Trial

3.4.1. Study design

This study is a secondary analysis of the PROPEL trial. All participants in the PROPEL study, a 24-month, cluster-randomized, two-arm clinical trial, were randomly assigned to either high-intensity lifestyle intervention programs or the

usual care group. The protocol and main results of the PROPEL trial have been previously published.[55]

3.4.2. Ethics approvals

The Pennington Biomedical Research Center approved the study (2015–052-PBRC) and all patients provided informed consent. The study was registered with ClinicalTrials.gov, with identifier NCT02561221.

3.4.3. Participants

A total of 439 participants from the intervention group were included in this analysis. All participants were measured at least twice, from baseline to 24 months. Participants were aged between 20 and 75 years, with a Body Mass Index (BMI) between 30 and 50 kg/m². All participants were willing to modify their diet, physical activity and weight. Exclusion criteria included current participation in a weight-loss program, use of weight loss medications and history of bariatric surgery or recent weight loss, and individuals with physical or psychological conditions. The full list of inclusion and exclusion criteria can be found in the protocol.[55]

3.4.4. The intensive lifestyle intervention

Participants received a 24-month, patient-centered, pragmatic, and scalable obesity treatment. In the intensive lifestyle intervention group, patients had weekly sessions (16 in-person and 6 telephone sessions) for the first 6 months, followed by monthly sessions for the remaining 18 months.[55] Two goals of this

behavioural intervention were to lose 10% weight in the first 6 months with coach support and to achieve ≥175 min/week of moderate-to-vigorous physical activity. Additionally, the PROPEL intervention integrated a Computerized Tracking System (CTS), which enables intervention customization and promotes engagement and adherence across clinics. The system calculates personalized daily energy goals for each patient, designed to achieve a 10% weight loss within six months, and generates a weight chart that tracks each patient's intended weight loss trajectory. The chart includes an adherence zone, which visually indicates whether the patient is meeting their energy intake goals and losing weight at the expected rate. All data available to the patient's health coach and the research team allows health coaches to tailor weight-loss strategies in real time to the patient's preferences, lifestyle, and regional differences, thereby improving treatment effectiveness and adherence. A more detailed process can be found in the protocol.[55]

3.4.5. Measures

Demographics & Health History

A self-report demographic and health history questionnaire was used to obtain information on age, sex, race/ethnicity, tobacco use, income and employment, educational level, and history of chronic disease at baseline.

Diet fat intake

Dietary fat intake was assessed using a validated questionnaire at baseline and at 6-, 12- and 24-month assessment visits. The National Cancer Institute (NCI) fat

screener estimates the percentage of energy from fat by reporting the frequency of consumption of specific foods over the past 12 months.[56]

Physical activity

Physical activity levels were self-reported at baseline and the 6-, 12-, and 24-month assessment visits using the International Physical Activity Questionnaire – Short Form (IPAQ-SF). This questionnaire includes items related to physical activity performed during the previous 7 days. The IPAQ-SF demonstrates reliability and has been shown to be sensitive to change in the context of a weight loss intervention. [57,58] For the analysis, we used estimates of time spent walking as well as time spent in moderate-intensity physical activity (MPA), and vigorous-intensity physical activity (VPA), and finally calculated total moderate-to-vigorous physical activity (MVPA). Finally, vigorous, moderate and walking time were summed to produce an estimate of total daily physical activity (min/day).

Anthropometric

Baseline height and weight were used in the study analysis. Height was measured to the nearest 0.1 cm using a stadiometer (Seca Model 213). Body weight and waist circumference were measured using a calibrated digital scale (Seca Model 876) and a non-elastic anthropometric tape (Graham Field Model 1340–2), respectively. All measurements were performed by trained personnel following standardized procedures. Measurements were duplicated to avoid error. If the two measurements differed by more than 0.5 cm for height, 0.5 kg for weight, and 0.5

cm for waist circumference, a third measurement was taken. The two closest measurements were averaged for the analysis.

3.4.6. Statistical analysis

Group-Based Multivariate Trajectory modeling (GBMT) was used to identify trajectory patterns of physical activity and dietary fat intake. We selected total physical activity and dietary fat intake as main indicators for trajectory model. Given the latent group trajectory models may arise with convergence issues, particularly with smaller samples or when using a larger number of groups.[59,60] The analysis process followed the Guidelines for Reporting on Latent Trajectory Studies (GRoLTS).[61] GBMT clusters individuals based on similar trajectories over time based on physical activity and dietary fat intake outcomes. Missing values were estimated using the Expectation-Maximization algorithm. *K* group (1-6) models were fitted, and 1-6 group models were compared using the following indicators: Bayesian information criterion (BIC), Akaike information criterion (AIC), adjusted AIC (CAIC), Hannan-Quinn information criterion [HQIC], Sample size-adjusted Bayesian information criterion [ssBIC]).[62] The BIC is a test statistic for model selection, and a value closer to zero indicates better model fit. Finally, the trajectory group with the lowest Bayesian information criterion (BIC) as the optimal choice and trajectory group with at least 5% of subjects in one group were considered reasonable.

After identifying the trajectory group, we explored the association of demographic and health history predictors with the different groups. Multilevel multinomial logistic regression was then performed. The following factors were considered: age,

sex, race/ethnicity, marital status, income, employment, educational level, history of diagnosed diabetes. A multinomial logistic regression model was used that included the random effect of sociodemographic, health history factors and trajectory group.[63,64] Data preparation and analysis were performed in R (version 4.3.1), and GBMT was performed in the R package "GBMT".

4. Results

4.1. General Results

This Doctoral Thesis results part presents the findings from Study I to Study III. Study I addressed the definitions, components, measurements, and factors that facilitate adherence through a scoping review. In Study I, 182 articles were included. The three questions of Study I were answered according to the most common definition of adherence proposed by the WHO. Measurement of adherence showed considerable variation, which is presented in Figure 5. And, the factors that facilitate adherence are summarized in Table 3 Finally, A road map is designed to guide future studies in defining, measuring, and selecting appropriate factors to promote adherence which is presented in Figure 6.

Study II addressed factors that facilitate and hinder adherence to weight loss interventions. It summarized 21 articles and identified 47 factors in six categories that influence adherence; a factor map was developed in Figure 8.

Study III analysed trajectory patterns of adherence to physical activity and dietary behavior in the PROPEL weight loss trial, identifying five distinct behavioural trajectories in 24 months (as shown in Figure 10), and identifying baseline predictors.

4.2. Study I Results: Adherence to Behavioural Weight Management: A Scoping Review of Definition, Measurement and Facilitators

4.2.1. Search results

Figure 4 summarizes the study selection process, which identified 182 articles that met the inclusion and exclusion criteria. The selection process was as follows: after removing duplicates, a total of 4,725 citations were identified by searching all academic databases and references of review articles.

After screening, 598 full-text articles were retrieved based on their title and abstract and assessed for eligibility. Ultimately, after screening, 182 articles were considered included studies. 416 articles were deemed ineligible based on the inclusion and exclusion criteria. The flowchart provides more detailed information and the reason for excluding the studies (shown in Figure 4).

4.2.2. Characteristic of included study

The general characteristics of the study, intervention details, and definition, components, measurements and adherence metrics are described, along with a description of the objective and method of each intervention. In addition, the BCTs used to promote adherence are described. All included studies were published between 2017 and 2024. The majority of studies were conducted in North America (*K*= 106, 58%), followed by Europe (*K*= 46, 26%), and the remainder in Asia (*K*= 15, 8%), Oceania (*K*=11, 7%) and South America (*K*= 4, 3%). Study designs included experimental studies (*K*= 137, 75%), observational studies (*K*= 22, 12%), review studies (*K*= 20, 11%) and qualitative studies (*K*= 3, 2%).

4.2.3. Definition of adherence

As shown in Table 2, we identified three different concepts related to adherence: i.) adherence (*K*=8), ii) attrition (*K*=4), and iii) dropout rates (*K*=1).

Eight studies presented a definition of adherence,[48,65–71], two of which cited the World Health Organization (WHO) definition. [65],[48] WHO defined adherence as "the extent to which a person's behavior – taking medication, following a diet, and/or executing lifestyle changes – corresponds with agreed recommendations from a health care provider." at a 2003 WHO consensus meeting on adherence. Three studies defined adherence within the research framework, analysing adherence to technology and adherence to self-monitoring.[68–70,72] The remaining three studies referred to medication adherence in the Cochrane database, defining it as the level to which participants comply with prescribed treatments or instructions.[66],[67],[71]

Of the remaining studies, four studies defined attrition and two systematic reviews analysed the definition of attrition. While attrition was defined as not returning, refusing to return, or being expelled from a treatment program;[65],[73] in another study, the time of attrition was specified as before completion, indicating "program attrition, defined as leaving a program before its designated completion".[74] Furthermore, in one qualitative study, dropout was defined as attrition or failing to continue weight loss treatment at any stage until the end of treatment.[75]

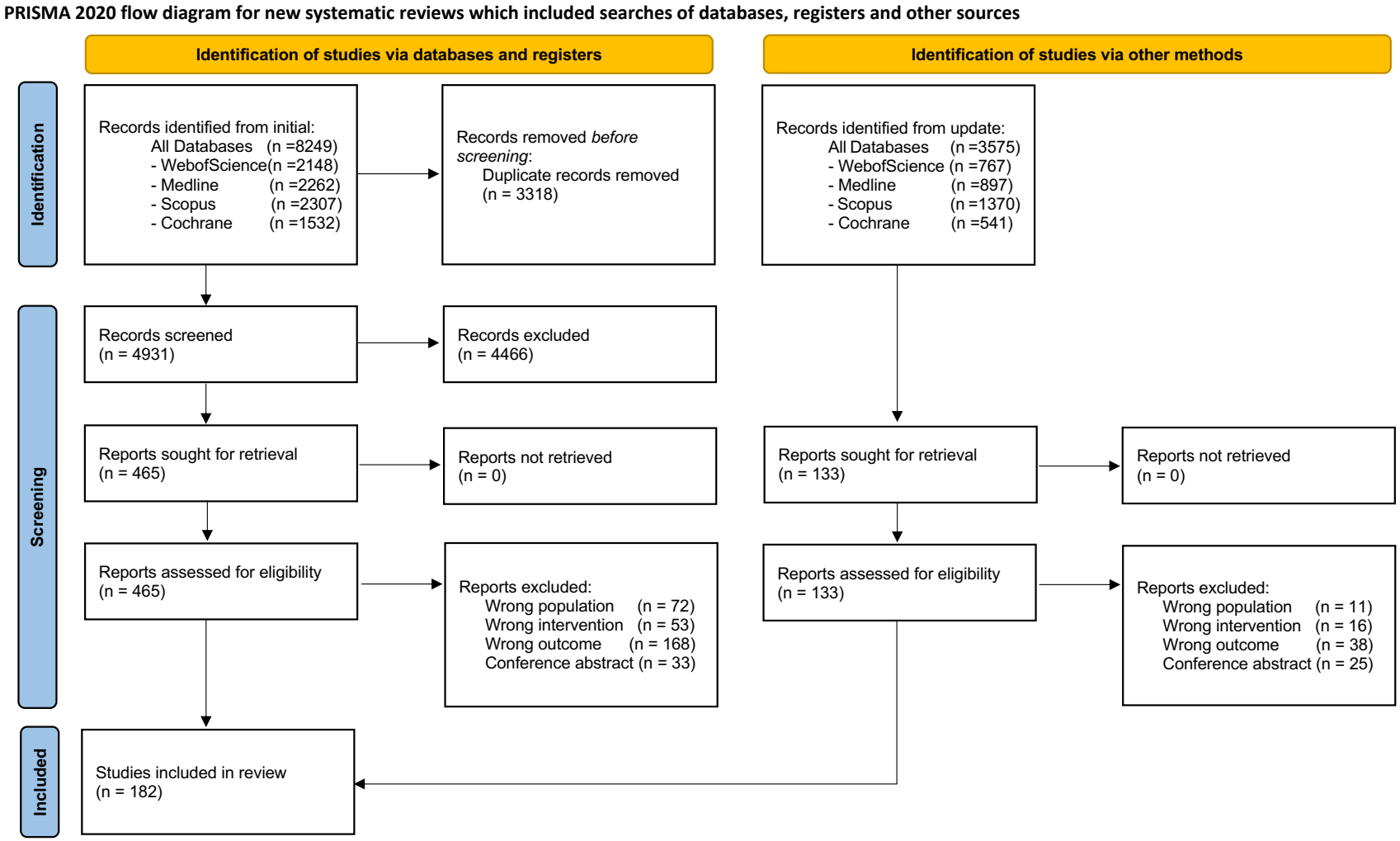

Figure 4. PRISMA flow diagram of study I.

Table 2. Terminology and definitions of adherence.

Term	Definition	Reference
Adherence	Adherence can be defined as the extent to which a person's behaviour corresponds with agreed recommendations.	Burgess et al. (2017)
Adherence	Adherence is defined as the level in which individuals comply with prescribed treatments or instructions.	Andersen et al. (2022)
Adherence	Adherence, defined as the "extent to which patients follow instructions given to them for prescribed treatments," is essential for achieving successful health outcomes.	Stinson et al. (2020)
Adherence	The extent to which a person's behavior: taking medication, following a diet, and/or executing lifestyle changes, corresponds with the 'agreed recommendations' from a health care provider.	Ihm et al. (2022)
Adherence Compliance Nonadherence Attrition	Adherence was described by the WHO as "the extent to which a person's behavior-taking medication, following a diet, and/or executing lifestyle changes, corresponds with agreed recommendations from a health care provider". A synonym commonly used in many publications is "compliance". Nonetheless, adherence is perceived as more neutral, emphasizing on the self-regulatory actions of an individual while compliance is perceived as paternalistic, emphasizing obedience to instructions. For this reason, adherence is used more often than compliance. Nonadherence implies the extent to which a person did not follow recommendations from health care providers, which hampers both external and internal validity or research studies. Attrition, which is an extreme form of non-adherence, is the most commonly reported adherence indicator in lifestyle modification programs as well as other weight loss programs.	Leung et al. (2017)
Technology adherence	Technology adherence, defined as the percentage of users who follow an intervention's intended use pattern, affects the implementation of large-scale digital health interventions	Andrade et al. (2021)
Technology adherence	Adherence to digital interventions has been succinctly defined as "a composite measure encompassing time online, activity completion, and active engagements with the intervention".	Lehmann et al. (2024)
Adherence to self-monitoring	Adherence to self-monitoring weight-related behaviors (i.e., exercise, weight, diet), as defined by the frequency of recommended recording, is associated with greater weight losses in BWL interventions.	Goldstein et al. (2019)
Adherence to medication	Adherence to medication is defined as the extent to which patients follow their healthcare providers' recommendations,9 and for patients with chronic diseases, it is linked with disease control, hospital admission rate, morbidity, and even mortality.	Ko et al. (2022)
Attrition	Program attrition, defined as leaving a program before its designated completion.	Isaman et al. (2021)
Attrition	Attrition is defined as failing to return, refusing to return, or being expelled from a treatment programme.	Pirotta et al. (2019)
Attrition/ Dropout	Dropout of weight-loss diet has been defined as attrition or failure to continue weight-loss treatment at any stage until the end of treatment.	Bazrafkan et al. (2021)

4.2.4. Components of adherence

Figure 5 shows the components of adherence documented in the reviewed studies, categorized according to various measures. Adherence, as a multifaceted concept, encompasses several components, described as "dietary adherence", "physical activity adherence", "self-monitoring weight", "medication adherence", "session attendance", "attrition", "dropout" and "retention" in the included studies. Most of these studies measured outcomes relevant to the research objective and intervention plans.

4.2.5. Measurement of adherence

Dietary adherence

Dietary adherence was assessed by various measurement methods, as summarized in Figure 5. These studies measured dietary adherence by self-reported questionnaires (e.g., questionnaires, diaries, logs), dietitian assessment, adipose tissue biopsies, and total energy expenditure using doubly labeled water (DLW).

Dietary adherence through questionnaire

Studies assessing dietary adherence have employed a variety of approaches, including the use of ratings or scale scores. Participants were frequently asked to report their level of dietary adherence by responding to various rating options, such as 1-4 non-adherent to adherent ,[76],[77] 1-5 non-adherent to adherent [78],[79], 1-7 non-adherent to adherent[80–82] and a binary adherence/non-adherence scale,[66],[67] and questions related to a specific diet.[83,84]

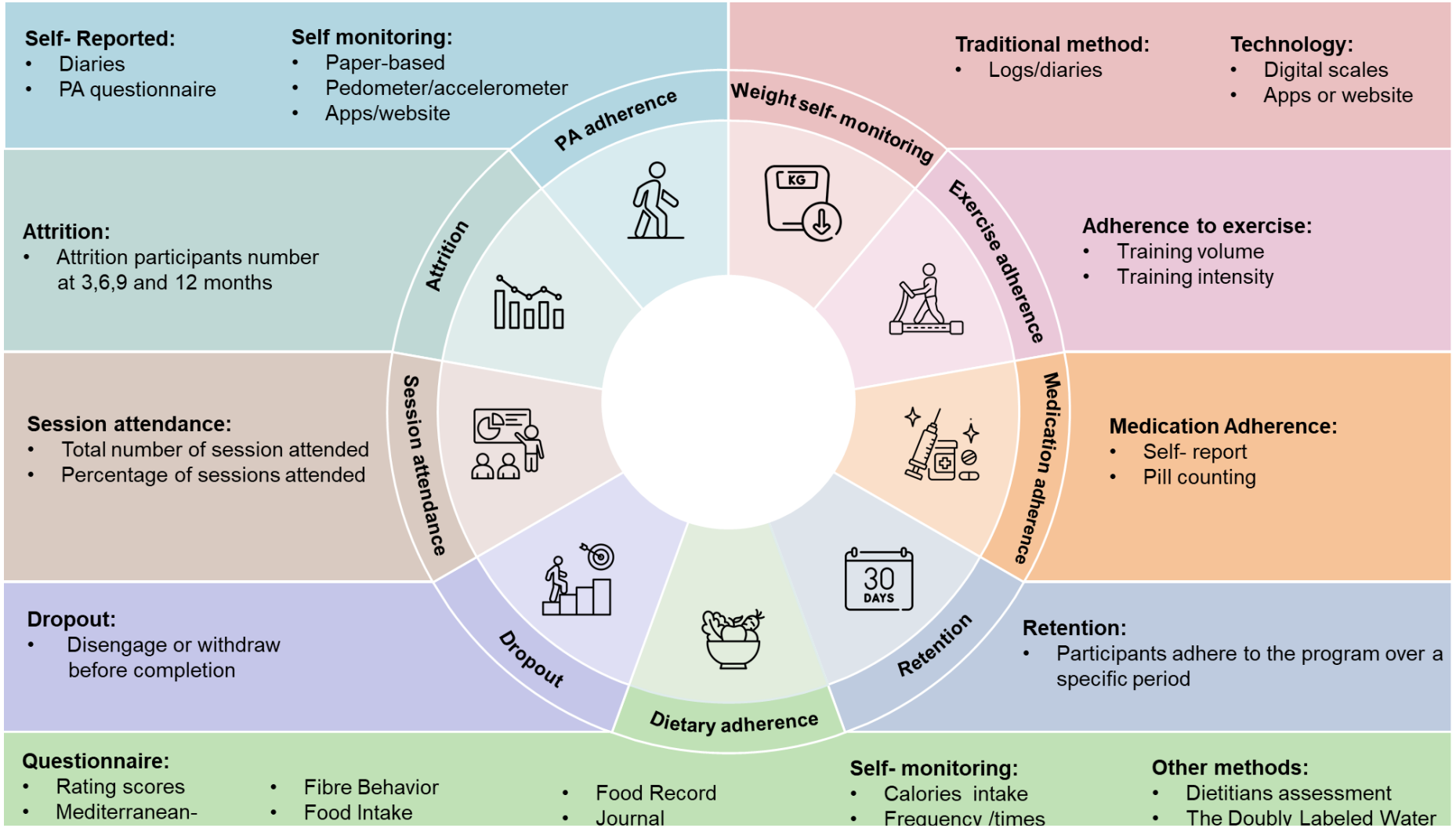

Figure 5. Measurement guidelines and components of adherence.

Additionally, a structured questionnaire was used to record energy intake; scores were then summed or the percentage of target energy intake (%), such as the Mediterranean diet adherence questionnaire, was calculated.[85–99] In addition, the questionnaires used were the Fat and Fiber Behavior Questionnaire (FFBQ),[100] Food Intake Assessment (FIA) and Food-Frequency and Activity Questionnaire (FFQ), respectively.[85,101–103]

Another approach was then used through food recording (e.g., 24-h dietary recalls,[104–108] 3-4 day food log,[109–113] 7-day food log,[114–116] diary and journal[117–122]).

Self-monitoring dietary adherence

Self-monitoring was implemented using various approaches. In addition to traditional methods (paper-and-pencil methods), technological options such as mobile applications and online platforms (e.g., MyFitnessPal, Calorie King) are available.

Self-monitoring of dietary adherence was defined as achieving a minimum calorie intake or staying within a specific calorie range and was calculated as percentage adherence (%). Regarding self-monitored dietary intake, various calorie intake thresholds have been used (e.g., ≥50% of recorded daily target kilocalories;[123–129] ≥800 recorded kcal;[130–134] ≥1,000 kcal,[120,135] ,1,200-1,500 kcal[136,137] , 1,200-1,800 kcal[138] and individualized goals).[106,139] In addition, the specific calorie range, for example, daily intake meets goal between 1,000 and 1,500 kcal,[140,141] and between 85% and 115% of daily calorie goal.[127] Others use the “traffic light diet” eating plan to categorize food intake.[142]

In addition, adherence was assessed based on the frequency of dietary self-monitoring, which includes food intake recording, interactions with apps, and time spent. More specifically, it includes the frequency of food intake recording [70,82,84,108,128,138,141,143–157] and interactions with apps or websites.[72,126,158–164]

Other methods of measuring dietary adherence

Dietitians can assess behavioural strategies to ensure participants implement effective lifestyle and dietary changes. This includes meetings with the dietitian and assessment of adherence .[76,78,110,165]

The doubly labeled water technique is a method for measuring individual energy expenditure, which indirectly assesses dietary adherence by considering whether the average energy expenditure meets the specific calorie goal (for example: 800 kcal).[166,167]

Furthermore, fatty acid analyses of subcutaneous adipose tissue biopsies before and after the intervention has been used to objectively measure adherence to the dietary intervention.[78]

Physical activity adherence

Self-reported physical activity adherence

Self-report measures of physical activity, such as diaries[145] and questionnaires[99,101,102,111,148,168] are commonly used to assess adherence to weight loss guidelines. These include steps, overall activity levels, and minutes of

moderate-to-vigorous physical activity (MVPA) to determine whether goals are being met.[101,102,111,145,148,168]

Self-monitoring physical activity

Self-monitoring of physical activity refers to the process of recording physical activity and comparing it with pre-set goals. This can be done using traditional paper-based methods[120,147,153] or using technological tools such as a pedometer,[130,131,133,158,169,170] an accelerometer,[83,100,108,109,118,136,162,171] smartphone applications or web-based tools that go beyond simple step measurement (Fitbit, Myfitnesspal etc.).[120,134,135,138,159,160,172,173]

Exercise adherence

Exercise adherence is measured by whether exercise frequency and intensity meet goals. Methods calculate adherence frequency by summing exercise session completion times or by dividing the actual exercise completed (in minutes or sets) by the prescribed exercise (in minutes or sets).[112,137,162,174–177] For exercise intensity, participants often wear heart rate monitors during sessions to monitor intensity.[176,178,179]

Self-monitoring weight

Adherence to weight self-monitoring was determined by recording weighing frequency during the intervention or by comparing body weights at different time points with respect to baseline (percentage change in body weight, %). Traditional

methods include logs and diaries,[120,141,145,153,159] while current technologies offer digital solutions such as wearable devices, bluetooth-based electronic scales [79,123,129,130,155,156,164,180,181] and mobile applications or websites[70,72,78,87,108,120,130,133–135,138,152,158,161] in such studies.

Session attendance

Session attendance in behavioural weight loss programs refers to participants' attendance at scheduled sessions, such as group meetings, counseling sessions, exercise classes, or educational workshops. Then, add the total number of session attendances or the percentage of sessions attended (sessions attended/total possible sessions) for analysis. [87,104,109,115,121,123,128,129,131,135–138,141,146,148,153,156,168,175,181–209]

Dropout

Dropout in behavioural weight loss interventions refers to participants disengaging or withdrawing from a weight loss program before completing it; the dropout rate percentage (%) is then calculated for further analysis. [109,174,210–213]

Attrition

Attrition in behavioural weight loss interventions refers to participants who discontinue programs. Measuring attrition typically involves tracking the number of participants who leave the intervention before completion. Attrition is typically measured at specific time intervals, for example at 3, 6, 9, and 12 months, to understand when attrition is most likely to occur.[104,149,187,204,214–216]

Attrition is essentially the term used to refer to a treatment that has begun but not yet completed. This can occur at any stage of the therapeutic process, including the first consultation, during therapy, or even after treatment but before follow-up appointments; with each step reflecting different elements and events.[217]

Retention

The term retention describes the degree of participant adherence to the program over a specific period. Retention is typically measured by the number of participants who continue to attend program sessions or remain enrolled in the program at different times.[80,132,146,153,177,218–222]

Medication Adherence

Individual medication adherence is observed in participants who consistently follow the prescribed medication regimen as part of a behavioural weight loss program. Measuring medication adherence in these programs involves self-reporting and pill-counting.[71,101,118,205,223,224]

4.2.6. BCTs to influence adherence

Table 3 summarizes research studies investigating BCTs that promote adherence to weight loss and obesity treatment programs.

Self-monitoring behavior/outcome and social support have both been shown to improve adherence. Specifically, evidence from systematic reviews and meta-analyses supports the role of both self-monitoring behavior and outcome in promoting adherence.[73,126,225,226] Furthermore, several studies have also reported the usefulness of self-monitoring behavior in improving adherence. For example, self-monitoring in a mHealth has been shown to lead to greater adherence,[210]

dietary self-monitoring behavior can improve adherence monitoring and, ultimately, weight-loss outcomes.[227] An intervention that encourages people to self-monitor their food intake been shown to improve weight loss success over time[228]

Regarding social support, the addition of telephone and text message support,[100,223,229] and the provision of social support,[230,231] improved adherence. Furthermore, providing support through motivational interviewing,[232] creating a behavioural contract[233]; and providing positive material such as financial incentives,[73,156] have been shown to improve adherence to weight loss treatment.

Table 3. Behavior Change Techniques (BCTs) promoting adherence.

Reference	BCTs listed in the Behaviour Change Techiques Ontology	Detail description	Evidence type
Antoun et al. (2022)	Self-monitor behaviour BCT [BCIO:007024] Self-monitor outcome of behaviour BCT[BCIO:007025]	Some studies in this review and the literature suggest that greater adherence to self-monitoring has been associated with greater weight loss. However, many articles do not provide detailed measurements of adherence to self-monitoring in weight loss apps.	Systematic Review and Meta-analysis
Burgess et al. (2017)	Deliver support BCT [BCIO:007039] Set behaviour goal BCT[BCIO:007003] Self-monitor behaviour BCT [BCIO:007024] Self-monitor outcome of behaviour BCT[BCIO:007025] Goal strategising BCT[BCIO:007008], Create behavioural contract BCT[BCIO:007014] Reframe past behaviour BCT[BCIO:007056]	Behavioural treatment strategies (e.g. motivational interviewing, goal setting, self-monitoring, problem solving, relapse prevention, behavioural contracting, cognitive restructuring.) improve adherence to lifestyle intervention programmes in adults with obesity. This meta-analysis shows that behavioural treatment interventions have a significant positive effect on session attendance (percentage) and physical activity (total min/week) in adults with obesity (M= 17.63 (95% confidence interval (CI) = 10.77, 24.50), z=5.0337, P< 0.0001 and M= 105.98 (95% CI = 58.64, 153.32), z=4.3878, P< 0.0001, respectively).	Systematic review and meta-analysis
Cavero-Redondo et al. (2020)	Self-monitor behaviour BCT [BCIO:007024] Self-monitor outcome of behaviour BCT[BCIO:007025]	mHealth self-monitoring: behavioural weight management interventions using lifestyle mHealth self-monitoring interventions showed a higher adherence	Systematic Review and Meta-Analysis

		than: (i) paper records at any time and (ii) any other intervention at six months and twelve months."	
Dunn et al. (2019)	Self-monitor behaviour BCT [BCIO:007024]	This correlation supports previous findings that adherence to self-monitoring, regardless of the method, is important in behavioural weight-loss interventions,[11,18,26,37,38] and indicate that discovering new and simpler methods of DSM may improve tracking adherence and eventually weight-loss outcomes.	Randomized Trial
Chew et al. (2022)	Self-monitor behaviour BCT [BCIO:007024] Self-monitor outcome of behaviour BCT[BCIO:007025]	Self-monitoring easy improve adherence. Nevertheless, studies have shown that off-loading the need for manual logging (e.g., keeping a food diary, taking pictures and scanning barcodes) reduces user burden and increases self-monitoring adherence. Of note, research has shown that the frequency rather than accuracy of self-monitoring is more significant in weight loss. Future studies could examine the efficiency and accuracy of triangulating gesture data with image and sound in self-monitoring for weight loss and actual weight loss.	Scoping review
Chhabria et al. (2020)	Social support BCT[BCIO:007028]	Supportive Accountability: Finally, consistent with Mohr's theory that supportive accountability could increase intervention adherence. Mohr et al [17] recently proposed Supportive Accountability Theory, which posits that adherence to technology-based interventions may be improved through the provision of both social support	Randomized trial

		(whether delivered in person or electronically and either synchronously or asynchronously) and accountability (the expectation that an individual would regularly have to explain their progress toward program goals).	
de Bruin et al. (2019)	Social support BCT[BCIO:007028] Context-specific repetition of behaviour BCT[BCIO:007096	1.The main adherence barriers were the social pressure to eat, lack of time and lack of flexibility in participants' meal schedules. 2.Common adherence enablers were having a set routine, social support and accountability.	Pilot study
Gibson et al.(2017)	Self-monitor behaviour BCT[BCIO:007024]	A dietary intervention that is tailored to a person's dietary preferences (whilst still aligning with nutritional recommendations), may also improve adherence. For this reason, government-based dietary guidelines are a very useful tool to use when tailoring a dietary intervention, as they are intended as population approach that are designed to be adapted to different dietary, cultural and cost preferences. Encouraging individuals to self-monitor their food intake has also been shown to improve the success of weight loss attempts and maintaining dietary changes overtime.	Review
Hartmann-Boyce et al. (2019)	Self-monitor behaviour BCT[BCIO:007024] Self-monitor outcome of behaviour BCT[BCIO:007025]	This synthesis provides new insights into the implications of self-monitoring on weight loss and maintenance. It suggests that self-monitoring can range from an aid to increase adherence to behavior change targets to a tool for facilitating analysis and self-experimentation.	Systematic Review of Qualitative Studies

Lewis et al. (2019)	Deliver support BCT [BCIO:007039] Set behaviour goal BCT[BCIO:007003], Goal strategising BCT[BCIO:007008],	Telephone and text message support (Motivational interviewing, goal setting, problem solving, stimulus control, and self-reinforcement) improved lifestyle intervention adherence and clinical outcomes when compared with standard care.	Randomized Clinical Trial
Li et al. (2020)	Prompt intended action BCT[BCIO:007080]	The text messages were developed by a team of medical and health professionals experienced in treating patients with overweight or obesity based on theoretically driven and empirically supported evidence. The topics were organized into six sections, including medicine, motivation, nutrition, activeness, coping strategies, and weight management. The results indicated that SMS reminders improved adherence for weight-loss medication in patients with overweight or obesity, and receiving five SMS per week led to a better improvement in medication adherence than three SMS per week.	Randomized Clinical Trial
Coupe et al. (2019)	Create behavioural contract BCT[BCIO:007014]	Behavioural contracts were ineffective in increasing adherence to physical activity goals in the short or long-term. It is unclear why contracts increased adherence to dietary changes but did not promote physical activity. Dietary goals specified in the contracts may have been more acceptable to participants or easier to implement than the physical activity	Systematic review

		goals, which would suggest that more work is needed in relation to goal development.	
Pirotta et al. (2019)	Promise positive material consequence for behaviourBCT[BCIO:007209], Self-monitor behaviour BCT[BCIO:007024] Self-monitor outcome of behaviour BCT[BCIO:007025]	Strategies that successfully reduced attrition included the incorporation of financial incentives (n = 8), a multicomponent approach (n = 13), and use of self-monitoring technology (n = 4).	Systematic review and meta-analysis
Shetty et al. (2024)	Promise positive material consequence for behaviourBCT[BCIO:007209]	Financial incentives (Incentivizing behaviors associated with weight loss improved adherence to those behaviors and does not appear to spill over to non-incentivized behaviors.)	Pilot study
Rumbo-Rodríguez et al. (2020)	Self-monitor behaviour BCT[BCIO:007024] Self-monitor outcome of behaviour BCT[BCIO:007025]	The use of technology also seems to allow improvement in adherence to treatment, as it allows a simpler and faster self-monitoring. In addition, although more research is needed, this could improve more when the technology is accompanied by immediate feedback. However, future research should focus on this, as, despite the use of technology, adherence to dietary-nutritional treatment often decreases over time, resulting in less weight loss as time passes.	A Systematic Review

Note:
BCT: Behavior Change Technique
BCTs: Behavior Change Techniques
BCIO: Behavior Change Intervention Ontology

4.2.7. Roadmap and measurement guidelines to adherence

Furthermore, we consolidate and map the findings from the various research objectives stablished in the scoping review and propose a roadmap for the research community to move forward in the study of adherence in the context of behavioural weight-management programs. The roadmap proposes four steps: i) development of a standardized and definition of adherence to behavioural weight-management programs, ii) identification and selection of adherence components, iii) identification and selection of appropriate metrics and measurement methods, and iv) incorporation of BCTs into the weight-loss program. The roadmap is detailed in Figure 6.

It prioritizes increased transparency, reproducibility, and comparability across different research contexts. The work developed in each step of the roadmap should be a collaborative, iterative and expert-based process, using consensus-based approaches, and ensuring that clear and operationalized recommendations are derived.

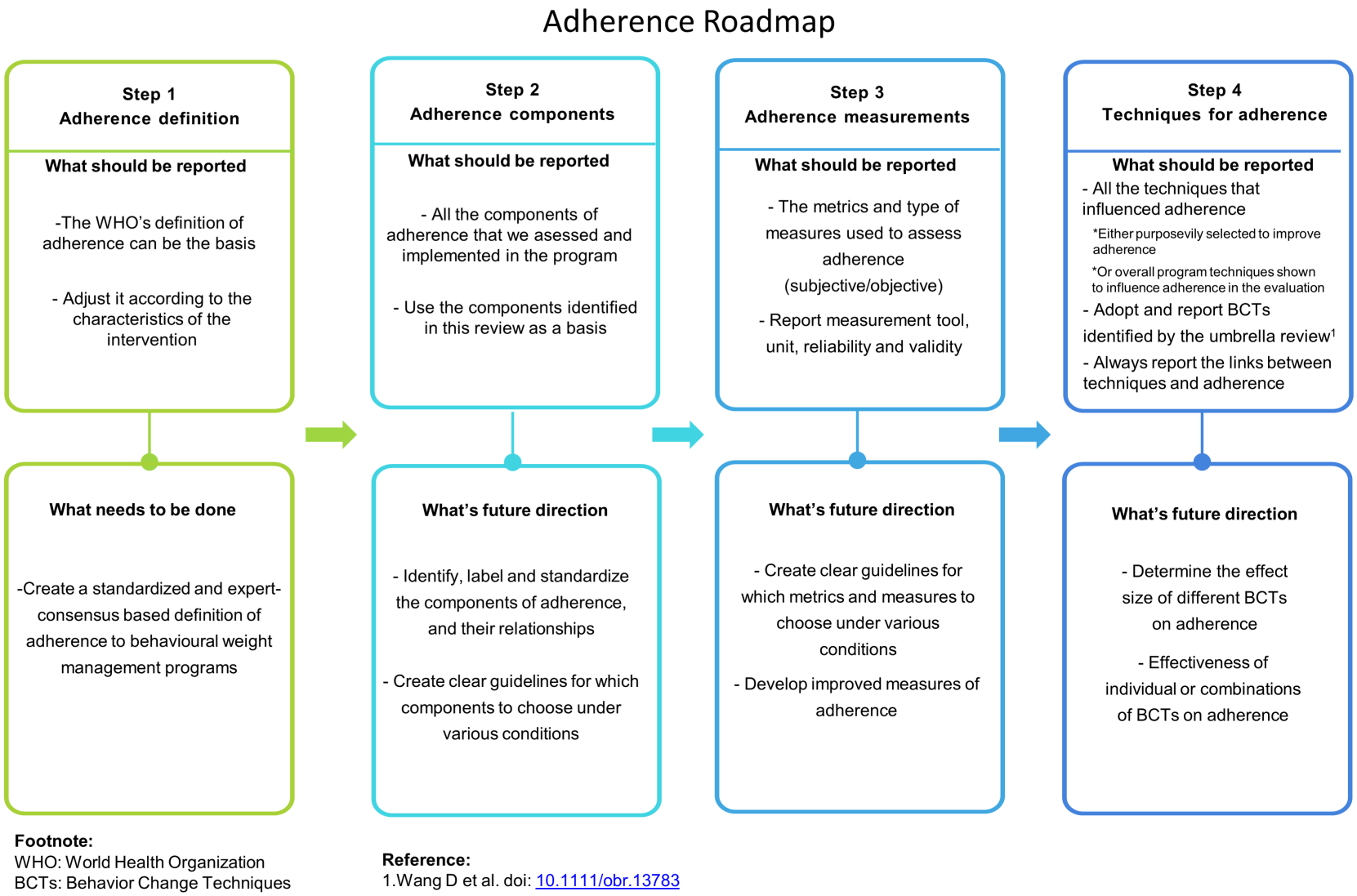

Figure 6. Roadmap for adherence.

4.3. Study II Results: Exploring factors of adherence to weight loss interventions in population with overweight/obesity: an umbrella review

4.3.1. Search results

A total of 4758 records were retrieved from bibliographic databases. After removing all duplicates (N = 1624), 3134 potential studies were screened based on their titles and abstracts, while 3034 studies were excluded due to their lack of relevance to the research. The full text was read, and the remaining 94 studies were assessed for eligibility. Seventy-three studies were excluded and categorized according to the excluded articles shown in Figure 7, which displays the PRISMA flowchart. The remaining 21 systematic reviews were considered eligible for the umbrella review.

4.3.2. Quality Assessment

The annexes of Study II, show the results of the AMSTAR-2 quality assessment. Most reviews had multiple methodological flaws: four were rated as 'low' quality,[234–237] five as 'moderate' quality[238–242] and 12 as 'critically low' quality.[243–254] The reasons that most contributed to the low and critically low ratings were as follows: only 8 of the 21 reviews included in the present study assessed risk of bias [234,236–238,241–243,254] and the remaining studies did not report outcome bias. Another reason was methodological limitations, such as lack of

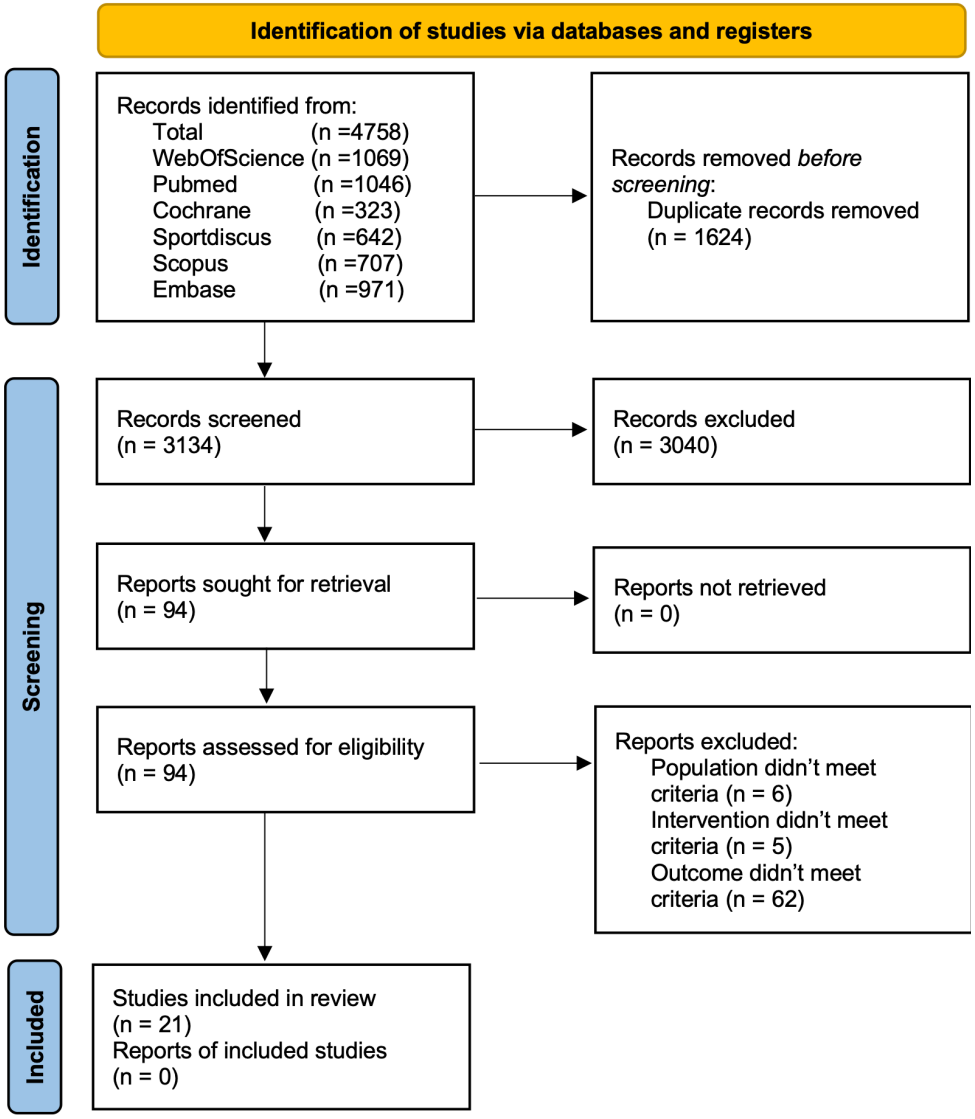

Figure 7. PRISMA flow diagram of study II.

protocol or pre-registration of reviews before conducting the review,[235,237,243–248,253,254] or failure to provide justification for the exclusion list.[246,247,249,250]

4.3.3. Description of included systematic reviews and meta-analyses

The characteristics of the 21 included systematic reviews and meta-analyses are described in Annexes of Study II, Regarding the publication date, twenty-one reviews were published in the last 15 years (after 2008). Regarding the study design of the 21 publications, 8 were systematic reviews,[236,238,240,241,246,249,252,254] 10 were systematic reviews with meta-analyses,[234,235,237,239,242,243,245,247,248,253] 2 were meta-analyses[244,250] and 1 was an overview.[250] The number of studies within the included reviews ranged from 7 to 103. The types of studies presented in the reviews were mainly randomized controlled trials (RCTs), 2 reviews included observational studies[244,248], and 2 included cohort studies.[237,240] Seven reviews included only randomized controlled trials (RCTs). [234,236,238,246,249,251,252] Considering all included studies, the total sample size was 36,805 participants, ranging in age from 18 to 65 years old, although several studies did not report age.[237,244,246,251,255] Regarding gender, 13 studies included predominantly females,[234–236,239,240,242,243,245,247–250,253] with fewer males in these studies. With the exception of three studies that used a body mass index (BMI) greater than 30 $kg \cdot m^{-2}$, [246,247],[249] all remaining studies reported BMI greater than 25 $kg \cdot m^{-2}$. Most of the included original studies originated in the United States, followed by European countries, with the remaining studies conducted in Australia[251,252] and Turkey,[236] and the remaining six reviews in Asia.[234,241–243,250,254]

Of the 21 studies, 4 focused on adherence to behavioural weight management,[239,241,246,247] 3 focused on dietary adherence,[234,251,252] and 2 focused on adherence and attrition to pharmacological interventions.[236,249] Additionally, 4 studies aimed to explore facilitators and barriers to adherence,[240,244,245,250] while the remaining 8 studies investigated the relationships between different interventions and adherence, including behavioural contract,[27] self-monitoring, technology-based interventions,[243] non-mobile versus smartphone apps,[254] financial incentives,[237,238] commitment therapy,[235] and pre-treatment expectancies.[248] (A detailed version table is in Annexes of Study II).

4.3.4. Definition and modulating factors of adherence

The definition of adherence varied among the 21 included studies, depending on the type of intervention analyzed (Adherence definition of 21 included reviews). In these studies, the main terminologies used in adherence to programs were represented by “adherence”, “attrition”, “dropout” and “retention”, with no obvious overlap between these definitions. The most frequent unit of measurement for attrition, dropout, and retention was percentage (%). Regarding adherence, the majority of the reported indicators were adherence to physical activity[235,242] and adherence to diet[242,251]. However, the units and measurements of adherence were heterogeneous among these studies. To better describe the heterogeneity observed in the literature, factors were grouped into the following 6 categories, according to the type of intervention: a. sociodemographic (n = 7) b. dietary (n = 8), c. physical activity (n = 2), d. behavioural (n = 4), e. pharmacological (n = 3), and f. multi-

intervention (n = 23). These categories can also be observed in detail in Table 5 and Figure 8.

4.3.4.1. Socio-demographic factors

Sociodemographic factors were reported in four reviews. [245,247,248,250] There was substantial evidence supporting adherence in males, which was consistently associated with greater adherence across several reviews. For example, one of the included systematic reviews strongly suggested that being male and older predicted adherence to lifestyle interventions, whereas younger females showed the opposite effects. Being male has also been suggested to predict greater adherence to self-monitoring.[250] Furthermore, this condition has been shown to predict attrition in behavioural and dietary programs.[250]

Likewise,, there were other specific sociodemographic factors that could be correlated with adherence. More specifically, being older, having a higher level of education,[245,250] a lower baseline BMI,[247] a higher baseline stage of change,[250] and greater initial weight loss[250] may predict better adherence. On the other hand, the relationship between higher expectations and attrition remains unclear due to the contradictory results observed in most of the included studies. [248]

4.3.4.2 Physical activity interventions

Acceptance and commitment therapy (ACT) and behavioural contract were 2 factors related to physical activity adherence.[242],[235] Interventions incorporating ACT showed an increase in physical activity adherence in 3 to 6 months.[235] However, the use of a behavioural contract did not improve adherence in either the short or long term (>12 months).[242]

Table 4 Adherence definition of 21 included reviews.

	Definition	Measurement and unit	Reference
Adherence	Adherence	Adherence to physical activity Adherence to Dietary	Coupe et al.(2019)
	Adherence	(1)The number of diaries submitted (2)Therapists' ratings of the completeness of diaries (3)Scores on a survey of self-monitoring (4)The number of self-reported weights over a specified period.	Burke et al.(2011)
	Adherence	Number of intervention sessions attended, or as engagement with any intervention component (1)Completion of food diaries (2)Number of times logged into a mobile application.	Birch et al. (2022)
	Adherence	(1)Session attendance (number, percentage), (2)Attrition, (3)Dietary intake (total calories/day, % calories from fat, protein and carbohydrates, fruit and vegetable serves/day), (4)Physical activity (frequency, total min/week, total METS/week, Kcal/week/kg, total steps/day) (5)Self-monitoring compliance (number of diaries completed; level of completion of diaries, number of days blood glucose was monitored, number of days calories were recorded).	Burgess et al. (2017)
	Adherence and/or attrition	(1)Objective or self-reported modifications to physical activity (2)and/or diet or by lifestyle intervention program session attendance or attrition).	Burgess et al. (2017)
	Treatment adherence through technology	Adherence to self-monitoring Adherence to program	Rumbo-Rodriguez et al.(2020)

	Adherence to smartphone apps	(1)Self-monitoring of weight, (2)Self-monitoring of dietary intake, (3)Self-monitoring of physical activity, and (4)Interaction with the app. Each of these themes was defined differently in terms of measurement of adherence.	Antoun et al.(2022)
	Adherence to completion of the weight loss program.	Intervention adherence rate%	Lemstra et al. (2016)
	Adherence to physical activity	Adherence to physical activity%	Manchon et al. (2022)
	Adherence to diet	(1)Adherence to diet% (2)Dropout	Enriquez Guerrero et al. (2021)
	Dietary adherence	Self-reported dietary assessment, such as food diaries or records or food frequency questionnaire.	Wibisono et al.(2016)
Attrition	Attrition	Attrition rates(%)	Moroshko et al. (2011)
	Attrition	Total attrition (%)	Fabricatore et al. (2009)
	Attrition/attendance.	Attrition rates(%)	Crawford et al. (2012)
	Attrition	Attrition rate(%) at the end of a weight loss program rather than the end of a study	Pirotta et al. (2019)
	Attrition(most common indicator),	Attrition rate(%)	Leung et al. (2017)

	Attendance and self-monitoring. Dietary adherence.		
	Attrition(non-use and dropout) Adherence(defined as compliance to the treatment protocol Engagement(metrics and intensity of use)	1.Attrition rates (%) of dropout attrition or non-usage attrition measures. 2. Non-usage attrition (%) was the rate of maximum non-usage of the intervention as defined by the study authors.	Young et al.(2019)
Dropout	Dropouts	Dropouts(%)	Cavero-Redondo et al. (2020)
	Dropout	Dropouts(%)	Ananthapavan et al.(2018)
	Dropouts	Dropout number	Neovius et al. (2008)
Retention	Participant retention	1.The rate of participant retention(%). 2.If it was not possible, participant retention was calculated using other information reported in the paper (e.g., the number of participants completing a specific number of the intervention sessions). "	Sykes-Muskett et al.(2022)

Table 5. Adherence guidelines.

Factor/intervention type	Dietary interventions	Physical activity interventions	Behavioural interventions	Pharmacological interventions	Multi-interventions
Only dietary intervention	+				
Behavioural contract	+				
Online dietary intervention	+				
Food suplementation	+				
Intermittent fasting	?				
Population (specific or general)	?				
Dietary change target	?				
Number of BCTs employed in the intervention	?				
Acceptance and commitment therapy		+			
Behavioural contract		-			
Self- monitoring			+		
Self-monitoring (diet, physical activity or self-weighting)			?		
Financial incentive			+		
Supervised attendance program			+		

Medicine (Orlistat)	+	
Medicine (Sibutramine)	+	
Completed a prerandomization lead in period	+	
Female	-	
Multicomponent(Combination of physical activity and nutrition regimens)		+
Multi techniques (personal assistants (PDAs), smartphones, wearable monitors or web-based)		+
Multi behavior approach		+
Early weight loss success		+
Healthier eating and physical activity behaviors		+
Better baseline mood		+
Social support		+
Strong body shape concern		-
Higher weight loss epectations and/or lower initial weight loss		-
Lower levels of physical activity		-
More previous weight loss attempts		-
Greater body dissatisfaction		-
Poorer body image		-
Poorer mental health		-

Being unemployed	-
Lower self-efficacy	-
Lower social support	-
Greater travel distance to the clinic	-
Financial difficulties or need to pay for the treatment	-
Depression	-
Stress	-
Self-efficacy	?
Motivation	?

Note:
*Guidelines of adherence factors.
Positive association (+),
Negative association (-),
Inconsistent conclusion (?)

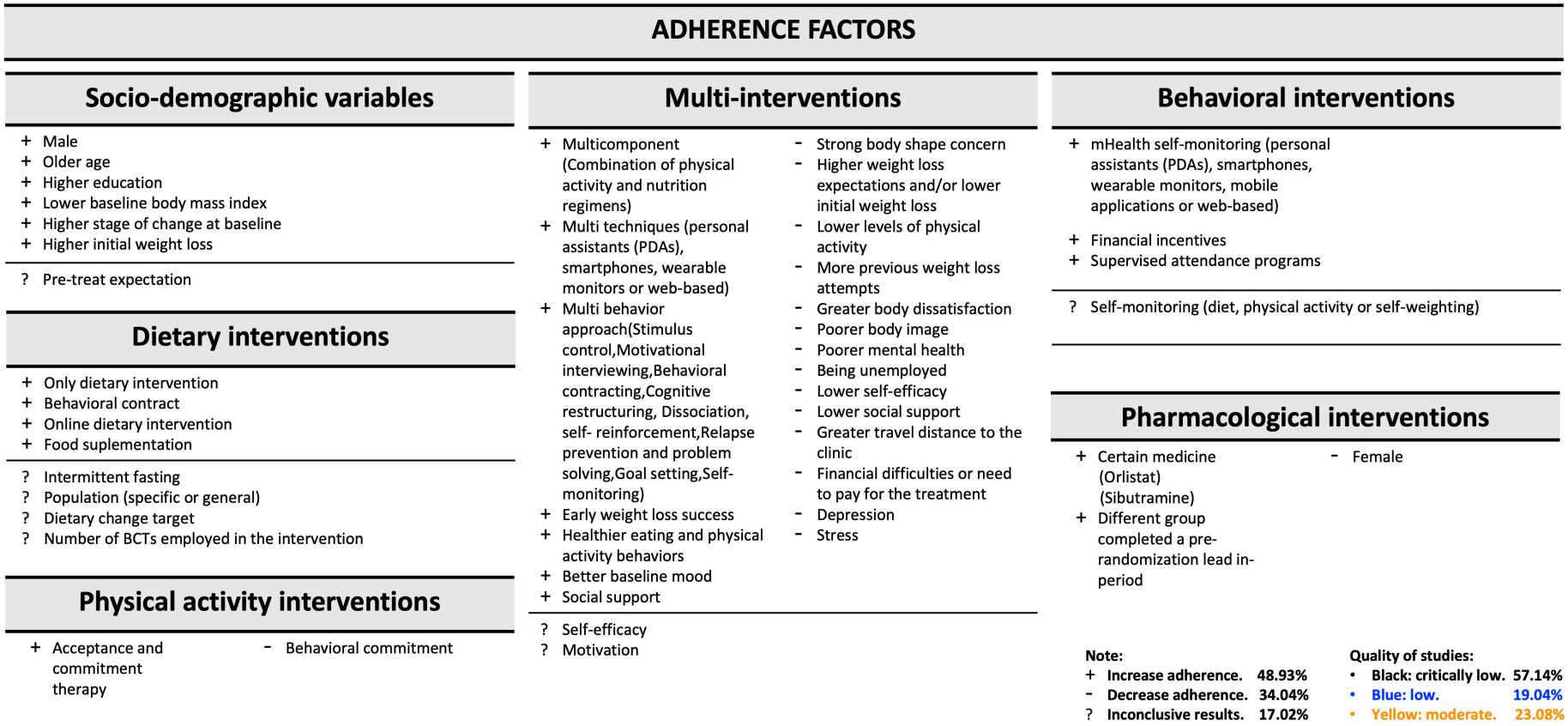

Figure 8. Exploring map of adherence factors.

4.3.4.3. Dietary interventions

Six articles evaluated 8 potential factors for dietary interventions. There is evidence that dietary intervention alone leads to greater adherence compared with exercise intervention alone.[244] Various dietary determinants, such as behavioural contracts,[242] online dietary interventions[234] and food supplements[252] have been shown to improve adherence. However, results were less conclusive regarding the effectiveness of interventions using intermittent fasting (IF) strategies.[251]

Specifically, behavioural contracts have been shown to be effective in promoting dietary change and program adherence, both in the short-term (≤6 months) and long-term (>12 months) .[242] Online dietary interventions have also been shown to improve eating behavior and reduce dropout rate.[234] Furthermore, a review showed that food supplements could be used as a factor to improve adherence, considering dietary advice and frequent monitoring as inseparable parts of the intervention.[252]

A recent review found inconsistent results on intermittent fasting, with some studies reporting a low dropout rate, while other authors suggested that intermittent fasting strategies may have low long-term adherence.[251] Furthermore, no associations were found between dropout rates and different populations, dietary change goals, and the number of behavior change techniques used in the intervention.[250]

4.3.4.4. Pharmacological interventions

Three factors were identified in pharmacological interventions. Specifically, certain types of medications[236],[249] and the pre-lead period[249] were associated

with a lower attrition, while female gender was considered a predictor of attrition.[249]

A previous meta-analysis found a lower medication attrition rate with the specific medications Sibutramine and Orlistat, as well as in the group that completed a pre-randomization introduction period.[249] Similarly, an alternative review highlighted that Sibutramine had higher adherence,[236] suggesting that Sibutramine had a low dropout rate. Of the seven studies comparing Sibutramine and Orlistat monotherapy, four showed that Sibutramine was more effective for weight loss.[236]

4.3.4.5. Behavioural interventions

Self-monitoring,[240,241,253] financial incentives[237,238,240] and supervised programs[244] were shown to be the three most effective behavioural intervention approaches.

Regarding self-monitoring, one review suggested the use of lifestyle mHealth tools, (i.e., personal digital assistants, smartphone or web-based) which have been shown to have a lower dropout rate compared to paper records.[241] Lower dropout rates were also observed for lifestyle mHealth compared to the usual care and waitlist groups at six and twelve months.[241]

Furthermore, another study reported that self-monitoring technology (including mobile apps, armbands or wearable monitors) reduced the risk of attrition from adult weight loss programs by effectively incorporating different components (personalized goal setting, feedback, social support and specific program structure).[240]

Other studies have reported a significant association between self-monitoring (diet, physical activity, or self-weighing) and weight loss.[253] However, the heterogeneity of adherence measures (including various diaries, ratings of health professionals, self-monitoring scores and self-reported weights), has made direct comparisons between them unfeasible.[253]

Regarding financial incentives, a recent review suggested that positive financial stimulants, such as rewarding participants for achieving their stated goals, increase acceptance of the program and may reduce dropout rates. [237] Incorporating financial incentives and combining them with behavior change programs, for example self-monitoring, has been shown to be effective in improving overall adherence.[240] Furthermore, monetary contingency contracts, which involve depositing money and returning it upon reaching the goal, have been identified as another factor that may improve adherence. A single refund has also been shown to be more effective than a multi-stage refund.[238]

The supervised attendance program also had higher adherence compared to an unsupervised program ([RR] 1.65; 95% CI 1.54–1.77).[244] When attendance was monitored (supervised) by the researcher or a program leader, participants adhered more than those who relied on self-monitoring of their interventions.[244]

4.3.4.6. Multi-interventions

Multi-component interventions are defined as the combination over two approaches simultaneously. Improved adherence has been observed in programs that apply a multi-component approach,[240] multiple techniques[243] and multiple behavioural interventions.[246]

A multicomponent approach, such as combining physical activity and nutrition with self-monitoring, has been shown to significantly reduce the risk of attrition.[240] Similarly, another study also found that diet and exercise programs combined with different types of techniques, such as smartphones, apps, websites, virtual reality or personal digital assistants, improved adherence.[243]

A multibehavioural approach (involving more than two behavioural strategies) improved adherence, showing significant positive effects on both session attendance (percentage) and physical activity (total minutes/week), respectively.[246]

Furthermore, body weight and shape factors, such as early weight loss success[247,250] and greater weight loss,[234] predicted adherence. Likewise, healthier eating and physical activity behaviors also had a positive impact on adherence.[250]

In addition, some psychological factors have been identified as predictors of adherence, such as better baseline mood,[247] motivation[250] and social support.[244] In contrast, the presence of a large group of factors predicted attrition: strong concern about body shape[250], higher weight loss expectations and/or lower initial weight loss,[245] lower physical activity levels,[245] depression,[250] stress,[250] more previous weight loss attempts,[245],[250] greater body dissatisfaction,[245] poorer body image,[245] poorer mental health,[245] being unemployed,[250] more previous diet attempts,[245] lower self-efficacy,[245] lower social support,[245] longer travel distance to clinic,[245] financial difficulties, or the need to pay for treatment.[245] Furthermore, there are conflicting results regarding self-efficacy[250] and motivation.[250]

4.4. Study III Results: Longitudinal Changes in Physical Activity and Dietary Fat Intake during an intensive lifestyle intervention: the PROPEL Trial

4.4.1. Trajectory group process

Total physical activity minutes/day and percentage of dietary fat were assessed at four time points: baseline and 6, 12, and 24 months postintervention. Table 6 and Figure 9 show the statistical indicators of model selection. The results indicated that the five-trajectory group model performed optimally accross all criteria. The fifth group had the smallest BIC value, 7848.919, and also optimized all indicators compared to the other groups (AIC :7581.018, CAIC: 7897.919, SSBIC: 7693.251, HQIC, 7680.051).

Table 6. Statistical metrics for model selection.

Model	AIC	BIC	CAIC	SSBIC	HQIC	APPA
1	8963.132	9012.339	9021.339	8983.746	8981.322	1
2	8252.208	8356.088	8375.088	8295.727	8290.609	0.986;0.962
3	7877.146	8035.700	8064.700	7943.569	7935.758	0.990;0.940;0.955
4	7692.436	7905.664	7944.664	7781.764	7771.258	0.959;0.933;0.935;0.931
5	**7581.018**	**7848.919**	**7897.919**	**7693.251**	**7680.051**	**0.898;0.960;0.899;0.944;0.942**

6	7597.351	7919.926	7978.926	7732.488	7716.595	0.897;0.968;0.946;0.937;0.897;0.838

Notes and Abbreviations: AIC, Akaike information criterion; BIC, Bayesian information criterion; CAIC, Consistent Akaike Information Criterion; SSBIC, Sample Size Adjusted BIC; HQIC, Hannan-Quinn Information Criterion; APPA, Average posterior probability of assignments.

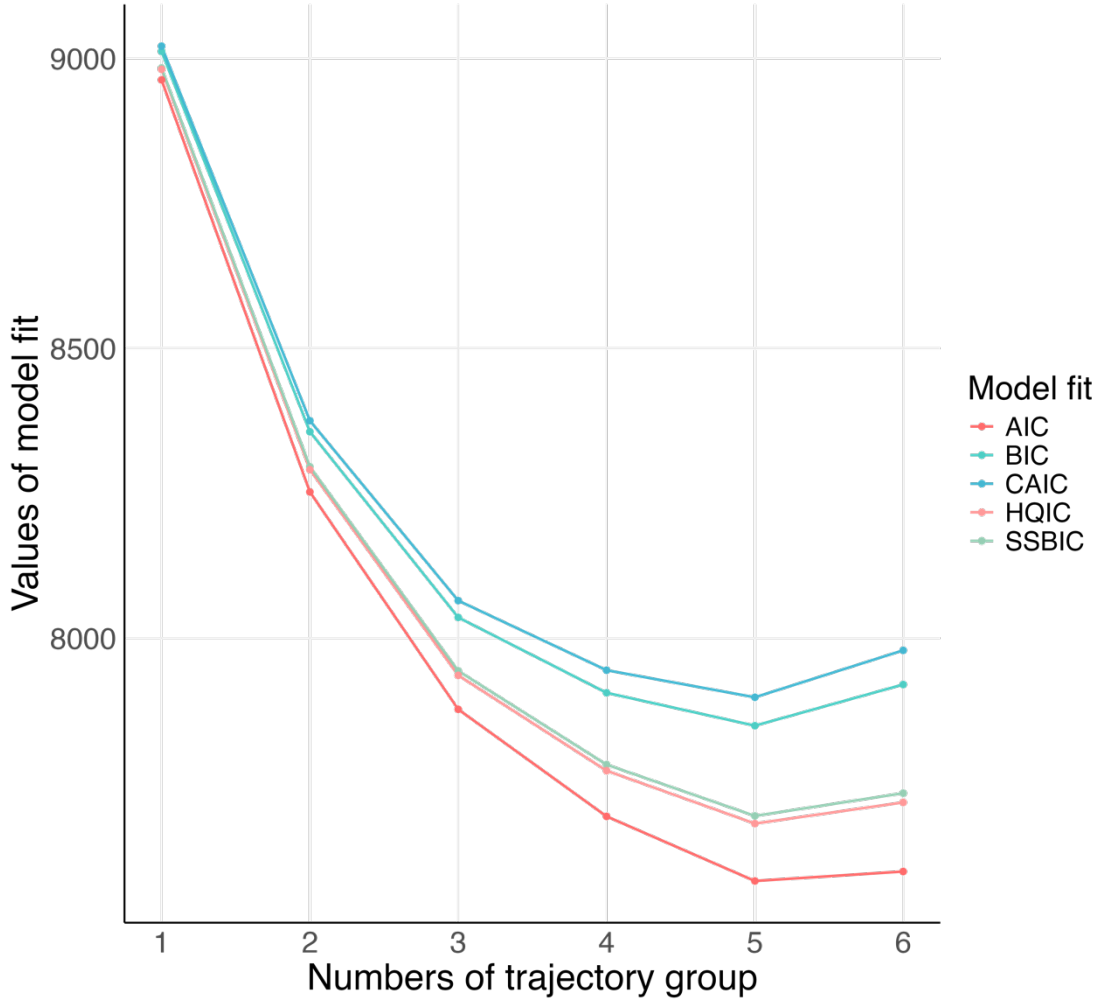

Figure 9. Statistical metrics for model selection.

Notes and Abbreviations: AIC, Akaike information criterion; BIC, Bayesian information criterion; CAIC, Consistent Akaike Information Criterion; SSBIC, Sample Size Adjusted BIC; HQIC, Hannan-Quinn Information Criterion.

Characteristics of trajectories group

Physical activity and dietary fat intake trajectories were fitted for groups k (1-6) from baseline to 24 months. Of all the models, the 5-group trajectory model offered the optimal balance between model fit and model complexity.

The five trajectories of physical activity and dietary fat intake are shown in Figure 10. In the first group (n = 92, 21% of the sample), with moderate levels of TPA and a slight decline between 6 and 24 months, dietary fat intake initially decreased and then plateaued around 31%. The second group (n = 72, 16%) showed a persistently lower level of TPA with minimal change during the intervention, with a U-shaped trajectory of dietary fat intake that decreased slightly to approximately 31% at 6 months and then increased during the intervention. The third group (n = 143; 33%) had high TPA and improved in the first 6 months, with a subsequent downward trend between 6 and 24 months. This group, with the lowest dietary fat intake, reduced to 30% at the beginning of the intervention and then maintained the same dietary intake pattern throughout the intervention. Then, the fourth group (n = 90; 20%) had high TPA levels, which increased from baseline to 12 months, followed by a marked decrease in fat intake initially, but which recovered between 6 and 24 months. Finally, the fifth group (n = 42; 10%) had low TPA, which increased slightly from baseline to 12 months and then decreased, while fat intake remained high and fluctuating.

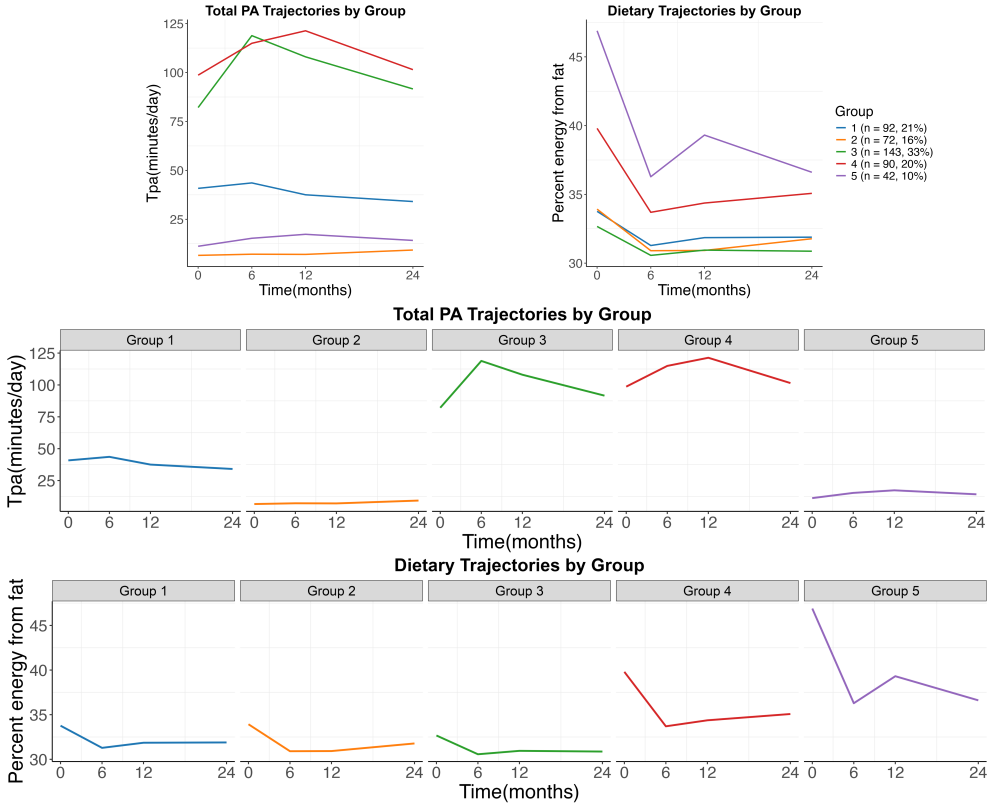

Figure 10. Five latent trajectory group based on TPA and dietary fat intake for 24 months.

4.4.2. Baseline characteristics of the study population

Table 7 shows the baseline characteristics of the participants. A total of 439 patients were included in the analysis. The majority, 398 (88%) participants, were female. The mean age was 48.9 (SD 12.6) years. Most participants were black (73.8%), followed by white (20.5%) and other racial backgrounds (5.7%). Regarding marital status, 40.3% were married, while 59.7% were in other categories. Educational status showed that 68.1% had a college education or higher, while 31.9% had completed high school or less. Income distribution varied across categories, with 19.1% in the lowest group and 18.2% in the highest. Employment status was relatively balanced, with 67.0% employed. Household size was

predominantly 1 to 4 members (87.0%). Regarding lifestyle factors, 10.5% of participants were smokers. Diabetes was present in 22.3% of patients. The mean BMI was 37.2 ± 4.56 kg/m².

Table 7. Baseline characteristics in each group and overall sample.

	Group 1 (N=92)	Group 2 (N=72)	Group 3 (N=143)	Group 4 (N=90)	Group 5 (N=42)	Overall (N=439)	p-value
Sex							
Male	7 (7.6%)	6 (8.3%)	22 (15.4%)	14 (15.6%)	2 (4.8%)	51 (11.6%)	
Female	85 (92.4%)	66 (91.7%)	121 (84.6%)	76 (84.4%)	40 (95.2%)	388 (88.4%)	0.11
Age							0.81
Mean (SD)	48.4 (12.9)	49.7 (12.6)	48.6 (12.6)	49.8 (12.3)	47.4 (12.6)	48.9 (12.6)	
Median [Min, Max]	50.0 [23.0, 73.0]	50.0 [21.0, 74.0]	50.0 [21.0, 74.0]	53.0 [23.0, 69.0]	50.0 [22.0, 71.0]	51.0 [21.0, 74.0]	
Race							0.59
Black	60 (65.2%)	55 (76.4%)	106 (74.1%)	70 (77.8%)	33 (78.6%)	324 (73.8%)	

	Group 1 (N=92)	Group 2 (N=72)	Group 3 (N=143)	Group 4 (N=90)	Group 5 (N=42)	Overall (N=439)	p-value
White	24 (26.1%)	13 (18.1%)	30 (21.0%)	17 (18.9%)	6 (14.3%)	90 (20.5%)	
Other	8 (8.7%)	4 (5.6%)	7 (4.9%)	3 (3.3%)	3 (7.1%)	25 (5.7%)	
Marital status							0.99
Married	36 (39.1%)	31 (43.1%)	58 (40.6%)	35 (38.9%)	17 (40.5%)	177 (40.3%)	
Others	56 (60.9%)	41 (56.9%)	85 (59.4%)	55 (61.1%)	25 (59.5%)	262 (59.7%)	
Educational level							0.49
High school or less	30 (32.6%)	24 (33.3%)	40 (28.0%)	28 (31.1%)	18 (42.9%)	140 (31.9%)	
College education or higher	62 (67.4%)	48 (66.7%)	103 (72.0%)	62 (68.9%)	24 (57.1%)	299 (68.1%)	
Income							0.63
<$10k/year	16 (17.4%)	10 (13.9%)	28 (19.6%)	18 (20.0%)	12 (28.6%)	84 (19.1%)	

	Group 1 (N=92)	Group 2 (N=72)	Group 3 (N=143)	Group 4 (N=90)	Group 5 (N=42)	Overall (N=439)	p-value
$10*k*–$19k/ year	16 (17.4%)	16 (22.2%)	28 (19.6%)	18 (20.0%)	12 (28.6%)	90 (20.5%)	
$20*k*–$39k/ year	18 (19.6%)	20 (27.8%)	36 (25.2%)	28 (31.1%)	8 (19.0%)	110 (25.1%)	
$40*k*–$59k/ year	18 (19.6%)	12 (16.7%)	21 (14.7%)	13 (14.4%)	4 (9.5%)	68 (15.5%)	
≥$60k/year	22 (23.9%)	14 (19.4%)	26 (18.2%)	12 (13.3%)	6 (14.3%)	80 (18.2%)	
Missing	2 (2.2%)	0 (0%)	4 (2.8%)	1 (1.1%)	0 (0%)	7 (1.6%)	
Employment							
Employed	62 (67.4%)	47 (65.3%)	96 (67.1%)	60 (66.7%)	29 (69.0%)	294 (67.0%)	
Not employed	30 (32.6%)	25 (34.7%)	47 (32.9%)	30 (33.3%)	13 (31.0%)	145 (33.0%)	0.99
Household size							
1-4	85 (92.4%)	59 (81.9%)	123 (86.0%)	78 (86.7%)	37 (88.1%)	382 (87.0%)	

	Group 1 (N=92)	Group 2 (N=72)	Group 3 (N=143)	Group 4 (N=90)	Group 5 (N=42)	Overall (N=439)	p-value
5	7 (7.6%)	13 (18.1%)	19 (13.3%)	12 (13.3%)	5 (11.9%)	56 (12.8%)	0.39
Missing			1 (0.7%)			1 (0.2%)	
Smoke							0.62
Current	10 (10.9%)	8 (11.1%)	13 (9.1%)	7 (7.8%)	8 (19.0%)	46 (10.5%)	
Never	65 (70.7%)	48 (66.7%)	97 (67.8%)	58 (64.4%)	25 (59.5%)	293 (66.7%)	
Former	17 (18.5%)	16 (22.2%)	33 (23.1%)	25 (27.8%)	9 (21.4%)	100 (22.8%)	
Diabetes							
No	70 (76.1%)	61 (84.7%)	114 (79.7%)	66 (73.3%)	29 (69.0%)	340 (77.4%)	
Yes	21 (22.8%)	11 (15.3%)	29 (20.3%)	24 (26.7%)	13 (31.0%)	98 (22.3%)	0.27
Missing	1 (1.1%)					1 (0.2%)	
BMI							0.19

	Group 1 (N=92)	Group 2 (N=72)	Group 3 (N=143)	Group 4 (N=90)	Group 5 (N=42)	Overall (N=439)	p-value
Mean (SD)	38.0 (4.54)	37.1 (4.20)	36.6 (4.81)	37.5 (4.35)	37.1 (4.61)	37.2 (4.56)	
Median [Min, Max]	38.5 [30.2, 48.9]	36.8 [29.7, 49.8]	35.4 [29.6, 49.8]	36.5 [30.3, 49.1]	36.9 [30.4, 47.1]	36.6 [29.6, 49.8]	

Note: BMI: body mass index, Others marital status: Divorced/separated; Never married; Widowed.

The p-values were obtained using t-test or ANOVA for continuous variables and Fisher's exact or chi-square test for categorical variables.

4.4.3. Predictors of trajectory group classification

This study used multinomial logistic regression analysis to explore the associations of demographic characteristics, socioeconomic status, and health-related factors with subgroup membership. As shown in Table 8, the results indicated that most variables did not exhibit statistically significant associations with trajectory group after controlling for confounders. However, it is noteworthy that in Group 5, the OR value for individuals with diabetes compared to individuals without diabetes was 3.10 (95% CI: 1.15-8.32, p=0.026), demonstrating a significant difference. Table 8 shows that Group 5 had lower levels of physical activity and higher dietary fat intake, and participants with diabetes were more likely to belong to Group 5.

Table 8. Multivariate multinomial logistic regression of factors associated with trajectory group classification.

Characteristic	Group 1	Group 3	Group 4	Group 5
	OR(95% CI)	OR(95% CI)	OR(95% CI)	OR(95% CI)
Sex				
Male	Reference	Reference	Reference	Reference
Female	1.45 (0.43,4.87)	0.51 (0.19,1.39)	0.58 (0.20,1.71)	2.12(0.38,11.7)
	p=0.6	p=0.2	p=0.3	p=0.4
Age(years)	0.99 (0.96,1.02)	0.99 (0.96,1.02)	1.00 (0.97,1.03)	0.98(0.95,1.02)
	p=0.4	p=0.4	p=0.8	p=0.3
Race				
Other	Reference	Reference	Reference	Reference
Black	0.60 (0.16,2.27)	1.14 (0.31,4.19)	1.71 (0.36,8.25)	0.90(0.18,4.51)
	p=0.5	p=0.8	p=0.5	p>0.9
White	1.12 (0.26,4.89)	1.55 (0.37,6.54)	2.24 (0.40,12.5)	0.84(0.13,5.38)
	p=0.9	p=0.6	p=0.4	p=0.9
Marital Status				
Others	Reference	Reference	Reference	Reference
Married	0.85 (0.42,1.72)	1.06 (0.56,2.03)	1.01 (0.50,2.04)	1.39(0.59,3.31)
	p=0.6	p=0.9	p>0.9	p=0.5
Educational level				
High school or less	Reference	Reference	Reference	Reference

College education or higher	0.95 (0.44,2.04) p>0.9	1.51 (0.75,3.04) p=0.3	1.28 (0.60,2.72) p=0.5	0.94(0.38,2.32) p>0.9
Income				
<$10k/year	Reference	Reference	Reference	Reference
$10*k*–$19k/year	0.61 (0.20,1.88) p=0.4	0.56 (0.20,1.52) p=0.3	0.51 (0.17,1.51) p=0.2	0.56(0.17,1.89) p=0.4
$20*k*–$39k/year	0.51 (0.17,1.57) p=0.2	0.55 (0.20,1.47) p=0.2	0.61 (0.21,1.74) p=0.4	0.28(0.08,1.01) p=0.051
$40*k*–$59k/year	1.08 (0.30,3.81) p>0.9	0.43 (0.13,1.40) p=0.2	0.43 (0.12,1.52) p=0.2	0.25(0.05,1.26) p=0.093
≥$60k/year	1.05 (0.28,3.85) p>0.9	0.43 (0.13,1.44) p=0.2	0.29 (0.08,1.12) p=0.073	0.33(0.07,1.58) p=0.2
Employment				
Not employed	Reference	Reference	Reference	Reference
Employed	1.17 (0.52,2.64) p=0.7	1.25 (0.60,2.59) p=0.6	1.48 (0.67,3.26) p=0.3	1.93(0.71,5.26) p=0.2
Household size				
1-4	Reference	Reference	Reference	Reference
≥5	0.37 (0.13,1.05) p=0.061	0.62 (0.27,1.45) p=0.3	0.72 (0.28,1.81) p=0.5	0.60(0.18,1.96) p=0.4
Smoke				
Current	Reference	Reference	Reference	Reference
Never	1.07 (0.35,3.20) p>0.9	1.42 (0.50,4.01) p=0.5	1.47 (0.46,4.67) p=0.5	0.57(0.17,1.91) p=0.4

Former	0.88 (0.25,3.10)	1.34 (0.42,4.29)	1.76 (0.49,6.31)	0.75(0.18,3.06)
	p=0.8	p=0.6	p=0.4	p=0.7
Diabetes				
No	Reference	Reference	Reference	Reference
Yes	2.05 (0.87,4.85)	1.43 (0.63,3.20)	1.93 (0.83,4.47)	3.10(1.15,8.32)
	p=0.10	p=0.4	p=0.13	p=0.025*
BMI	1.05 (0.98,1.13)	0.97 (0.91,1.03)	1.01 (0.94,1.09)	0.99(0.91,1.08)
	p=0.2	p=0.3	p=0.8	p=0.8

Note. *p < 0.05, **p < 0.01, ***p < 0.001

BMI: body mass index, Others marital status: Divorced/separated; Never married; Widowed.

5. Discussion

5.1. General Discussion

The Doctoral Thesis investigated adherence to behavioural weight loss interventions through three studies. Study I clarified the definitions of adherence, its components, measurement methods, and facilitating factors in weight loss programs. Study II reviewed existing factors influencing adherence to weight loss interventions and identified key elements that facilitate the design of effective intervention programs. Study III analysed long-term adherence to physical activity and dietary behavior during an intensive lifestyle intervention in the PROPEL weight loss study.

In this section, the Thesis discuss the results of the three studies, interpret the significance of the findings, compare them with previous research, acknowledge the studies' limitations, and suggest future research directions.

5.2. Study I Discussion: Adherence to Behavioural Weight Management: A Scoping Review of Definition, Measurement and Facilitators

In this scoping review, we identified 182 studies addressing the conceptualization and investigation of adherence measurement in behavioural weight loss settings for participants living with overweight and obesity. Our findings indicate that there is no consensus on the definition of adherence, as studies frequently use the WHO definition. Therefore, it is suggested to use WHO definition of adherence as a baseline and adapting it to the specific intervention setting. We also observed

that adherence measurement shows substantial heterogeneity, with the most frequently measured components including dietary adherence, physical activity adherence, and sessions attendance. The findings suggest the use of reliable (validated/objective) measurement tools. In conclusion, to improve adherence to weight loss interventions, we recommend self-monitoring,[70,73,126,144,210,225–227] and social support.[80],[100,223,229],[230,231] After answering our research questions, the need to promote transparency, reproducibility, and comparability in subsequent research methodologies is highlighted. Therefore, the roadmap for adherence is recommended for the future (as shown in Figure 6).

Summary of findings

Adherence definition

Understanding how adherence has been defined is a first step in examining the relationship between adherence and weight loss.[256] Currently, there are several overlapping terms (e.g. treatment engagement, adherence, retention, attrition, and dropout) and a lack of consensus. However, previous reviews found that studies vary considerably in their definition of adherence; there is no uniformity in the terminology used to describe it.[257,258] In our review, based on previous research, we identified more than six different terms. While some described adherence in general terms (WHO definition), others referred to specific aspects of adherence (e.g., adherence to technology, self-monitoring, medication), and still referred to non-adherence (attrition, dropout).

Adherence components and measurements

In this work, we present a summary of the adherence components identified in recent years. Further research is required to identify the main components. Furthermore, various methods currently exist for measuring adherence, both directly and indirectly. Each approach has its advantages and disadvantages, and no single method is considered the gold standard. The most widely used methods for measuring adherence in the context of weight loss are questionnaires, often referred to as self-reports, due to their ease of use, affordability, and effectiveness. Furthermore, they may make adherence measurement smarter and more efficient as digital technologies develop. However, challenges such as investment costs and comparability across devices and software remain. Establishing standardized measures to ensure accuracy, transparency, reproducibility, and comparability is essential for the future.

Dietary adherence: Regarding dietary adherence, the first key finding of this review was that there is no 'gold standard' or single physiological marker that indicates whether an individual is following the dietary recommendation. This finding is consistent with recent results; dietary adherence was reported heterogeneously across included studies.[259] Another review also confirmed that monitoring of dietary adherence using smartphone apps varied widely.[126] Furthermore, our review findings include subjective (questionnaires, food records), objective (dietitian evaluations, doubly-labeled water measurements, and muscle tissue biopsies) and self-monitoring methods (self-monitoring of adherence to the diet consisted of measuring dietary intake, frequency of self-monitoring and interaction with self-monitoring app). Weight-loss diet plans are offered with various combinations of caloric restriction, macronutrients, foods, and dietary

intake patterns.[260] In conclusion, the findings indicate that objective measurement of energy expenditure using instrumentation is optimal, and food record questionnaires serves as an alternative method for assessing dietary intake.

Physical activity and exercise adherence: Physical activity adherence is a critical factor in the effectiveness of an exercise program.[261] Accurate adherence measurement can inform healthcare providers about a patient's commitment to prescribed exercise regimens. Self-reported and self-monitored adherence were included in physical activity adherence. Similarly, in the context of self-monitored physical activity adherence, adherence (i.e., step count, energy expenditure and time spent in light/moderate/vigorous activity intensities) was assessed using wearable activity trackers.[262,263] Studies using self-reported adherence measures continue to exist, and the tools used varied considerably. There is a discrepancy between self-reported and objective physical activity.[264,265] Each method has advantages and disadvantages, objective methods are costly and laborious, but with greater accuracy, others are more feasible. These pros and cons should be considered when measuring adherence.[265] Furthermore, the difference between self-reported and directly measured physical activity makes it difficult to compare cross-sectional adherence studies.

Additionally, exercise adherence can also be measured by recording exercise frequency and intensity. As suggested in a previous study, the difference in adherence might be influenced by disparities in recommended levels of frequency and duration.[266] Exercise is a more pleasurable experience at an intensity that does not exceed threshold, and is more acceptable when the intensity is self-selected rather than imposed.[267]

Self-monitoring weight: In weight self-monitoring, body weight tracking allows an individual to monitor their progress towards negative energy balance and weight loss, and to adjust their dietary and exercise behaviors as needed.[268,269] It differs from the previous traditional paper-based approach.[270] The use of technology, such as the Internet, mobile phone applications and digital scales, has significantly improved the ease and accuracy of self-monitoring.[268] Digital scales, fitness trackers, and smartphone apps can automate the tracking process, provide real-time feedback, and even offer personalized recommendations based on the recorded data. These tools can help overcome some of the barriers to manual tracking, such as time consumption and forgetfulness. The integration of technology into self-management practices has further strengthened its effectiveness, making it a critical component of weight management programs.

Session attendance: Session attendance is a key measure of participant adherence, and previous studies indicate that it has a significant impact on the effectiveness of behavioural weight loss interventions.[197,271,272] Measuring adherence involves recording the number of scheduled sessions attended during the program. Identifying participant dropout will contribute to both the effectiveness and the cost-effectiveness of weight loss interventions.[273] Our study also provided an overview of several methodologies for measuring participant withdrawal, including attrition, retention, and dropout rates. These terms are often treated as synonyms.[73,273]

Adherence measurement is presented using graphs and tables. A substantial body of evidence indicates that comparison across studies is difficult.[126,274] Our scoping review reveals that adherence was often considered a secondary outcome measure,

in addition to body weight-related factors in the included studies. There is a lack of detailed description of measurement and assessment methods.[126] Disparities in adherence make it difficult to compare data across studies. To address this variation, a measurement guide (as shown in Figure 5) was developed with several adherence measures; and it can be chosen according to the study objectives when conducting prospective studies.

BCTs to influence adherence

Regarding BCTs to improve adherence, seven studies identified self-monitoring behavior and six studies identified social support as potentially useful techniques. The findings regarding self-monitoring were consistent with those of previous studies. Several studies have shown that higher rates of self-monitoring lead to better weight loss outcomes.[275] The use of mobile-based health self-monitoring was higher than direct paper-based recording of adherence to behavioural weight management interventions.[210] Self-monitoring of physical activity and diet is effective in contributing to weight loss in adults living with obesity or overweight, especially when personalized advice is provided.[276] Furthermore, consistent with previous studies, interventions that offered social support had higher adherence than those without.[50]

Recent studies have summarized the factors that facilitate and hinder adherence, factors that should be considered when designing weight loss programs.[258] Furthermore, it is necessary to determine the effectiveness of different behavior change techniques (BCTs) on adherence outcomes, and the effectiveness of

individual BCTs, as well as the impact of BCT combinations in promoting adherence.

5.3. Study II Discussion: Exploring factors of adherence to weight loss interventions in population with overweight/obesity: an umbrella review

This umbrella review provides the first comprehensive synthesis of adherence factors to weight loss programs from the past 15 years. It also identifies variables that enhance or hinder adherence to different types of interventions. In the first section of this umbrella review, we compiled and assessed the level of evidence from 21 reviews. Subsequently, in the second section, we developed an adherence map to facilitate intervention optimization.

Due to the breadth of the topic and the many behaviors that encompass it, a single term (i.e., "adherence") or definition cannot meet all the needs of the field. Therefore, there is a clear need to build a consensus within which future activities can be framed, to provide concise and appropriate definitions and an associated conceptual framework that can meet the needs of both clinical research and medical practice.[277]

In this umbrella review, 21 reviews were summarized, and 47 factors were identified as modulators of adherence to weight loss interventions (see Figure 8). Primarily, a wide variety of factors were found, falling into the multi-intervention and behavioural intervention areas, with a limited number of factors related to adherence to physical activity. Two main results were obtained. If we aim to maximize people's adherence to weight loss programs, 1) self-monitoring should be

improved and 2) multicomponent or behavioural interventions should be the first option, considering demographics, when designing intervention programs, especially for disadvantaged groups.

Socio-demographic factors

Our results suggest a substantial number of factors, (i.e., male gender, older age, better education and body shape characteristics) that can be considered predictors. From the perspective of promoting adherence to weight loss programs, it is important to know which factors are modifiable and which are not. Among socio-demographic factors, some are nonmodifiable and have been shown in the literature to be related to adherence to interventions and attrition levels. These factors should be carefully considered before initiating any intervention, to allow for individualization of the intervention for each individual. However, to individualize weight-loss programs and maximize adherence, other factors, such as physical activity, diet, pharmacological, behavior and multiple-interventions, may affect individuals' adherence to weight loss programs and should be described in more detail.

Physical activity interventions

In term of physical activity interventions, our evidence only confirmed that the use of ACT increased adherence to physical activity.[235] The physical activity recommendation (≥ 60 minutes per day or 3 times per week of moderate to high intensity physical exercise) was added into a program, aiming to change behavior and improve adherence to physical activity.[235] Our findings align with a previous study that also identified the potential of ACT to promote physical activity.[278]

Furthermore, ACT improves psychological flexibility, which is an individual's ability to cope with challenges.[279,280] This explains why it may improve adherence to a weight loss program and prevent dropout.

Dietary interventions

Regarding dietary interventions, self-monitoring has been considered a factor with great potential.[234,252] Both online dietary interventions and food supplements have been shown to improve adherence, with self-monitoring being the key to improving it.[234,252] Dietary change goals within the online dietary intervention included a general and a specific objective (overall diet quality, energy intake, and specific aspects of dietary intake, including increased fruit and vegetable intake, and increased intake of dairy products). Food supplements provided to participants to modify behaviors, specifically by incorporating them into their daily diet, have also been found to shape eating habits in real-life situations. However, long-term dietary adherence remains a challenge, as a recent study found that adherence in self-monitoring dietary interventions decreases over time.[281] Therefore, adherence to long-term weight loss dietary intervention programs remains a challenge.

Pharmacological interventions

Regarding pharmacological interventions, two factors were found to favor a lower dropout rate, while females had a higher attrition rate. Specifically, according to our results, the medications Sibutramine and Orlistat had lower dropout rates. However, it is important to highlight that they were published in 2008[236] and 2009.[249] Furthermore, it is crucial to highlight that Sibutramine has been banned

by the European Medicines Agency since 2010 due to associated risks for patients with preexisting heart problems. Therefore, Orlistat could represent an alternative medication, as it reported lower adverse events and dropout rates. Adverse events are frequently associated with adherence and attrition.[282] The effectiveness of the medication and the number of adverse events explain the differences between these medications. Specifically, in a recent study comparing different pharmacological interventions for adverse events with discontinuation, Orlistat ([IRR]1.72, 1-44 - 2-05) showed advantages compared to other drugs.[283] Another study also showed that Orlistat had a lower dropout rate compared to the other four drugs (the median dropout rates of Orlistat 29.0%, phentermine–topiramate 34.9%, Lorcaserin 40.9%, Naltrexone–bupropion 49.1%, respectively).[284] But little is known about adherence to different medications, and further studies are needed to compare adherence to different medications in the future.

Behavioural interventions

Regarding behavioural interventions, self- monitoring and financial incentive were considered effective approaches to improve adherence. There is evidence to support the effectiveness of self-monitoring in reducing attrition.[240,241] Consistent with this, a recent review suggested the potential of self-monitoring in weight loss.[285] One possible explanation could be that self-monitoring of physical activity may be easier to record, as self-monitoring of dietary adherence can be effortful and time-consuming.[286] Financial incentive is another behavioural approach that promotes short-term adherence. Full reimbursement at the end of the program would be more effective than a multi-stage refund,[238] but the minimum amount needed to

improve adherence has not yet been determined. Furthermore, the use of technology also appears to improve treatment adherence by allowing for simpler and more convenient self-monitoring.[241] Thus, self-monitoring was found to improve adherence in multiple intervention studies.[240]

Multi-interventions

There is increasing evidence supporting the role of multi-interventions in adherence. For interventions to be effective, it is necessary to recognize that adherence is an interactive set of behaviors influenced by individual, social, and environmental factors.[287] With the increasing number of weight loss interventions, multi-interventions appear to be an effective strategy, that could consider all of these elements. Interventions using multiple components,[240] multi-techniques, [243] and multi-approaches[246] have been shown to increase adherence. Multi-interventions have also been recommended by the International Obesity Guidelines.[288],[289] They emphasize psychological aspects, behavioural strategies, cognitive reframing therapy, and diet and activity modification in weight loss programs, which may improve adherence through improved health and quality of life.[288] Furthermore, multiple intervention strategies are consistent with the American Guidelines, which recommend that weight loss programs should have three components 1) a prescription of a reduced-calorie diet, 2) a program to increase physical activity, and 3) the use of behavioural strategies to promote adherence to diet and activity recommendations.[289]

To answer the question of how treatment can improve adherence, all adherence factors were summarized and found that it is difficult to achieve a successful

weight loss program through a single intervention. Therefore, based on the characteristics of the factors that promote adherence, treatment could be based on: a) the use of contracts (behavioural contract, financial, etc.) that improve adherence, which can allow for more binding and strict participation in programs, b) the use of technologies to monitor physical activity and diet (moreover, self-monitoring has proven to be the key to promoting adherence), and, c).the use of multiple interventions. Multi-intervention approaches are more effective in addressing multiple barriers, while a single component only addresses one of the barriers. Multi-component, multi-technology and multi-behavioural interventions can serve as an effective way to improve adherence.

5.4. Study III Discussion: Longitudinal Changes in Physical Activity and Dietary Fat Intake during an intensive lifestyle intervention: the PROPEL Trial

This study investigated the longitudinal characteristics of physical activity and dietary fat intake over 24 months and explored baseline characteristics that might affect them. Five unique clusters with heterogeneous trajectories were identified. Regarding physical activity, our analysis identified two clusters with the lowest physical activity in the intervention cohort. Notably, these low-responder groups did not show improvements during the intervention. Our study is one of the largest cluster analyses of a behavioural lifestyle program conducted to date.

Similarly, in a population-based lifestyle weight loss intervention in the United States of America, four step counting trajectory groups were identified: all four groups transitioned from sedentary to active according to the physical activity

trajectory.[290] The two groups with fewer initial steps continued with little change during the intervention.[290] This is consistent with the results obtained in our study, two groups with less change during the intervention. Research highlights 6 months as a key point of behavior change in intensive lifestyle intervention. And one review has found the effectiveness of interventions to increase physical activity, its effects can be sustained for up to 12 months.[291] Another review confirmed that the intervention can be effective in promoting small, but clinically meaningful, increases in objectively measured physical activity for up to 48 months[292].

There is growing evidence to suggest that studying dietary trajectories provides more in-depth information than single-point dietary assessments.[293] Our study found the first six months to be a critical period for dietary change, which was consistently observed across all five groups. Consistent with the results of the NOW study, we observed rapid dietary change from baseline to the 6-month intervention time point.[294] Therefore, long-term physical activity and diet should be considered in future studies. Lifestyle interventions are a cornerstone of obesity treatment. Growing evidence suggests that increased adherence to these interventions is key to successful weight loss in both the short and long term.[295] Regarding baseline characteristics, a systematic review of adherence to physical activity interventions in people with T2D found that adherence rates varied widely, from 32% to 100%, with a median of 58%.[296] This explains the prediction of participants with diabetes at the beginning of the study for group 5.

Individual progression trajectory analysis can be integrated into external platforms (mobile phones and computer applications) to facilitate clinical feedback.

Furthermore, practitioners can use multibehavioural profiles, including data on physical activity and diet, to design personalized dietary interventions. For example, sedentary individuals or individuals with suboptimal dietary intake can be identified early, enabling individualized behavioural therapies that improve the effectiveness of weight loss through targeted lifestyle modifications. Future implementation of automated adherence monitoring systems, complemented by physical activity and diet monitoring using mhealth sensor technology, will help to better achieve weight loss outcomes. Furthermore, greater attention should be paid to those who increase their PA and then reduce it, as it is important to understand how this might reduce the potential response to the intervention.

This study is presented as an exploratory study and has several strengths and implications for future studies. Trajectory analysis has been used in other weight loss intervention studies to identify subgroups based on behavioural and psychosocial characteristics. [290,297] Our study extended the lifestyle intervention literature by assessing participant's physical activity and dietary behavior, not just weight-based outcome indicators. Baseline predictor analysis revealed critical determinants of trajectory group membership. There are several limitations that should be addressed in future research. First, measures of percentage energy from fat using the fat screener (NCI) and physical activity IPAQ-SF were obtained using the self-report method. More objective data through activity trackers and accelerometers are suggested for future research. Our study included a minor deviation from the protocol, with the initial goal of analyzing all physical activity, dietary behavior, and long-term macronutrient change (e.g.: the frequency of

consumption of fruits and vegetables). However, considering the sample size and facilitating model convergence, TPA and dietary fat intake were used in the final analysis. Future studies should consider more metrics, such as different domains of physical activity, as well as more detailed dietary measurements. Furthermore, in larger samples, the use of pooled data across weight-loss programs for trajectory analysis would be beneficial, which also leads to more robust results. Finally, this study was an exploratory analysis, and further research, particularly intervention research, is needed in these populations

6. Conclusions

6.1. Study I Conclusions: Adherence to Behavioural Weight Management: A Scoping Review of Definition, Measurement and Facilitators

Adherence is important for long-term success, like a two-sided coin, it can facilitate or hinder effective weight loss management. The aim of this scoping review was to identify gaps in definition, measurements and BCTs that can guide future research with less heterogeneity. First, to define adherence, we recommend the WHO adherence terminology. Second, there is no gold-standard measure for any component currently. Comparing adherence across studies is difficult because few researchers report on it and because measurements and metrics differ widely. We define components (as a behavioural intervention that includes a group of components, including dietary changes, exercise, self-monitoring, and attendance at program sessions) and adherence measures, and explain this complexity through graphs and charts. However, conducting a meta-analysis across future studies is challenging due to the wide variety of adherence measurement methods. This justifies the need for high-quality research to identify behavioural strategies. Furthermore, measurements must be valid, reliable, and sensitive to change, using the same measures and units across all studies. BCTs, self-monitoring strategies and social support have been shown to have the potential to improve adherence. The adherence roadmap and measurement guidelines can be used to investigate procedures and improve weight management outcomes.

6.2. Study II Conclusions: Exploring factors of adherence to weight loss interventions in population with overweight/obesity: an umbrella review

In conclusion, the findings of this umbrella review serve as a comprehensive guide for the design of effective weight loss programs by identifying factors that may facilitate or hinder adherence.

Based on the overall analysis of the included studies and their quality, it is recommended that multi-intervention, self-monitoring and financial incentives (three, two and three studies confirmed, respectively) be considered in program design. The quality of these studies is shown in Figure 8. Our umbrella review showed that multi-intervention and behavioural strategies showed the highest adherence, which contributed to enhancing their effect, as they offered the option of combining different techniques or behavioural approaches in the intervention, with self-monitoring being highlighted as a determining factor for adherence. Furthermore, despite the extensive knowledge gained in this review, it is critical to emphasize that future research is warranted. The absence of a standardized definition of adherence to weight loss programs presents a challenge when comparing different interventions, highlighting the need for more extensive research.

6.3. Study III Conclusions: Longitudinal Changes in Physical Activity and Dietary Fat Intake during an intensive lifestyle intervention: the PROPEL Trial

The study highlights that cluster-based trajectory modeling can be used to identify distinct physical activity and dietary behavior within a weight-loss intervention trial. Additional strategies may be needed to improve adherence in individuals who consistently exhibit low PA and high dietary fat intake. Participants with diabetes at baseline were more likely to belong to trajectory group 5, with low physical activity and high dietary fat intake. Future studies should build on these findings and examine trajectories in more detail using other objective measures in larger and more diverse samples.

6.4. General Conclusion

This Doctoral Thesis comprehensively addressed the definition, measurement, factors influencing adherence, and longitudinal changes in physical activity and dietary behavior during weight loss interventions.

This Doctoral Thesis strengthened the general understanding of adherence to behavioural weight-loss interventions by offering structured approaches to defining, measuring, and improving adherence. Specifically, the adherence roadmap, measurement guidelines, and adherence factor map represent important advances in the field and provide practical frameworks for researchers and practitioners. The findings contribute to both theoretical frameworks and practical applications in practice and research settings.

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8. Annexes

8.1. Annexes of study I

Supplementary_T1. Search information in different databases.

PICO Strategy adapted to Scoping Review:

- Patient = Population or Participants.
- Intervention = Intervention Context.
- Comparison = Not applicable.
- Outcome = Outcome

Population	Intervention Context	Outcome	Excluding
1. Obes*	AND	AND	NOT
2. Overweight	1. "behav* treatment*"	1. Adher*	1. animal*
3. Over-weight	2. "behav* intervention*"	2. Nonadher*	2. mice*
4. "Over weight"	3. "behav* therap*"	3. "Non-adher*"	3. rat*
	4. "weight los*"	4. complian*	4. cancer*
	5. weight-los*	5. Noncomplian*	5. surger*
	6. "fat los*"	6. "Non-complian*"	6. surgical
	7. fat-los*	7. attend*	7. pregnan*
	8. "weight management"	8. attrition*	8. child*
	9. "weight-management"	9. Persist*	9. youth
		10. Participat*	10. pediatric
		11. withdrawal	11. "mental ilness*"
		12. drop-out	12. replacement*
		13. "drop out"	13. "meal replacement*"
		14. Dropout*	
		15. "follow up"	
		16. "follow-up"	
		17. retention	

Databases and number of literatures searched

Database	Search sentence	Number of studies
Web of Science	TS=((obes* OR overweight OR over-weight OR “over weight”) AND ("behav* treatment*" OR "behav* intervention*" OR "behav* therap*" OR "weight los*" OR weight-los* OR "weight management" OR weight-management OR "fat los*" OR fat-los*) AND (adher* OR nonadher* OR non-adher* OR complian* OR noncomplian* OR non-complian* OR attend* OR attrition* OR persist* OR participat* OR withdrawal OR dropout* OR drop-out* OR "drop out*" OR follow-up OR "follow up" OR retention*) NOT (animal* OR mice* OR rat* OR cancer* OR surger* OR surgical OR pregnan*))	7139 *(13/07/2022)*
Web of Science (last 5 years)	TS=((obes* OR overweight OR over-weight OR “over weight”) AND ("behav* treatment*" OR "behav* intervention*" OR "behav* therap*" OR "weight los*" OR weight-los* OR "weight management" OR weight-management OR "fat los*" OR fat-los*) AND (adher* OR nonadher* OR non-adher* OR complian* OR noncomplian* OR non-complian* OR attend* OR attrition* OR persist* OR participat* OR withdrawal OR dropout* OR drop-out* OR "drop out*" OR follow-up OR "follow up" OR retention*) NOT (animal* OR mice* OR rat* OR cancer* OR surger* OR surgical OR pregnan*))	2385 *(13/07/2022)*
Web of Science (last 10 years [13/07/2012 to 13/07/2022])	TS=((obes* OR overweight OR over-weight OR “over weight”) AND ("behav* treatment*" OR "behav* intervention*" OR "behav* therap*" OR "weight los*" OR weight-los* OR "weight management" OR weight-management OR "fat los*" OR fat-los*) AND (adher* OR nonadher* OR non-adher* OR complian* OR noncomplian* OR non-complian* OR attend* OR attrition* OR persist* OR participat* OR withdrawal OR dropout* OR drop-out* OR "drop out*" OR follow-up OR "follow up" OR retention*) NOT (animal* OR mice* OR rat* OR cancer* OR surger* OR surgical OR pregnan*))	4566 *(13/07/2022)*
Web of Science (since 01/01/2004)	TS=((obes* OR overweight OR over-weight OR “over weight”) AND ("behav* treatment*" OR "behav* intervention*" OR "behav* therap*" OR "weight los*" OR weight-los* OR "weight management" OR weight-management OR "fat los*" OR fat-los*) AND (adher* OR nonadher* OR non-adher* OR complian* OR noncomplian* OR non-complian* OR attend* OR attrition* OR persist* OR participat* OR withdrawal OR dropout* OR drop-out* OR "drop out*" OR follow-up OR "follow up" OR retention*) NOT (animal* OR mice* OR rat* OR cancer* OR surger* OR surgical OR pregnan* OR child* OR youth OR pediatric OR “mental ilness*” OR replacement* OR “meal replacement*”))	4781 *(14/07/2022)*
Web of Science (since 01/01/2017)	TS=((obes* OR overweight OR over-weight OR “over weight”) AND ("behav* treatment*" OR "behav* intervention*" OR "behav* therap*" OR "weight los*" OR weight-los* OR "weight management" OR weight-management OR "fat los*" OR fat-los*) AND (adher* OR nonadher* OR non-adher* OR	2148 *(18/07/2022)* +206

	complian* OR noncomplian* OR non-complian* OR attend* OR attrition* OR persist* OR participat* OR withdrawal OR dropout* OR drop-out* OR "drop out*" OR follow-up OR "follow up" OR retention*) NOT (animal* OR mice* OR rat* OR cancer* OR surger* OR surgical OR pregnan* OR child* OR youth OR pediatric OR "mental ilness*" OR replacement* OR "meal replacement*"))	*(04/05/2023)* *+561* *(01/08/2024)*
Medline (since 01/01/2017)	(((obes*[Title/Abstract] OR overweight[Title/Abstract] OR over-weight[Title/Abstract] OR "over weight"[Title/Abstract]) AND ("behav* treatment*"[Title/Abstract] OR "behav* intervention*"[Title/Abstract] OR "behav* therap*"[Title/Abstract] OR "weight los*"[Title/Abstract] OR weight-los*[Title/Abstract] OR "weight management"[Title/Abstract] OR weight-management[Title/Abstract] OR "fat los*"[Title/Abstract] OR fat-los*[Title/Abstract])) AND (adher*[Title/Abstract] OR nonadher*[Title/Abstract] OR non-adher*[Title/Abstract] OR complian*[Title/Abstract] OR noncomplian*[Title/Abstract] OR non-complian*[Title/Abstract] OR attend*[Title/Abstract] OR attrition*[Title/Abstract] OR persist*[Title/Abstract] OR participat*[Title/Abstract] OR withdrawal[Title/Abstract] OR dropout*[Title/Abstract] OR drop-out*[Title/Abstract] OR "drop out*"[Title/Abstract] OR follow-up[Title/Abstract] OR "follow up"[Title/Abstract] OR retention*[Title/Abstract])) NOT (animal*[Title/Abstract] OR mice*[Title/Abstract] OR rat*[Title/Abstract] OR cancer*[Title/Abstract] OR surger*[Title/Abstract] OR surgical[Title/Abstract] OR pregnan*[Title/Abstract] OR child*[Title/Abstract] OR youth[Title/Abstract] OR pediatric[Title/Abstract] OR "mental ilness*"[Title/Abstract] OR replacement*[Title/Abstract] OR "meal replacement*"[Title/Abstract])	2262 *(18/07/2022)* +308 *(04/05/2023)* + *589* *(01/08/2024)*
Scopus (since 01/01/2017)	(TITLE-ABS-KEY ((obes* OR overweight OR over-weight OR "over weight")) AND TITLE-ABS-KEY (("behav* treatment*" OR "behav* intervention*" OR "behav* therap*" OR "weight los*" OR weight-los* OR "weight management" OR weight-management OR "fat los*" OR fat-los*)) AND TITLE-ABS-KEY ((adher* OR nonadher* OR non-adher* OR complian* OR noncomplian* OR non-complian* OR attend* OR attrition* OR persist* OR participat* OR withdrawal OR dropout* OR drop-out* OR "drop out*" OR follow-up OR "follow up" OR retention*)) AND NOT TITLE-ABS-KEY ((animal* OR mice* OR rat* OR cancer* OR surger* OR surgical OR pregnan* OR child* OR youth OR pediatric OR "mental ilness*" OR replacement* OR "meal replacement*"))) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017))	2307 *(18/07/2022)* +613 *(04/05/2023)* *+757* *(01/08/2024)*
	((obes* OR overweight OR over-weight OR "over weight")):ti,ab,kw AND (("behav* treatment*" OR "behav* intervention*" OR "behav* therap*" OR "weight los*" OR weight-los* OR "weight management"	

Cochrane (since 01/01/2017)	OR weight-management OR "fat los*" OR fat-los*)):ti,ab,kw AND ((adher* OR nonadher* OR non-adher* OR complian* OR noncomplian* OR non-complian* OR attend* OR attrition* OR persist* OR participat* OR withdrawal OR dropout* OR drop-out* OR "drop out*" OR follow-up OR "follow up" OR retention*)):ti,ab,kw NOT ((animal* OR mice* OR rat* OR cancer* OR surger* OR surgical OR pregnan* OR child* OR youth OR pediatric OR “mental ilness*” OR replacement* OR “meal replacement*”)):ti,ab,kw	1532 *(18/07/2022)* +208 *(04/05/2023)* +333 *(01/08/2024)*

8.2. Annexes of study II

Supplementary: List of search syntax in all databases

Search date: 13/04/2022

Overview:

	Search outcome
Web of Science:	1069
Pubmed	1046
Cochrane library:	323
Sportdiscus	642
Scopus:	707
Embase	971
Sum	4758

Total after excluding duplicate by endnote:3132

Web of Science references:

((((TS=(obes* OR overweight OR over-weight OR "over weight")) **AND** TS=(weight OR "Body Weight" OR bmi OR "body mass index" or "Quetelet* Index" OR "body composition" OR fatness OR "body fat*" OR adipos* OR "fat mass" OR "Waist Circumference" OR "waist hip ratio" OR "waist–hip ratio")) **AND** TS=(adher* OR Nonadher* OR "Non-adher*" OR complian* OR Noncomplian* OR "Non-complian*" OR attend* OR attrition* OR Persist* OR Participat* OR withdrawal OR drop-out OR "drop out" OR Dropout* OR "follow up" OR "follow-up" OR "predictors of adherence" OR retention)) **AND** TI=("meta-anal*" OR "meta anal*" OR metaanal* OR "meta-synthes*" OR"meta synthes*" OR metasynthes* OR "systematic review*")) **NOT** AB=(animal* OR mice OR rats OR rat OR cancer OR surgery OR surgical OR pregnan* OR diabete*)

- DW: 1069
- MA: 1069

Pubmed references:

((((obes* OR overweight OR over-weight OR "over weight") **AND** (weight OR "Body Weight" OR bmi OR "body mass index" or "Quetelet* Index" OR "body composition" OR fatness OR "body fat*" OR adipos* OR "fat mass" OR "Waist Circumference" OR "waist hip ratio" OR "waist–hip ratio")) **AND** (adher* OR Nonadher* OR "Non-adher*" OR complian* OR Noncomplian* OR "Non-complian*" OR attend* OR attrition* OR Persist* OR Participat* OR withdrawal OR drop-out OR "drop out" OR Dropout* OR "follow up" OR "follow-up" OR "predictors of adherence" OR retention)) **AND** ("meta-anal*"[Publication Type] OR "meta anal*"[Publication Type] OR metaanal*[Publication Type] OR "meta-synthes*" OR"meta synthes*"[Publication Type] OR metasynthes*[Publication Type] OR "systematic

review*"[Publication Type])) **NOT** (animal*[Title/Abstract] OR mice[Title/Abstract] OR rats[Title/Abstract] OR rat[Title/Abstract] OR cancer[Title/Abstract] OR surgery[Title/Abstract] OR surgical[Title/Abstract] OR pregnan*[Title/Abstract] OR diabete*[Title/Abstract])

- DW: 1046
- MA:1046

Cochrane library references:

(obes* OR overweight OR over-weight OR "over weight") **in All Text AND** (weight OR "Body Weight" OR bmi OR "body mass index" or "Quetelet* Index" OR "body composition" OR fatness OR "body fat*" OR adipos* OR "fat mass" OR "Waist Circumference" OR "waist hip ratio" OR "waist–hip ratio") **in All Text AND** (adher* OR Nonadher* OR "Non-adher*" OR complian* OR Noncomplian* OR "Non-complian*" OR attend* OR attrition* OR Persist* OR Participat* OR withdrawal OR drop-out OR "drop out" OR Dropout* OR "follow up" OR "follow-up" OR "predictors of adherence" OR retention) **in All Text AND** ("meta-anal*" OR "meta anal*" OR metaanal* OR "meta-synthes*" OR"meta synthes*" OR metasynthes* OR "systematic review*" **in Title Abstract Keyword** NOT (animal* OR mice OR rats OR rat OR cancer OR surgery OR surgical OR pregnan* OR diabete*) **in Title Abstract Keyword**

- DW: 323
- MA: 323

Sportdiscus references:

TX (obes* OR overweight OR over-weight OR "over weight") **AND TX** (weight OR "Body Weight" OR bmi OR "body mass index" or "Quetelet* Index" OR "body composition" OR fatness OR "body fat*" OR adipos* OR "fat mass" OR "Waist Circumference" OR "waist hip ratio" OR "waist–hip ratio") **AND TX** (adher* OR Nonadher* OR "Non-adher*" OR complian* OR Noncomplian* OR "Non-complian*" OR attend* OR attrition* OR Persist* OR Participat* OR withdrawal OR drop-out OR "drop out" OR Dropout* OR "follow up" OR "follow-up" OR "predictors of adherence" OR retention) **AND TI** ("meta-anal*" OR "meta anal*" OR metaanal* OR "meta-synthes*" OR"meta synthes*" OR metasynthes* OR "systematic review*") **NOT AB** (animal* OR mice OR rats OR rat OR cancer OR surgery OR surgical OR pregnan* OR diabete*)

- DW: 642
- MA:642

Scopus:

(TITLE-ABS-KEY (obes* OR overweight OR over-weight OR "over weight") AND TITLE-ABS-KEY (weight OR "Body Weight" OR bmi OR "body mass index" OR "Quetelet* Index" OR "body composition" OR fatness OR "body fat*" OR adipos* OR "fat mass" OR "Waist Circumference" OR "waist hip ratio" OR "waist–hip ratio") AND TITLE-ABS-KEY (adher* OR nonadher* OR "Non-adher*" OR complian* OR noncomplian* OR "Non-complian*" OR attend* OR attrition* OR persist* OR participat* OR withdrawal OR drop-out OR "drop out" OR dropout* OR "follow up" OR "follow-up" OR "predictors of adherence" OR retention) AND TITLE ("meta-anal*" OR "meta anal*" OR metaanal* OR "meta-synthes*" OR "meta synthes*" OR metasynthes* OR "systematic review*") AND NOT TITLE-ABS-KEY (animal* OR mice OR rats OR rat OR cancer OR surgery OR surgical OR pregnan* OR diabete*))

- DW: 707
- MA:707

Embase:

(obes* OR 'overweight'/exp OR overweight OR 'over weight') AND (weight OR 'body weight' OR bmi OR 'body mass index' OR 'quetelet* index' OR 'body composition' OR fatness OR 'body fat*' OR adipos* OR 'fat mass' OR 'waist circumference' OR 'waist hip ratio' OR 'waist–hip ratio') AND (adher* OR nonadher* OR 'non-adher*' OR complian* OR noncomplian* OR 'non-complian*' OR attend* OR attrition* OR persist* OR participat* OR withdrawal OR 'drop out' OR dropout* OR 'follow up' OR 'follow-up' OR 'predictors of adherence' OR retention) AND ('meta-anal*':ti OR 'meta anal*':ti OR 'metaanal*':ti OR 'meta-synthes*':ti OR 'meta synthes*':ti OR metasynthes*:ti OR 'systematic review*':ti) NOT (animal*:ti,ab,kw OR mice:ti,ab,kw OR rats:ti,ab,kw OR rat:ti,ab,kw OR cancer:ti,ab,kw OR surgery:ti,ab,kw OR surgical:ti,ab,kw OR pregnan*:ti,ab,kw OR diabete*:ti,ab,kw)

- DW: 971
- MA:971

TOTAL

- Deng: 4758
- Miguel:4758

*Total after excluding duplicate by endnote:3132

Characteristics of the 21 included reviews

Ω	Type of review/Guide/registration	Included studies	Type of studies inclued	Countries	Sample Characteristics	Search period	Data bases searched	Interventions	Adherence Outcomes
Pirotta et al. (2019)	SR with MA. PRISMA recommendation and PROSPERO registered	57	RCT or quasi-RCT	Mainly in North America and one being multinational.	N= 7581 participants Age (26.6 to 60.7 yrs). Gender: (at least 6092 female). BMI ≥25 kg/m²	From inception to 11 August 2017	5 Databases	Multicomponent intervention; Single intervention strategies; Online or telephone support intervention	Attrition (attrition rate at the end of a weight loss programme rather than the end of a study)
Burgess et al. (2017)	SR with MA. Not followed guide. No registered	9	9 RCTs	6 in USA, one each in Switzerland, Portugal and multinational.	N= EG 1,387 CG 1,288 Age: NA Gender: NA BMI:≥30 kg/m²	From their inception to August 2016	5 Databases	Behavioural treatment strategies,	The use of behavioural treatments in obesity management.
Burgess et al. (2017)	SR. Not followed guide.	24	18 quantitative	9 in USA, 6 in Italy, 2 in Spain, one	N= 6,563 Age: (18-55 yrs)	From their inception to August 2016	5 Databases	Lifestyle intervention programmes within community	Adherence and/or attrition (as measured by objective or self-reported modifications to physical activity and/or diet or

	No registered.		articles. 6 qualitative studies	each in Africa, Isreal, Slovenia, Croatia, Sweden and Europe. One is NA.	Gender: The majority female BMI:≥30 kg/m²				by lifestyle intervention programme session attendance or attrition).
Lemstra et al. (2016)	MA. Not followed guide. No registered.	27	20 RCT.7 observational intervention	21 in USA, one each in UK, Australia, Israel, Canada, German.	N=6,803 Age: NA Gender: NA BMI:NA	From January 2004 to August 2015.	10 Databases	All weight loss intervention neither pharmacological nor surgical.	Intervention adherence rate% Adherence was defined as completion of the weight loss program or, in certain cases, was assessed by the level of consistency with the weight loss intervention of interest.
Crawford et al. (2012)	SR. Not followed guide. No registered.	13	Mainly RCTs and observational	10 in America, 2 in Italy, 1 in German	N: From25-1,801 Gender: Mainly female. Age: ≥ 18 yrs BMI≥ 25 kg/m²	From 1990 to 2010	3 Databases	A range of weight loss interventions. Except for bariatric surgery which is performed at one time point.	Attrition/attendance.

			intervention						
Moroshko et al. (2011)	SR. PRISMA recommendation No registered.	61	Mainly RCTs	Mainly in USA	N=14,714 Age: 18-62 yrs Gender: Mainly female. BMI≥ 25 kg/m²	Until May 2011	5 Databases	All types of Face-to-face weight loss interventions requiring attendance to more than one session.	Attrition rates
Fabricatore et al. (2009)	SR with MA. Not followed guide. No registered	24	RCTs	7 in North America, 12 in Europe and 5 in multiple or other continents.	N=18918 Age:47.9±0.8 yrs Gender: The majority female. (69.4±1.9%) BMI:35.5± 0.2 kg/m²	September 2007	1 Database	Pharmacological intervention	Total attrition (%)

Birch et al. (2022)	SR. PRISMA recommendation and PROSPERO registered.	103	Randomized or cluster-RCTs	Most studies were from USA (n = 57).	N=36,805, Age: ≥ 18 yrs Gender: 66% were female. BMI≥ 25 kg/m^2	(June 2017). The updated search on March 5, 2020	4 Database	All types of behavioural weight management interventions	Adherence was defined as number of intervention sessions attended of offered or as engagement with any intervention component (completion of food diaries or times logged into a mobile application).
Manchon et al. (2022)	SR. PRISMA recommendation Not registered.	21	10 were RCTs, 2 were case series, one quasi-experimental design, and the rest of the studies had no	Most studies were from USA	N=744 Age: mean range from 20.95-54 yrs Gender: Mainly female BMI:NA	Up to September 2019	4 Databases	Acceptance and Commitment (ACT)	Physical activity adherence

			control design.						
Leung et al. (2017)	Overview Not followed guide. No registered.	19	9 RCTs, 8 pre/post interventions and 2 longitudinal studies.	8 in USA, 2 in German, and one each in Canada Australia New zealand, Netherland,Italy,Israel,Japan,Brazil,Denmark.	N:51 to 9599. Age: Over 40 yrs. Gender: Mainly female. BMI: ≥25 kg/m², one study except < 25kg/m²	There was no time limit on the publication date of articles	4 Databases	Lifestyle Modification Programs	Mainly attrition, followed by attendance and self-monitoring. Only one study used dietary adherence as the indicator of adherence.
Cavero-Redondo et al. (2020)	SR with MA. PRISMA recommendation and PROSPERO registered	20	RCTs, non-RCTs and pilot studies	12 in the United States, 2 in the United Kingdom, 3 in Australia, one in New Zealand, one in South Korea and one in Finland.	N: EG:1132 CG:1064 Age:20.5 and 59.8 yrs Gender: NA BMI:27.0 -40.1 kg/m²	From inception until March 2020.	4 Databases	Studies comparing the effect of lifestyle (diet and physical activity) mHealth self-monitoring (i.e., personal digital assistants (PDAs), smartphones or web-based)	Dropouts (%)

Enriquez Guerrero et al. (2021)	MA. PRISMA recommend ation and PROSPERO registered	18	RCTs	5 in Australia, 3 in Norway,3 in Spain,2 in US,2 in UK,2 in America 1 in Canada	N=913 Age: Mainly in 50- to 60 yrs Gender: NA BMI: ≥ 25kg/m 2	From their inception until October, December 2019	5 Databases	Nutritional interventions based on IF (intermittent fasting)	Adherence to the diet
Neovius et al. (2008)	SR with MA. Not followed guide. No registered.	8	RCTs	Most studies were from Turkey. (n=6) 2 in Italy,1 in America,	N: 885 Age:NA Gender: both male and female BMI:NA	NA	1 Database	Weight loss drugs approved in the European Union	Dropout number
Wibisono et al.(2016)	SR with MA. PRISMA recommend	16	RCTs	9 in USA,2 in Australia. one each in Iceland,Denm	N= 5144 Age:≥ 18 yrs Gender: both male and	Between January 2004 and March 2015	3 Databases	Dietary intervention trials	Dietary adherence

	ation and PROSPERO registered.			ark,Germany, Scotland,Spain.	female BMI: range from 26-49 ·9 kg/m.,two studies <25 kg/m				
Ananthapavan et al.(2018)	SR. Not followed guide. Not registered.	20	11 randomized trials; 8 cohort studies, 4 with controls; and 1 meta-analysis.	14 were conducted in the USA, and the remain were from South Africa (four), UK (one) and Germany (one).	Sample size: total: NA range from 32 to over 250,000 Gender: NA Age: NA BMI: NA	Between 1998 and September 2016	3 Databases	incentives provided by health insurers with respect to weight loss	Dropouts (%)
Burke et al.(2011)	SR PRISMA recommendation Not registered	24	Most (n=14) used descriptive designs	All in the America.	N= 9668 Age:≥ 18 yrs Gender: mainly female BMI:≥ 25kg/m^2	Between 1989 and 2009	2 Databases	self-monitoring in behavioural weight loss	Adherence, the number of diaries submitted, therapists' ratings of the completeness of diaries, scores on a survey of self-monitoring, or the number of self-reported weights over a specified period.

Young et al.(2019)	SR. PRISMA recommend ation and PROSPERO registered.	21	RCTs	USA n=8, the United Kingdom n=3, Netherlands n=3, Australia n=2, One each in, Iran, South Korea, Germany, multinational.	N= 7,389 Age: ≥ 18yrs Gender: participants (3,541 males) BMI: General/Obese/o verweight	Published up to January, 2018	6 Databases.	Randomized controlled trials of online dietary interventions	Engagement adherence Attrition rates Non-usage attrition
Coupe et al.(2019)	SR. PRISMA recommend ation and PROSPERO registered	10	Random ized or non-randomi zed control trials	7 in USA, one each in Denmark, India and Japan	N= 1320 Age: ≥ 18yrs Gender: Four studies only investigated female BMI:≥ 25kg/m 2	From inception to March 2018:	5 Databases.	Intervention comprised a soft commitment device accompanying a behavioural lifestyle intervention targeting diet and/or physical activity	Physical activity adherence Dietary adherence

Antoun et al.(2022)	SR with MA. PRISMA recommendation.Not registered	34	RCTs	United States: 22 Australia and New Zealand: 3 Europe: 4 Asia: 5	N: 16 to 440. Age: ≥ 20yrs Gender: both men and women BMI:≥ 25kg/m²	From inception date and January 31, 2022.	3 Databases.	Smartphone apps for weight loss intervention	Adherence to Smartphone Apps (%)
Sykes-Muskett et al.(2022)	SR with MA. /Not followed guide. PROSPERO registered	30	RCTs	All but one of the 30 studies were conducted in USA.	N: NA Age: ≥ 18rs Gender: NA BMI:NA	conducted in January 2014.	5 Databases.	Monetary Contingency Contracts (MCCs) intervention	Retention rate.

Rumbo-Rodriguez et al.(2020)	SR. PRISMA recommendation. Not registered	47	30 RCTs. 6 were randomized pilot studies and 1 was a non-randomized pilot. 6 randomized pretest-posttest design,4 quasi experimental.	34 were in the United States, 3 in Australia, and 2 in Spain. 3 in China and 2 in the United Kingdom. 1 each in Italy, Korea, and one in Iran.	N: NA Age: 40.9 yrs. Gender: 51.08% were women and 48.77% were men, BMI:NA	last search was 26 February 2020	4 Databases.	Technology-Based Interventions, including smartphones, app, websites, virtual reality, and personal digital assistant	Treatment adherence through self-monitoring

8.3. Deng Wang's Curriculum Vitae

Deng Wang

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I am currently pursuing a PhD at the Universidad Politécnica de Madrid (INEF) in the Exercise Physiology Laboratory(LFE) Research Group. My doctoral research focuses on physical activity and nutritional interventions for populations with overweight/obese. Regarding athletic background,I have finished years of professional track and field training and was a national-level athlete in the 400 meters. My personal best is 48.00 seconds, and I've competed in multiple provincial and national competitions.

Skills and Languages

Skills	400m-Sprinter (National First-Class Athlete) Strength Training
Research	Intervention studies, Behavioral Change, Database Analysis, Epidemiology
Data Analysis	R language, Cardiopulmonary Function Testing; Lactate Threshold , Fitness Assessment; Exercise Prescription
Languages	**English** — Reading & Writing (Good), Listening & Speaking (Fluent); **Spanish** — Basic

Education

2025 2021.10	Department of Health and Human Performance, **Universidad Politécnica de Madrid** PhD in Sciences of Physical Activities and Sports
2021.06 2019.09	School of Physical Education and Sport, **Beijing Normal University** Master in Physical Education
2019.06 2015.09	School of Law, **Wuhan University** Bachelor of Law

Publications

- Wang Deng, Benito PJ, Rubio-Arias JÁ, Ramos-Campo DJ, Rojo-Tirado MA. Exploring factors of adherence to weight loss interventions in population with overweight/obesity: an umbrella review. Obes Rev. 2024 Sep;25(9):e13783. doi: 10.1111/obr.13783 IF:8.0 JCR Q1 First author.
- Wang Deng, Su R, Li D, Ling J, Zhao M, Xu J, Chen D, Zuo R, Tian H, Zhao J. Association Between Leisure Time Physical Activity and Insulin Resistance: A Nationally Representative Study of American Adults. American Journal of Lifestyle Medicine (Accepted) IF:1.5 JCR Q4 First author.
- Wang D, Rojo-Tirado MA, Benito PJ, Rubio-Arias JÁ, Ramos-Campo DJ, Marques MM. Adherence to Behavioral Weight Management: A Scoping Review of Definition, Measurement and Facilitators. Obes Rev. 2025.01.17 Submitted (Under Review) First author, Under Review
- Wang D, Rojo-Tirado MA, Katzmarzyk PT. Longitudinal Changes in Physical Activity and Dietary Fat Intake During an intensive lifestyle intervention: the PROPEL Trial. First author, Under Review
- Li D, Li L, Zang W, Wang Deng, Miao C, Li C, Zhou L, Yan J. Effect of physical activity on attention in school-age children with ADHD: a systematic review and meta-analysis of randomized controlled trials. Front Physiol. 2023 Jul 27;14:1189443. doi: 10.3389/fphys.2023.1189443 IF:3.2 JCR Q2
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