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REVIEW ARTICLE

Components of multiple health behaviour change interventions for patients with chronic conditions: a systematic review and meta-regression of randomized trials

Carolina C. Silva[a], Justin Presseau [b,c,d], Zack van Allen[b,d], John Dinsmore[a], Paulina Schenk[e], Maiara Moreto[f] and Marta M. Marques[g]

[a]Trinity Centre for Practice and Healthcare Innovation, School of Nursing and Midwifery, Trinity College Dublin, Dublin, Ireland; [b]Clinical Epidemiology Program, Ottawa Hospital Research Institute, Ottawa, ON, Canada; [c]School of Epidemiology and Public Health, University of Ottawa, Ottawa, ON, Canada; [d]School of Psychology, University of Ottawa, Ottawa, ON, Canada; [e]Department of Clinical, Educational and Health Psychology, University College London, London, UK; [f]ISPA – Instituto Universitário, Lisbon, Portugal; [g]NOVA National School of Public Health, NOVA University of Lisbon, Comprehensive Health Research Centre, Lisbon, Portugal

ABSTRACT

Interventions addressing more than one health behaviour at a time could be an efficient way of intervening to manage chronic conditions. Within a systematic review of multiple health behaviour change (MBHC) interventions, we identified key components of interventions in patients with chronic conditions, assessed how they are linked to theory, behaviour change techniques implemented, and evaluated their impact on intervention effectiveness. Studies were identified by systematically searching five electronic databases. Subgroup analyses and meta-regressions were conducted to analyse the association between intervention components and behavioural changes. In total, 61 studies were included spanning different chronic conditions (e.g., cardiovascular conditions, type 2 diabetes). Most interventions sought to change behaviours simultaneously (72%), often targeting the 'physical activity, diet and smoking' cluster of behaviours (33%), and were not theory informed (55%). A total of 36 behaviour change techniques were identified, most commonly *goal setting behaviour* and *self-monitoring of behaviour*. Subgroup analyses indicated that MHBC interventions delivered entirely face-to-face might not be as effective for physical activity outcomes, and not using *goal setting (behaviour)* might be more effective for smoking cessation outcomes. Meta-regressions indicated that a longer intervention duration may work best to achieve better physical activity outcomes. This review provides a comprehensive understanding of interventions and contributes to the field of MHBC by facilitating data-driven insights for future optimisation and dissemination.

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Introduction

Noncommunicable diseases such as cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes, represent the primary causes of death globally (WHO, 2022). Behaviour change interventions can support individuals in preventing the development of these conditions or in managing

CONTACT Carolina C. Silva silvac@tcd.ie
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risk factors successfully by targeting modifiable behaviours such as physical activity, diet, alcohol consumption, smoking, and medication adherence (Michie, 2008).

In the context of behaviour change, multiple health behaviour change (MHBC) interventions refer to those that aim to change more than one behaviour sequentially or simultaneously (Prochaska et al., 2008). These interventions are of particular interest due to the frequent co-occurrence (or clustering) of multiple health risk behaviours (Geller et al., 2017; Prochaska & Prochaska, 2011; van Allen et al., 2023). MHBC interventions can be a more synergistically effective way of intervening, where the change of one health behaviour may act as a gateway for other behavioural changes (Presseau et al., 2013; Prochaska & Prochaska, 2011). For instance, having the successful experience of changing one behaviour could increase one's motivation or self-efficacy to change others (Prochaska et al., 2008; Prochaska & Prochaska, 2011).

Despite the potential of MHBC interventions, and evidence from meta-analyses of randomised trials demonstrating their effectiveness in achieving behaviour change (Duan et al., 2021; Silva et al., 2024), limited research has examined their components and characteristics. Yet, to fully understand how, why, in which context, and for whom interventions may be more effective, it is important to not only assess their effectiveness, but to also identify their key components, such as their mode of delivery (MoD), scheduling, source, use of techniques to promote behaviour change, and of theories to inform the interventions development (Michie et al., 2011, 2020). Using existing taxonomies and ontologies can provide a transparent and consistent way of describing interventions, providing a shared and standardised language to describe the key components of behaviour change interventions, which facilitates the way information extracted from multiple sources is organised and integrated, enabling the comparison of findings across studies (Larsen et al., 2017).

Previous reviews of randomised trials in the context of chronic disease management have identified some components of MHBC interventions, and a few have analysed their impact on intervention effectiveness (Alageel et al., 2017; Cradock et al., 2017; Duan et al., 2021). The Behaviour Change Techniques (BCTs) Taxonomy (Michie et al., 2013) was used in two of these reviews to describe the interventions' 'active ingredients' (e.g., Alageel et al., 2017; Cradock et al., 2017). In doing so, Cradock et al. (2017) found the BCTs *instruction on how to perform a behaviour*, *behavioural practice/rehearsal*, *demonstration of the behaviour* and *action planning* to be associated with improved glycaemic control (reduction in HbA1c), whereas Alageel et al. (2017) found *review of behaviour goals* to be associated with worse blood pressure outcomes and *action planning* with greater weight loss. To assess the use of theory to inform intervention development, the Theory Coding Scheme (Michie & Prestwich, 2010) was also employed in these studies. Specifically, Alageel et al. (2017) found that studies that reported using a theory-informed approach led to increased weight and serum total cholesterol outcomes, and Cradock et al. (2017) did not find sufficient studies reporting using a theory to conduct further analyses. While Duan et al. (2021) did not use ontologies or taxonomies to inform their data extraction, they assessed the impact of a theory-driven approach to the design and development of eHealth interventions, showing interventions informed by theory resulted in more effective physical activity outcomes, but not diet-related outcomes. Regarding the MoD, scheduling and source of interventions, although these reviews looked into some aspects of these components, none used ontologies or taxonomies for their reporting. Nevertheless, Duan et al. (2021) found that in the context of eHealth, using text messages or telephone counselling achieved better diet-related outcomes when compared to web-based interventions, and that intervention duration had no effect on either physical activity or diet-related outcomes. Further, Cradock et al. (2017) found that interventions with supervised physical activity, delivered in a group format, with an exercise physiologist or a dietitian, and with greater frequency and intensity, were more effective for reduction in HbA1c. Alageel et al. (2017) found no association between the number of sessions and intervention duration and clinical outcomes. Overall, while components of MHBC interventions have been explored in some contexts, few reviews have assessed their impact on *behavioural* outcomes (e.g., diet and physical activity on eHealth interventions, Duan et al., 2021), and none have used established ontologies and taxonomies to

systematically inform the data extraction process regarding the various aspects of intervention components (e.g., MoD, scheduling), nor have they established connections among these.

Conducting in-depth analyses of the effectiveness and key components in rigorously evaluated MHBC interventions can help to clarify not only whether targeting more than one behaviour is advised, but also, which specific components are associated with greater effectiveness to inform future optimisation. However, very few reviews of MHBC in the context of chronic disease management have looked at intervention components and analysed their impact on intervention effectiveness (Alageel et al., 2017; Cradock et al., 2017; Duan et al., 2021), particularly on behavioural outcomes (Duan et al., 2021). Moreover, only two reviews have used existing taxonomies to guide their data extraction process, and these have only done so for BCTs and theory usage (Alageel et al., 2017; Cradock et al., 2017).

Responding to the lack of systematic reviews assessing the effectiveness of MHBC interventions in individuals with chronic conditions with a focus on behaviour change as the outcome of interest, we conducted a systematic review that assessed the overall effectiveness of these interventions in changing health-related behaviours in the context of chronic disease management (Silva et al., 2024). Here, we aim to comprehensively identify and describe the key components of the interventions identified in the review using available classification systems (i.e., setting, MoD, source, scheduling, theory usage, and BCTs usage) and how are they linked, and to assess their association with behavioural outcomes.

Methods

This study is a complementary analysis to a review conducted and reported in Silva et al. (2024). The review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) and was registered in PROSPERO (CRD42022327085) and Open Science Framework (https://osf.io/58ue6/ and https://osf.io/hr7u3).

Data sources and search strategy

In November 2023, we applied a pre-specified search strategy to five electronic databases (Web of Science, PubMed, CINAHL, EMBASE and Cochrane) to identify existing interventions targeting more than one health-related behaviours of individuals with chronic conditions (i.e., MHBC interventions). Three sets of search terms were used that represented the population of interest (i.e., individuals with chronic conditions), the type of intervention (i.e., MHBC interventions), and the study design (i.e., randomised trials).

To complement this search, previous reviews of MHBC interventions were also identified (namely, Alageel et al., 2017; Cradock et al., 2017; Duan et al., 2021; Minian et al., 2020, Prochaska & Prochaska, 2011, Spark et al., 2013), and their included studies were assessed for eligibility.

See table 1 of supplementary material 1 for complete search strategy information.

Inclusion/Exclusion criteria

To be included in the review, studies had to report randomised trials of interventions aiming to change more than one health-related behaviour in adults with at least one physical chronic condition. Chronic conditions were identified after conducting the searches by assessing if the conditions in each paper met our criteria of being a physical disease with a long duration, requiring continuous medical care and that leads to some form of functional impairment (Bernell & Howard, 2016, Sutton et al., 2016).

Interventions had to target two or more behavioural domains (e.g., diet and physical activity) to be considered a MHBC intervention.

Any type of comparison group was considered for the narrative review (e.g., usual care, minimal intervention). However, to be included in the meta-analyses we only considered studies with control groups receiving no intervention, receiving usual care only or minimal interventions.

In terms of outcomes, at least two behavioural domains had to be assessed.

Also, studies had to be published in peer-reviewed journals and written in English. Studies without available full-texts, conference proceedings and protocols were excluded.

Study selection

RAYYAN was used to aggregate all identified records and duplicates were first removed. An independent assessment was made at both abstract and full-text screening stages for 20% of studies by two authors (CCS and MM), with discrepancies being resolved through discussion with a third reviewer (MMM).

Reasons for exclusion recorded at the full-text stage included: (i) not being a randomised trial, (ii) not being a behavioural intervention, (iii) behavioural intervention not targeting multiple behaviours, (iv) participants not having a physical chronic condition, (v) participants not being adults, (vi) not having more than one behavioural outcome of interest, (vii) study not being published in English, and (viii) not being able to obtain full-text.

Data extraction

To develop a standardised data extraction form in Microsoft Excel, existing classification systems (i.e., ontologies and taxonomies) were consulted, and relevant aspects related to the context of multiple behaviour change were incorporated. The final form covered information regarding study details, sample details, setting, intervention characteristics, MoD, source, scheduling, theory usage, behaviour change techniques usage, and statistical information. Each of this information was extracted for all intervention and comparison/ control groups separately. See Table 1 for complete data for extraction and coding information.

Data extraction was performed in full by one author (CCS) and 20% was extracted independently by a second author (PS), with disparities being resolved through joined discussion. Inter-rater reliability was calculated using Cohen's kappa for data extraction, except for behaviour change techniques (BCTs) codification, for which the PABAK measure was used due to being identified as the most appropriate way to measure intercoder reliability for this task (Abraham et al., 2015).

The information extracted was obtained from data provided in the studies and protocols, and no scholars were contacted for additional data.

Quality assessment

The validated tool Cochrane Risk of Bias (RoB) 2 for randomised controlled trials and for cluster-randomised trials was used to assess the methodological quality of the included studies (Sterne et al., 2019).

The tool assesses five domains for randomised controlled trials (bias arising from the randomisation process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcome, and bias in selection of the reported result), with an additional domain for cluster-randomised trials (identification/ recruitment bias). The domains include signalling questions that feed algorithms to score them as 'low risk', 'some concerns' or 'high risk', and these scores are then mapped into an overall risk of bias judgement.

Two authors independently assessed the methodological quality and risk of bias, with disagreements being discussed with a third author. Inter-rater reliability was calculated using Cohen's kappa.

Table 1. Data extraction form.

Data extracted	Coding rules
Study details	
Authors	
Year of Publication	
Study Design	E.g., Cluster-randomised trial
Sample details	
Type of condition of participants	E.g., type 2 diabetes
Mean age of participants	In years
Sex of participants	Percentage of females
Setting – Two items were used from the Intervention Setting Ontology v1 (Norris et al., 2020):	
Country where the intervention was based	As stated by the authors
Site of intervention	As stated by the authors
Intervention characteristics	
Intervention and control groups' designations	As stated by the authors
Behaviours targeted by the intervention	As stated by the authors
Type of MHBC intervention	Sequential, Simultaneous or Unclear
Type of intervention	Behaviour change intervention only, Part of a larger trial or Unclear
Type of control	E.g., Usual care, different intervention
Mode of Delivery (MoD) – The following items from the Mode of Delivery Ontology (Marques et al., 2020) were used:	
Human interactional MoD	In person, At a distance, Both or Unclear
Printed material MoD	Yes or No If yes, excerpts were extracted from study and categorised using the ontology's labels at sub-level 2
Electronic MoD	Yes or No If yes, excerpts were extracted from study and categorised using the ontology's labels at sub-level 2
Visual informational MoD	Yes or No If yes, excerpts were extracted from study
Textual MoD	Yes or No If yes, excerpts were extracted from study
Individual-based MoD	Yes, No or Unclear
Pair-based MoD	Yes, No or Unclear
Group-based MoD	Yes, No or Unclear
Uni-directional/ interactional MoD	Uni-directional, Interactional, Both or Unclear
Synchronous/ asynchronous	Synchronous, Asynchronous, Both or Unclear
Push/ pull	Push, Pull, Both or Unclear
Gamification	Yes or No
Source (interventionists) – The following items from the Intervention Source Ontology v3 (Norris et al., 2021):	
Occupational role of source	As stated by the authors
Number of people delivering intervention to each participant	As stated by the authors
Relatedness between source and the target	As stated by the authors
Expertise of source	As stated by the authors
Source's role related to intervention	Especially recruited, Within usual role or Unclear
Source involved in development of intervention	Yes, No or Unclear
Payment model of source	Yes, No or Unclear
Scheduling – The following items from the Preliminary Schedule Ontology v0 (consulted at OSF) were used:	
Number of contacts	
Number of behaviour change techniques (BCTs) used in the intervention group and in the control group	
Frequency of contacts	
Frequency of delivery of a BCT	
Overall duration of contacts	Coded in weeks
Duration of each contact	Coded in minutes
Theory usage – Extent to which behaviour change theories were used to inform intervention development coded using 4 items from the Theory Coding Scheme (Michie & Prestwich, 2010):	
Theory/model of behaviour mentioned	Yes, No or Don't know If coded as yes, the name of theory/ies was indicated
Intervention based on single theory	Yes, No, Don't know or Not applicable if no intervention was used If coded as no, the number of theories used was indicated
Theory/predictors used to select recipients for the intervention	Yes, No, Don't know or Not applicable if no intervention was used)

(*Continued*)

Table 1. Continued.

Data extracted	Coding rules
Theory/predictors used to select/develop intervention techniques	Yes, No, Don't know or Not applicable if no intervention was used)
Behaviour change techniques usage	
BCTs used in the intervention and control group were extracted	Coded using the BCT taxonomy (Michie et al., 2013)
Information on which BCTs were used for each behaviour	
Statistical information – The following information was extracted regarding each behavioural outcome provided by authors:	
Protocol available	Yes or No
Primary/ secondary outcome	Primary, Secondary or Unclear
Type of measurement	Objective or Subjective
Type of data	Dichotomous or Continuous
Intended direction of effect	Increase or Decrease
Interval between beginning of intervention and last follow-up	Coded as months
Interval between end of intervention and last follow-up	
Sample size of intervention group and control group	
Type of statistics used to calculate effect size	
Effect size provided by authors (when available)	
Effect size calculated	Cohen's d for continuous data and Risk Ratio for dichotomous data

Human Behaviour Change Project (HBCP). (2021). Preliminary Schedule Ontology – 27.02.19. https://doi.org/10.17605/OSF.IO/H4SDY; Marques et al. (2020), Michie et al. (2013) and Norris et al. (2020, 2021).

Data synthesis

For the included studies, a synthesis of key aspects was provided narratively, as well as through frequencies and percentages. This included information on study and sample details, setting, intervention characteristics, MoD, source, scheduling, theory usage, and BCTs usage. Summary tables containing this information were organised per condition.

In addition, mapping between specific intervention components was performed by linking BCTs and theory usage, as well as linking BCTs to the behaviours targeted by the interventions, to detect existing gaps and trends.

Meta-Regressions and subgroup analyses

Information on study and outcome selection for meta-analytic approaches, and methods and results from the meta-analyses conducted can be found in Silva et al. (2024). Briefly, studies were only included in the meta-analyses if they used what we considered a 'true' control group (i.e., no intervention, usual care, delayed intervention, or minimal intervention), and provided usable data to calculate effect sizes. Estimated effect sizes were calculated using Cohen's *d* for continuous outcomes and Risk Ratios for dichotomous outcomes (calculated considering a higher value is a positive change, i.e., > 1), and respective 95% confidence intervals (CIs). The I^2 statistics was used to explore the presence and extent of heterogeneity. To ensure higher comparability across studies, analyses were separated based on the (i) type of behavioural outcome (physical activity, sedentary behaviour, fruit and vegetable intake, fat intake, smoking cessation, alcohol consumption, and medication adherence), (ii) type of measurement used (subjective or objective), (iii) type of statistical data provided (continuous or dichotomous), and (iv) according to the follow-up timepoints provided (at the end of intervention and at the latest follow-up available). Publication bias was assessed by using funnel plots to check for asymmetry and using the trim and fill methods to identify potential missing studies. Sensitivity analyses were conducted if studies in the analyses obtained a high overall risk of bias according to the RoB2 tool, the targeted behaviours of the interventions were unclear (e.g., using descriptions such as 'lifestyle'), and/or used extremely long follow-ups (e.g., 60 months).

Subgroup analyses and meta-regressions were conducted when the outcome was reported in at least 10 studies, i.e., for: physical activity subjective and continuous at the end of the intervention, physical activity subjective and dichotomous at the end of the intervention, fat intake subjective and continuous at the end of the intervention, and smoking cessation subjective and dichotomous at the end of the intervention.

Subgroup analyses were conducted to investigate differential effects of categorical intervention components on behavioural outcomes, and aimed to compare: (i) specific behavioural clusters identified as the most frequent in the included studies of this review (i.e., 'diet, physical activity and smoking' vs other clusters, and 'diet and physical activity' vs other clusters); (ii) use of specific MoD (i.e., intervention delivered entirely face to face vs other MoDs, intervention entirely delivered through electronic MoD vs other MoDs, intervention delivered using a combination of in person and at a distance human MoD vs other MoDs, and automated MoD only vs other MoDs); (iii) use of specific sources to deliver interventions (i.e., healthcare professionals involved in intervention delivery vs other sources); (iv) theory usage (i.e., theory-based interventions vs not theory based); and v) use of specific BCTs identified as the most frequently used to target the behavioural outcomes in this review (i.e., using '*1.1 goal setting (behaviour)*' vs not, using '*1.2 problem solving*' vs not, and using '*2.3 self-monitoring of behaviour*' vs not). Estimated effect sizes were calculated, and Q statistics to assess between-study variability associated with potential intervention components.

Meta-regressions were performed to examine the association between the behavioural outcomes and continuous intervention components: intervention duration (in weeks) and number of behaviours targeted by the interventions. Coefficient β was used to assess strength of association and the adjusted R^2 was used to assess the proportion of heterogeneity accounted for by the variables.

All analyses were conducted using the Comprehensive Meta-Analysis (CMA) software (Brüggemann & Rajguru, 2022).

Results

Following deduplication and applying inclusion criteria at both screening stages, 25 studies were included from the electronic searches. In addition, 36 studies were then identified by checking the included studies of the following reviews: Spark et al. (2013), Alageel et al. (2017), Cradock et al. (2017), Minian et al. (2020), and Duan et al. (2021). A total of 61 studies were included in this review (see supplementary material 1 figure 1 for PRISMA flow chart and list 1 for list of included studies).

For the complete list of reasons of excluded studies at the full-text screening stage, see table 2 of supplementary material 1.

Sample, study and setting details

Of the 61 included studies, 40.98% related to cardiovascular diseases ($k = 25$), 24.59% to type 2 diabetes ($k = 15$), 16.39% to hypertension ($k = 10$), 11.48% to cancer ($k = 7$), 4.92% to one or more chronic conditions ($k = 3$), and 1.64% to multiple chronic conditions ($k = 1$). The average age of participants was 58.55 years, and the percentage of females in all studies was 48.45%. Year of publication varied between 1994 and 2023 and the studies were conducted across 24 countries. See table 1 of supplementary materials 2 for table with summary of study, sample and setting information.

Intervention characteristics

From the MHBC interventions included, the number of targeted behaviours varied between two and five, with an average of three. Of these, physical activity and diet were the most frequently targeted behaviours ($k = 60$ and $k = 56$ respectively). As for the behavioural clusters targeted by the

interventions, the most frequent ones were 'physical activity, diet and smoking' ($k = 20/61$ studies, 32.79%) and 'physical activity and diet' ($k = 16/61$, 26.23%).

When looking at the type of intervention being conducted, most were considered 'behaviour change interventions only', i.e., focused solely on changing behaviours ($k = 53/61$, 86.89%), a few were 'part of a larger trial', i.e., a trial where behaviour change was only a small part of the overall goal ($k = 7/61$, 11.48%), or did not provide clear information and was deemed 'unclear' ($k = 1/61$, 1.64%). Whereas most interventions aimed to change multiple behaviours simultaneously ($k = 46/64$ intervention groups, 71.88%), some aimed to change them sequentially ($k = 8/64$, 12.50%). However, some did not provide sufficient information to determine the sequence in which the behaviours were being targeted ($k = 10/64$, 15.63%).

Most studies had one intervention group and one comparison group, with three studies having two intervention groups (Glasgow et al., 2012; Hyman et al., 2007; Liu et al., 2018), and one study having one intervention group and two possible comparison groups (Swoboda et al., 2016). Most control groups used standard/routine care as comparisons ($k = 27/61$, 44.26%). See table 2 of supplementary materials 2 for information on types of interventions and targeted behaviours.

Mode of delivery (MoD) of interventions

Most interventions were delivered in full, or at least in part, through a human MoD, either in person ($k = 23/64$ intervention groups, 35.94%) or at a distance ($k = 15/64$, 23.44%), while some used a combination of both ($k = 18/64$, 28.13%). Only eight interventions (12.5%) did not involve any contact with an interventionist (e.g., automated messages).

Most intervention groups used some form of electronic MoD ($k = 41/64$, 64.06%), of which 18 combined this approach with in-person contact, the remaining 23 studies relied exclusively on an electronic MoD. These included 'call modes of delivery' ($k = 22/64$, 34.38%), which can be further categorised into audio calls ($k = 18$), video calls ($k = 1$), messaging ($k = 2$), and a combination of messaging and audio calls ($k = 1$). Additional MoDs included 'website' ($k = 5$), 'email' ($k = 3$), 'playable electronic storage' (i.e., DVD/VCR video; $k = 1$), and combinations between these modes ($k = 10$). The percentage of electronic MoDs was highest in interventions targeting individuals with cancer or cancer survivors ($k = 5/7$, 71,13%) and with cardiovascular diseases ($k = 17/25$, 68.00%).

Printed materials were used as a MoD in 30 intervention groups ($k = 30/64$, 46.88%), including printed publications such as booklets, manuals, leaflets, and others. The percentage of interventions using printed materials was highest in those targeting individuals with one or more chronic conditions ($k = 2/3$, 66.67%) and with hypertension ($k = 6/12$, 50.00%).

Most interventions were delivered in an individual-based format ($k = 45/64$, 70.31%), others were a combination of individual- and group-based ($k = 15/64$, 23.44%), two were group-based only ($k = 2/64$; 3.13%), one was individual- and pair-based ($k = 1/64$; 1.56%), and one was individual-, pair- and group-based ($k = 1/64$; 1.56%).

Source of intervention

As for the interventionists, 35 interventions had at least one healthcare professional as the person delivering the intervention (e.g., nurse, physician, nutritionist; $k = 35/64$, 54.69%), 19 had other types of interventionists (e.g., researchers, peers; $k = 19/64$, 29.69%), and three studies did not provide information regarding the individuals delivering the interventions ($k = 3/64$, 4.69%).

Schedule

A wide range of intervention duration was found, varying from one day only to 7.8 years. Most interventions lasted up to 6 months ($k = 34/64$, 53.13%; median = 26 weeks), for example in the context of

Table 2. Interventions' mode of delivery, source, and scheduling with unique identifier of ontologies.

Authors (year)	Human MoD (BCIO:011002)	Printed MoD (BCIO:011008)	Electronic MoD (BCIO:011010)	Format (BCIO:011000)	Role of source (BCIO:010003)	N.o of contacts (BCIO:009000)	Frequency of contacts (BCIO:009000)	Overall duration (BCIO:009000)
Cardiovascular diseases								
Haskell et al. (1994)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Written goals and instructions for their individualised risk-reduction plan	Audio call (BCIO:011022) & Email (BCIO:011025)	Individual based (BCIO:011055)	SCRIP nurse (BCIO:010013) Dietitian (BCIO:010022) Staff Psychologist – for smokers (BCIO:010038)	Unclear	Unclear	209 weeks (4 years)
Allison et al. (2000)	Face to face (BCIO:011003)	Not used	Not used	Individual based (BCIO:011055)	Nurse (BCIO:010013)	At least 3 (Additional follow-up was scheduled as clinically indicated)	Initial 1 h appointment (6 to 10 days after discharge from the hospital or chest pain unit) Second 1 h appointment (25 to 35 days later) Additional follow-up was scheduled as clinically indicated Final 1 h appointment (24 to 28 weeks after discharge)	28 weeks
VHSG (2003)	Face to face (BCIO:011003)	Not used	Not used	Individual based (BCIO:011055) & Group based (BCIO:011057)	Specially educated physical therapist (BCIO:010021) Study nurse (BCIO:010013) Study physician (BCIO:010009) Clinical nutritionist (BCIO:010022)	At least 38	First 6 weeks: physical exercise supervised + regular group meetings twice a week Also, 9 weeks of: PA twice weekly After initial 6 weeks: group meetings every 3rd month for 2 years	15 weeks
Jiang et al. (2007)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Manual	Audio calls (BCIO:011022)	Individual based (BCIO:011055) & Group based – includes family members (BCIO:011057)	Experienced cardiac nurse – researcher (BCIO:010013, BCIO:010083)	Unclear	Unclear	12 weeks

Jolly et al. (2007)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	The heart manual (second edition)	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Rehabilitation nurse (BCIO:010013)	At least 4	1st visit: call at about 3 weeks post-recruitment – visit took place 6 weeks post-recruitment Final visit took place at 12 weeks. Additional visits were made as deemed necessary by the rehabilitation nurse	6 weeks
Wister et al. (2007)	At-a-distance (BCIO:011004)	Not used	Audio call (BCIO:011022) & Email (BCIO:011025)	Individual based (BCIO:011055)	Clinical lifestyle counsellors (BCIO:010039)	3 (smokers received 4 more sessions)	Within 10 days of the patient receiving the Annual report card and every 6 months thereafter Smokers received additional sessions at 2, 4, 8 and 12 weeks	52 weeks (1 year)
Charlson et al. (2008)	Face to face (BCIO:011003)	'Tip sheets' for each of the risks they selected to change, as well as referrals for behaviour change programs and other community resources	Not used	Individual based (BCIO:011055)	Unclear	Unclear	Unclear	104 weeks (2 years)
Lindsay et al. (2008)	At-a-distance (BCIO:011004)	Not used	Website (BCIO:011027)	Individual based (BCIO:011055)	Researchers (BCIO:010083)	26	Weekly drop-in sessions and phone-in support was also available to both groups Experimental group was better informed about the drop-in sessions as these were promoted via the portal	26 weeks
Naser et al. (2008)	Face to face (BCIO:011003)	Manual	Audio calls (BCIO:011022)	Individual based (BCIO:011055) & Group based – PA	Program manager Exercise leader (BCIO:010061)	At least 19	1st year: 7 PA sessions for 6 months, 2 during the first month and	104 weeks (2 years)

(*Continued*)

Table 2. Continued.

Authors (year)	Human MoD (BCIO:011002)	Printed MoD (BCIO:011008)	Electronic MoD (BCIO:011010)	Format (BCIO:011000)	Role of source (BCIO:010003)	N.o of contacts (BCIO:009000)	Frequency of contacts (BCIO:009000)	Overall duration (BCIO:009000)
	& At-a-distance (BCIO:011004)			sessions (BCIO:011057)			the remaining 1 per month; Remaining 6 months had regular lifestyle sessions and calls 2nd year: sessions every 3 months (4 in total). Two calls every 3 months (8 in total)	
Pischke et al. (2008)	Face to face (BCIO:011003)	Not used	Not used	Group based (BCIO:011057)	Clinical psychologist (BCIO:010038)	104	Every day for 1 week Two times per week after, for 1 year	52 weeks (1 year)
Wood et al. (2008)	Face to face (BCIO:011003)	Personal record card for lifestyle and risk factor targets and family support packs	Not used	Individual based (BCIO:011055), Pair based – with family (BCIO:011056), & Group based – workshops and group PA sessions (BCIO:011057)	Nurse (BCIO:010013) Dietitians (BCIO:010022) Physiotherapist (BCIO:010021)	8 sessions + group workshop and a supervised exercise class	8 sessions – one every week + group workshop and a supervised exercise class once a week	16 weeks
Lindsay et al. (2009)	At-a-distance (BCIO:011004)	Not used	Website (BCIO:011027)	Individual based (BCIO:011055)	Researchers (BCIO:010083)	26 contacts to check in	Weekly drop-in sessions and phone-in support was also available to both groups although the experimental group was better informed about the drop-in sessions because they were promoted via the portal	26 weeks
Neves et al. (2009)	Face to face (BCIO:011003)	Not used	Not used	Individual based (BCIO:011055) & Group based (BCIO:011057)	Trained instructor (BCIO:010085)	40	Same as control: 4 counselling sessions (1 stress management, 1 smoking cessation, and 2 nutrition), as well as 3 sessions per week of exercise training for 12 weeks Additional relaxation therapy: total of 36 hours (3 one-	12 weeks

							hour sessions per week) of supervised group sessions	
Redfern et al. (2009)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Leaflets	Audio calls (BCIO:011022)	Individual based (BCIO:011055) & Group based – for those that chose PA (BCIO:011057)	Treating medical doctors (BCIO:010009)	Unclear	1 h initial consultation and multiple follow-up phone calls over 3 months	13 weeks
Wolfe et al. (2010)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	'Keeping well plan' printed in hard-copy form with evidence-based information and advice tailored to the individual on strategies to improve current risk factor management	Email (BCIO:011025)	Individual based (BCIO:011055)	General practitioners (BCIO:010010)	Unclear	Unclear	35 weeks
Eckman et al. (2012)	Face to face (BCIO:011003)	Booklet	DVD/VCR video (BCIO:011019)	Individual based (BCIO:011055)	Medical doctor (BCIO:010009) or Nurse (BCIO:010013)	1	40 minutes to read/see materials followed by an appointment with HCP	.14 weeks (1 day)
Ijzelenberg et al. (2012)	Face to face (BCIO:011003)	Results and a written medical report focusing on risk factors and risk behaviour	Not used	Individual based – smoking (BCIO:011055) & Group based – first 3 months, 12 people (BCIO:011057)	Physician (BCIO:010009) Specialised team member (BCIO:010083) Physiotherapist (BCIO:010021) Psychologist – for smokers (BCIO:010038) Nutritionist (BCIO:010022)	At least 32	First 3 months: physical training, education, and counselling Exercise program – offered twice weekly, consisting of an individualised exercise session of 1 h followed by a relaxation session of 30 min., giving a total of 22 sessions in 3 months. Group counselling program – 7 sessions Second 3 months: monthly exercise sessions Other contacts' timings	26 weeks

(*Continued*)

Table 2. Continued.

Authors (year)	Human MoD (BCIO:011002)	Printed MoD (BCIO:011008)	Electronic MoD (BCIO:011010)	Format (BCIO:011000)	Role of source (BCIO:010003)	N.o of contacts (BCIO:009000)	Frequency of contacts (BCIO:009000)	Overall duration (BCIO:009000)
							and numbers are unclear	
Sher et al. (2014)	Face to face (BCIO:011003)	Not used	Not used	Group based (BCIO:011057)	Therapist (BCIO:010039)	18	12 weekly sessions followed by 6 alternate week sessions over a total of 24 weeks	24 weeks
Chow et al. (2015)	No human contact	Not used	Messaging (BCIO:011024)	Individual based (BCIO:011055)	N/A (automatic messages only)	96 SMSs	Participants received 4 messages per week for 24 weeks	24 weeks
Pfaeffli Dale et al. (2015)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Not used	Messaging (BCIO:011024) & Website (BCIO:011027)	Individual based (BCIO:011055)	Exercise scientists (BCIO:010061) Nutritionists (BCIO:010022) Cardiologists (BCIO:010011) Study team (BCIO:010083)	168	Traditional CR: 1 h per week for 6 weeks Exercise program: 16 sessions supervised (frequency unclear) Intervention: for 13 weeks, 7 messages/ week for 11 weeks, 5 messages/week (1 text per day)	24-26 weeks
Park et al. (2015)	At-a-distance (BCIO:011004)	Not used	Messaging (BCIO:011024) & Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Nurses in the coronary unit – calls Head nurse – SMS (BCIO:010013)	10 phone counselling sessions and 21 short message service messages	The intervention was performed five times on the 1st, 3rd, 7th, 21st and 30th day Thereafter, the phone counselling was performed once a month for 6 months (5 times) – 10 times in total	52 weeks (1 year)
Kadda et al. (2016)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Booklet	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Nurse (BCIO:010013) Dietitian – for those who needed (BCIO:010022)	12	Monthly sessions	52 weeks (1 year)
Xavier et al. (2016)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Poster with health messages and images, and a lower calendar portion with 12 monthly sheets for recording details of up to six	Audio calls (BCIO:011022)	Individual based (BCIO:011055) & Pair based – included primary caregiver (BCIO:011056)	SPREAD project officer (BCIO:010083) Community health worker (BCIO:010052)	1 (initial) + 6 (follow-up) + 12 calls	There were six follow-up visits in the intervention group, four at the hospital outpatient clinics at 1, 5, 7, and 12 months, and two home visits	52 weeks (1 year)

		cardiovascular drugs with corresponding checkboxes for the patient to mark when they took each drug in that month					at 3 and 9 months Community health worker made a telephone call every month to enquire about the patient's health status and adherence to drugs and to provide advice on lifestyle changes	
Wan et al. (2016)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Not used	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Stroke nurses (BCIO:010013)	4 (1 in person education (same as the control group) + 3 telephone follow-up calls	3 telephone follow-up calls at 1 week and at 1 and 3 months after discharge	13 weeks
Duan et al. (2018)	No human contact	Not used	Website (BCIO:011027)	Individual based (BCIO:011055)	N/A	8	Once a week for 8 weeks	8 weeks
Type 2 Diabetes								
Argurs-Collins et al. (1997)	Face to face (BCIO:011003)	Program outline of topics to be covered and a folder in which to put handouts that were distributed in class	Not used	Individual based (BCIO:011055) & Group based (BCIO:011057)	Registered dietitian (BCIO:010022) Exercise physiologist (BCIO:010061)	19	For 3 months: 12 weekly group sessions with 8-10 Participants (60 min of nutrition education followed by 30 min devoted to exercising in the physical therapy area of the clinic), with 1 individual diet counselling session For 3 months: Six biweekly group sessions were offered during the subsequent 3 months. All group sessions were 90 min long	26 weeks
Gæde et al. (2003)	Face to face (BCIO:011003)	Not used	Not used	Individual based (BCIO:011055)	Medical doctor (BCIO:010009)	At least 31	At least every third month	407 weeks (7.8 years)

(*Continued*)

Table 2. Continued.

Authors (year)	Human MoD (BCIO:011002)	Printed MoD (BCIO:011008)	Electronic MoD (BCIO:011010)	Format (BCIO:011000)	Role of source (BCIO:010003)	N.o of contacts (BCIO:009000)	Frequency of contacts (BCIO:009000)	Overall duration (BCIO:009000)
					Nurse (BCIO:010013) Dietitian (BCIO:010022)			
Clark et al. (2004)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Booklet	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Research psychologist (BCIO:010038)	7	One in person meeting with interventionist + phone calls at weeks 1, 3 and 7 post assessment + phone calls at weeks 12, 24 and 52	52 weeks (1 year)
Toobert (2010)	Face to face (BCIO:011003)	Not used	Not used	Individual based (BCIO:011055) & Group based (BCIO:011057)	Registered dietitian (BCIO:010022) Exercise physiologist professional with at least master's level training (BCIO:010061) Peer leader (BCIO:010104)	Approx. 33 to 73	3-day retreat + weekly group meetings for 6 months + Maintenance phase CLM-LL (44 over 18 months) / maintenance phase CLM-CR (4 over 18 months)	104 weeks (2 years)
Koo et al. (2010)	Face to face (BCIO:011003)	Not used	Not used	Individual based (BCIO:011055)	Professional exercise therapist (BCIO:010061)	12	Diet: every 2 weeks PA/Exercise therapist: every 2 weeks	12 weeks
Griffin et al. (2011)	Face to face (BCIO:011003)	Theory-based educational materials ('Getting Started with Diabetes')	Not used	Individual based (BCIO:011055) & Group based (BCIO:011057)	Family physicians (BCIO:010010) Nurses (BCIO:010013)	Unclear	Unclear	157 weeks (3 years)
Shetty et al. (2011)	At-a-distance (BCIO:011004)	Not used	Messaging (BCIO:011024)	Individual based (BCIO:011055)	Unclear	101 SMSs (median)	SMS once every 3 days for 52 weeks	52 weeks (1 year)
Toobert et al. (2011)	Face to face (BCIO:011003)	Not used	Not used	Individual based (BCIO:011055) & Group based (BCIO:011057)	Registered dietitian (BCIO:010022) Exercise physiologist professional with at least master's level training (BCIO:010061) Peer leader (BCIO:010104)	42	2.5-day retreat + weekly sessions for 6 months + 2 per month for 6 months	52 weeks (1 year)
Glasgow et al. (2012)	i. CASM	At-a-distance (BCIO:011004)	Not used	Computer (BCIO:011013), Audio calls (BCIO:011022) &	Individual based (BCIO:011055)	Research staff members (BCIO:010083)	Unclear	As much computer access as participants wanted	6 weeks (but participants could access

			Website (BCIO:011027)					website for 52 weeks)
ii. CASM+	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Not used	Computer (BCIO:011013), Audio calls (BCIO:011022) & Website (BCIO:011027)	Individual based (BCIO:011055) & Group based (BCIO:011057)	Research staff members (BCIO:010083) Bilingual family physician (BCIO:010010)	5	As much computer access as participants wanted + 2 phone calls at weeks 2 and 8 + 3 group sessions	8 weeks (but participants could access website for 52 weeks)
Jansink et al. (2013)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Not used	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Nurses (BCIO:010013)	Unclear	Unclear	61 weeks (1.2 years)
Eakin et al. (2014)	At-a-distance (BCIO:011004)	Workbook	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Unclear	27	27 calls over 18 months 4 initial weekly calls; fortnightly calls for 5 months; monthly calls for 12 months	78 weeks (1.5 years)
Griffin et al. (2014)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Theory-based education to provide a shared framework for the causes, consequences and treatment of diabetes ('Getting Started with Diabetes')	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Trained lifestyle facilitators – not part of the practice team (BCIO:010085)	11	Unclear	52 weeks (1 year)
Kim et al. (2014)	Face to face (BCIO:011003)	Not used	Not used	Individual based (BCIO:011055) & Group based (BCIO:011057)	Exercise physiologists (BCIO:010061) Registered dietitian (BCIO:010022)	50	Exercise program supervised by exercise physiologists three times a week The dietary intervention consisted of 14 educational sessions with a registered dietitian	12 weeks
Shahid et al. (2015)	At-a-distance (BCIO:011004)	Written information leaflets related to information regarding diet given by the nutritionist, initiating and maintaining	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Principal investigator (BCIO:010083)	8	Call every 15 days for 4 months	17 weeks
Swoboda et al. (2016)	Face to face (BCIO:011003)	Not used	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Dietitian (BCIO:010022)	8	Biweekly phone calls	16 weeks

(*Continued*)

Table 2. Continued.

Authors (year)		Human MoD (BCIO:011002)	Printed MoD (BCIO:011008)	Electronic MoD (BCIO:011010)	Format (BCIO:011000)	Role of source (BCIO:010003)	N.o of contacts (BCIO:009000)	Frequency of contacts (BCIO:009000)	Overall duration (BCIO:009000)
		& At-a-distance (BCIO:011004)							
Hypertension									
Korhonen et al. (2003)		Face to face (BCIO:011003)	'Follow-up card' that contained the basic principles of lifestyle changes to help control hypertension	Not used	Individual based (BCIO:011055) & Group based (BCIO:011057)	Personnel of the local health care centres: Nurse (BCIO:010013) Study physician (BCIO:010009) Clinical nutritionist (BCIO:010022)	9	At 1, 3, 6, and 9 months during the first year At 15, 18, and 21 months during the second year At 6 and 18 months (group sessions)	104 weeks (2 years)
Hyman et al. (2007)	i.Simultanous	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Printed manual	Audio calls (BCIO:011022) Videotape (BCIO:011019)	Individual based (BCIO:011055)	Health educator (BCIO:010085)	24	In person every 6 months. Each clinic counselling visit was followed by 7 telephone counselling sessions scheduled 2, 4, 6, 8, 12, 16, and 20 weeks later	78 weeks (1.5 year)
	ii.Sequential	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Printed manual	Audio calls (BCIO:011022) Videotape (BCIO:011019)	Individual based (BCIO:011055)	Health educator (BCIO:010085)	24	In person every 6 months. Each clinic counselling visit was followed by 7 telephone counselling sessions scheduled 2, 4, 6, 8, 12, 16, and 20 weeks later	78 weeks (1.5 year)
Han et al. (2010)		At-a-distance (BCIO:011004)	Not used	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Bilingual nurse (BCIO:010013)	20	Biweekly telephone counselling	39 weeks* *52 weeks in total, but first 3 months were the same as control group; 39 weeks corresponds to the intervention only
Mendis et al. (2010)		Face to face (BCIO:011003)	Translated patient information materials and follow-up cards to	Not used	Individual based (BCIO:011055)	Healthcare professionals (BCIO:010008)	4	At baseline, 4 months, 8 months and 12 months	52 weeks (1 year)

		encourage adherence						
Tobari et al. (2010)	Face to face (BCIO:011003)	Printed educational leaflets about treatment of hypertension	Not used	Individual based (BCIO:011055)	Physicians (BCIO:010009) Pharmacist (BCIO:010019)	7	1 session per month	26 weeks
Drevenhorn et al. (2012)	Face to face (BCIO:011003)	Not used	Not used	Individual based (BCIO:011055)	Nurses (BCIO:010013)	Unclear	Unclear	104 weeks (2 years)
Migneault et al. (2012)	No human contact	Printouts of the participant's progress in each health behaviour	Video calls (BCIO:011023)	Individual based (BCIO:011055)	N/A (automated – study staff monitored participant use of the system and contacted those who did not call to assist or re-engage them with the system)	32	One call per week for 32 weeks	32 weeks
Kim et al. (2016)	At-a-distance (BCIO:011004)	Not used	Website (BCIO:011027) & Mobile application (BCIO:011028)	Individual based (BCIO:011055)	Nursing staff (BCIO:010013)	Unclear	Unclear	26 weeks
Liu et al. (2018) i. Expert-driven	No human contact	Not used	Email (BCIO:011025)	Individual based (BCIO:011055)	N/A (automated)	17	Weekly emails sent for 4 months	17 weeks
ii. User – driven	No human contact	Not used	Email (BCIO:011025)	Individual based (BCIO:011055)	N/A (automated)	17	Weekly emails sent for 4 months	17 weeks
Jafar et al. (2022)	Face to face (BCIO:011003) & At-a-distance (BCIO:011004)	Not used	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Physicians (BCIO:010009) Nurses (BCIO:010013)	At least 11 with nurses Unclear with physician	One face-to-face session followed by calls scheduled at monthly intervals for the first 3 months and then 3-month intervals for the 2-years (with nurses) Individuals visited the clinic every 6-8 weeks until their blood pressure is controlled to target, and then every 3-4 months. More visits were scheduled for	104 weeks (2 years)

(*Continued*)

Table 2. Continued.

Authors (year)	Human MoD (BCIO:011002)	Printed MoD (BCIO:011008)	Electronic MoD (BCIO:011010)	Format (BCIO:011000)	Role of source (BCIO:010003)	N.o of contacts (BCIO:009000)	Frequency of contacts (BCIO:009000)	Overall duration (BCIO:009000)
							participants with any symptoms or adverse events or those reporting very high blood pressure	
Cancer and cancer survivors								
Demark-Wahnefried et al. (2006)	At-a-distance (BCIO:011004)	Personalised workbook (with name on the front cover and throughout the introduction) of diet and physical activity information	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Registered dietitian (BCIO:010022) Exercise physiologist (BCIO:010061)	13	Telephone counselling calls of up to 30 minutes every 2 weeks for 6 months	26 weeks
Demark-Wahnefried et al. (2007)	No human contact	Newsletter	Not used	Individual based (BCIO:011055)	N/A (automated)	7	7 newsletters at 6-week intervals	43 weeks
Ibfelt et al. (2011)	Face to face (BCIO:011003)	Not used	Not used	Individual based (BCIO:011055) & Group based (BCIO:011057)	Retreat: Medical doctor (BCIO:010009) Nurses (BCIO:010013) Physiotherapist (BCIO:010021) Social worker (BCIO:010039) Psychologist (BCIO:010038) Free-lance experts (e.g., dietician, a vicar, theologian) who are affiliated with the rehabilitation centre	6-day retreat	Every day for 6 days	.86 weeks (6 days)
Hawkes et al. (2013)	At-a-distance (BCIO:011004)	Participant handbook and regular motivational postcard prompts	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Health coaches (BCIO:010052)	11	Biweekly for 5 months, followed by final telephone session 4 weeks later	26 weeks
Bantum et al. (2014)	At-a-distance (BCIO:011004)	Not used	Website (BCIO:011027)	Individual based (BCIO:011055) & Group based (BCIO:011057)	Peers – cancer survivors (BCIO:010104)	6	6 sessions over 6 weeks	6 weeks

Lee et al. (2014)	No human contact	Not used	Website (BCIO:011027) Messaging (BCIO:011024)	Individual based (BCIO:011055)	N/A (automated)	24	At least twice weekly	12 weeks
Kanera et al. (2016)	No human contact	Not used	Website (BCIO:011027)	Individual based (BCIO:011055)	N/A (automated)	8 modules	Unclear	26 weeks
One or more chronic conditions								
Eakin et al. (2009)	At-a-distance (BCIO:011004)	Detailed workbook that contained information on physical activity and healthy eating	Audio calls (BCIO:011022)	Individual based (BCIO:011055)	Counsellors (BCIO:010039)	18	18 phone calls Calls went from weekly to biweekly to monthly	52 weeks (1 year)
Rosenberg et al. (2014)	Face to face (BCIO:011003)	The Depression Helpbook, a booklet and other materials on chronic disease management	Not used	Individual based (BCIO:011055)	Registered nurses (BCIO:010013) Primary care physicians (BCIO:010010)	Approx. 17 to 30	Structured visits in each patient's primary care clinic every 2 to 3 weeks for 52 weeks	52 weeks (1 year)
Potempa et al. (2023)	At a distance (BCIO:011004)	Not used	Two-way videoconferencing (Zoom) via the study website (BCIO:011023, BCIO:011027)	Individual-based (BCIO:011000)	Nurse coach (BCIO:010013)	9	A two-way videoconference home assessment, a narrative session, a planning session, and six weekly personalised sessions	8 weeks
Multiple conditions								
Zgibor et al. (2017)	Face to face (BCIO:011003)	Prevention In Practice (PIP) Report – Guidelines for adults aged 50 and over	Not used	Individual based (BCIO:011055)	Community health workers (BCIO:010052)	20	20 sessions over 10 weeks	10 weeks

Abbreviations: MoD, mode of delivery; N/A, not applicable; CR, cardiac rehabilitation; BCIO: 'unique identifier', behaviour change intervention ontology.

cardiovascular diseases ($k = 15/25$, 60.00%). For type 2 diabetes, 11 interventions lasted up to a year ($k = 11/16$, 68.75%), and for hypertension half lasted between one year to two years ($k = 6/12$; 50.00%). All interventions in the context of cancer management lasted less than a year ($k = 7/7$; 1 to 43 weeks), and those targeting individuals with multiple conditions lasted up to a year ($k = 3/3$; 8 to 52 weeks). Table 2 presents further information regarding the MoDs, source and scheduling of interventions.

Use of theory

Out of the 64 intervention groups included, 35 had no mention of a theory being used for intervention development (54.69%). In those that did mention theory use, 20 different theories were identified, with the most frequent ones being the *Transtheoretical Model* (TTM; Prochaska & DiClemente, 1982; $k = 14/29$, 48.27%) and *Social Cognitive Theory* (SCT; Bandura, 1986; $k = 12/29$, 41.38%). The TTM was mostly used in interventions targeting individuals with hypertension ($k = 6$), that aimed to change 'diet and physical activity' or 'diet, physical activity and smoking' ($k = 4$ each), and it was used as a standalone theory in most studies ($k = 10$). SCT was more frequent in studies in the context of type 2 diabetes ($k = 6$), when 'diet and physical activity' were the two behaviours being targeted ($k = 5$), and it was mostly used in combination with other theories ($k = 10$). Table 3 provides a summary of the theories used in each study.

Behaviour change techniques (BCTs) usage

For the intervention groups, the average number of BCTs identified across studies was four, ranging from none to 13. The most identified BCTs were *1.1 goal setting behaviour* ($k = 45/64$, 70.31%), *2.3 self-monitoring of behaviour* ($k = 26/64$, 40.63%), and *1.2 problem solving* ($k = 19/64$, 29.69%).

Of the 36 different BCTs used in the intervention group, 28 were used to change physical activity and diet, 18 to promote smoking cessation, 8 to reduce alcohol consumption and 16 to increase medication adherence. Overall, six BCTs were used at least once to target each behavioural domain (*1.1 goal setting behaviour, 1.2 problem solving, 1.4 action planning, 2.2 feedback on behaviour, 5.1 information about health consequences*, and *10.4 social reward*). Looking at the studies individually, 21 ($k = 21/64$; 32.81%) used the same BCTs across all of their targeted behaviours.

Information on the specific behavioural targets of BCTs was not clear for all intervention groups or behavioural domains, with 25 interventions having at least one technique that was unclear in terms of the behaviour being targeted. Still, the BCT *1.1 goal setting behaviour* was the most used technique to promote change for all behavioural domains ($k = 39$ for physical activity, $k = 32$ for diet, $k = 15$ for smoking cessation, $k = 4$ for alcohol consumption, and $k = 7$ for medication adherence).

Studies that reported using the TTM ($k = 14$) were frequently identified as using the BCTs *1.1 goal setting behaviour* ($k = 12/14$), *12.5 adding objects to environment* ($k = 6/14$), and *1.3 goal setting (outcome)* and *2.3 self-monitoring of behaviour* ($k = 5/14$). Whereas studies that reported using the SCT ($k = 12$) were frequently identified as using the BCTs *1.1 goal setting behaviour* ($k = 11/12$), *1.2 problem solving* ($k = 8/12$), and *2.3 self-monitoring of behaviour* ($k = 7/12$).

Most studies did not provide detailed descriptions of their control groups, which limited the codification of BCTs. BCTs were identified in 14 studies, ranging from one to five, and the most frequent ones were *12.5 adding objects to environment* ($k = 5$) and *1.1 goal setting (behaviour*; $k = 5$).

Table 4 presents a summary of BCTs used in each study and Table 5 provides an overview of links between BCTs of the intervention groups and the behavioural domains targeted.

For data extraction in general, on average a moderate inter-rater reliability was obtained ($k = .716$), and for coding of BCTs an excellent inter-rater reliability was obtained (PABAK = .948).

Table 3. Use of theories and behaviour change techniques.

Authors (year) Behaviours	N.o BCTs IG	BCTs IG	N.o BCTs CG	BCTs CG	N.o of Theories	Theories that informed intervention development	
Cardiovascular diseases							
Haskell et al. (1994) – Diet – Physical activity – Smoking	5	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 2.2. Feedback on behaviour 2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform the behaviour	0	NI	0	NI	N/A
Allison et al. (2000) – Diet – Physical activity – Smoking	0	NI	0	NI	0	NI	N/A
VHSG (2003) – Diet – Physical activity – Smoking	7	1.1 Goal setting (behaviour) 1.4 Action planning 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behaviour 6.1 Demonstration of the behaviour 8.1 Behavioural practice/ rehearsal	0	NI	0	NI	N/A
Jiang et al. (2007) – Diet – Physical activity – Smoking – Medication adherence	7	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome (s) of behaviour 3.1. Social support (unspecified) 10.7 Self-incentive 12.5 Adding objects to the environment	0	NI	0	NI	N/A

(*Continued*)

Table 3. Continued.

Authors (year) Behaviours	N.o BCTs IG	BCTs IG	N.o BCTs CG	BCTs CG	N.o of Theories	Theories that informed intervention development	
Jolly et al. (2007) – Lifestyle – Physical activity – Smoking	1	1.1 Goal setting (behaviour)	3	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 2.4 Self-monitoring of outcome(s) of behaviour	1	Health belief model	Extent unclear
Wister et al. (2007) – Diet – Physical activity – Smoking	4	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 1.5 Review behaviour goal(s) 1.7 Review outcome goal(s)	0	NI	1	Transtheoretical model (Stage of change model)	Extent unclear
Charlson et al. (2008) – Diet – Physical activity – Smoking and/or – Medication adherence	1	1.1 Goal setting (behaviour)	0	NI	1	Economic theory	Theory/predictors used to select/develop intervention techniques
Lindsay et al. (2008) *Lifestyle* – Diet – Physical activity – Smoking – Alcohol consumption	1	12.5 Adding objects to the environment	1	12.5 Adding objects to the environment	0	NI	N/A
Naser et al. (2008) – Diet – Physical activity – Alcohol consumption	6	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 2.2. Feedback on behaviour 2.7 Feedback on outcome(s) of behaviour 4.1 Instruction on how to perform the behaviour 12.5 Adding objects to the environment	0	NI	1	Transtheoretical model (Stage of change model)	Theory/predictors used to select/develop intervention techniques
Pischke et al. (2008) – Diet	5	1.1 Goal setting (behaviour) 3.1 Social support (unspecified) 4.1 Instruction on how to	0	NI	0	NI	N/A

– Physical activity		perform the behaviour 6.1 Demonstration of the behaviour 8.1 Behavioural practice/ rehearsal					
Wood et al. (2008) – Diet – Physical activity – Smoking	7	1.1 Goal setting (behaviour) 1.2 Problem solving 1.3 Goal setting (outcome) 1.4 Action planning 1.5 Review behavioural goal(s) 2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment	0	NI	1	Transtheoretical model (Stage of change model)	Extent unclear
Lindsay et al. (2009) – Diet – Physical activity – Smoking	1	12.5 Adding objects to the environment	1	12.5 Adding objects to the environment	0	NI	N/A
Neves et al. (2009) – Diet – Physical activity – Smoking	0	NI	0	NI	0	NI	N/A
Redfern et al. (2009) – Diet – Physical activity – Smoking	4	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 1.5 Review behavioural goal(s) 1.7 Review outcome goal(s)	0	NI	0	NI	N/A
Wolfe et al. (2010) – Smoking – Alcohol consumption	0	NI	0	NI	0	NI	N/A
Eckman et al. (2012)	2		2		0	NI	N/A

(*Continued*)

Table 3. Continued.

Authors (year) Behaviours	N.o BCTs IG	BCTs IG	N.o BCTs CG	BCTs CG	N.o of Theories	Theories that informed intervention development	
– Diet – Physical activity – Smoking		5.1 Information about health consequences 12.5 Adding objects to the environment		5.1 Information about health consequences 12.5 Adding objects to the environment			
Ijzelenberg et al. (2012) – Diet – Physical activity – Smoking	5	1.1 Goal setting (behaviour) 2.1 Monitoring of behaviour by others without feedback 4.1 Instruction on how to perform the behaviour 6.1 Demonstration of the behaviour 8.1 Behavioural practice/ rehearsal	0	NI	0	NI	N/A
Sher et al. (2014) – Diet – Physical activity – Medication adherence	4	1.2 Problem solving 3.2 Social support (practical) 3.3 Social support (emotional) 12.1 Restructuring the physical environment	1	1.2 Problem solving	2	Self-determination theory Transtheoretical model (Stage of change model)	Theory/predictors used to select/develop intervention techniques
Chow et al. (2015) – Diet – Physical activity – Smoking	6	1.2 Problem solving 4.1 Instruction on how to perform the behaviour 5.1 Information about health consequences 7.1 Prompts/cues 8.2 Behaviour substitution 8.7 Graded tasks	0	NI	6	Control theory Information-motivation-behavioural skills model Operant conditioning Social cognitive theory Theory of planned behaviour Theory of reasoned action	Theory/predictors used to select/develop intervention techniques
Pfaeffli Dale et al. (2015) – Diet – Physical activity – Smoking – Alcohol consumption	13	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.5 Review behaviour goal(s) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 5.1 Information about health consequences 6.1 Demonstration of the	0	NI	2	Social cognitive theory Common sense model	Theory/predictors used to select/develop intervention techniques

		behaviour 6.2 Social comparison 8.7 Graded tasks 10.9 Self-reward 12.5 Adding objects to the environment					
Park et al. (2015) – Diet – Physical activity – Smoking	2	3.1. Social support (unspecified) 12.4 Distraction	0	NI	0	NI	N/A
Kadda et al. (2016) – Diet – Physical activity – Smoking – Alcohol consumption – Medication adherence	2	1.1 Goal setting (behaviour) 8.7 Graded tasks	1	1.1 Goal setting (behaviour)	0	NI	N/A
Xavier et al. (2016) – Diet – Physical activity – Smoking – Alcohol consumption – Medication adherence	5	1.2 Problem solving 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 5.1 Information about health consequences 7.1 prompts/cues	0	NI	0	NI	N/A
Wan et al. (2016) – Diet – Physical activity – Smoking – Alcohol consumption – Medication adherence	3	1.1 Goal setting (behaviour) 1.4 Action planning 10.4 Social reward	0	NI	0	NI	N/A
Duan et al. (2018)	6	1.1 Goal setting (behaviour) 1.2 Problem solving	0	NI	1	HAPA theory	

(*Continued*)

Table 3. Continued.

Authors (year) Behaviours	N.o BCTs IG	BCTs IG	N.o BCTs CG	BCTs CG	N.o of Theories	Theories that informed intervention development	
– Diet – Physical activity		1.4 Action planning 1.5 Review behaviour goal(s) 2.2 Feedback on behaviour 3.1 Social support (unspecified)					Theory/predictors used to select/develop intervention techniques
Type 2 Diabetes							
Agurs-Collins et al. (1997) – Diet – Physical activity	7	1.1 Goal setting (behaviour) 1.2 Problem solving 1.3 Goal setting (outcome) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behaviour	0	NI	1	Social action theory	Theory/predictors used to select/develop intervention techniques
Gæde et al. (2003) – Diet – Physical activity – Smoking	1	1.1 Goal setting (behaviour)	0	NI	0	NI	N/A
Clark et al. (2004) – Diet – Physical activity	8	1.1 Goal setting (behaviour) 1.2 Problem solving 1.6 Discrepancy between current behaviour and goal 2.1 Monitoring of behaviour by others without feedback 3.1 Social support (unspecified) 8.2 Behaviour substitution 12.1 Restructuring the physical environment 13.2 Framing/reframing	0	NI	2	Social cognitive theory Social learning theory	Extent unclear
Toobert (2010) – Diet – Physical activity – Smoking	6	1.1 Goal setting (behaviour) 3.3 Social support (emotional) 4.1 Instruction on how to perform the behaviour 8.1 Behavioural practice/ rehearsal	0	NI	3	Social cognitive theory Social ecologic theory Karoly's goal-systems theory	Theory/predictors used to select/develop intervention techniques

			8.2 Behaviour substitution 8.7 Graded tasks					
Koo et al. (2010) – Diet – Physical activity		2	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour	1	1.1 Goal setting (behaviour)	0	NI	N/A
Griffin et al. (2011) *Lifestyle* – Diet – Physical activity – Smoking		0	NI	0	NI	0	NI	N/A
Shetty et al. (2011) – Diet – Physical activity – Medication adherence		0	NI	0	NI	0	NI	N/A
Toobert et al. (2011) – Diet – Physical activity – Smoking		6	1.1 Goal setting (behaviour) 1.2 Problem solving 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behaviour 8.2 Behaviour substitution 8.7 Graded tasks	0	NI	3	Social cognitive theory Social ecologic theory Karoly's goal-systems theory	Theory/predictors used to select/develop intervention techniques
Glasgow et al. (2012) – Diet – Physical activity – Medication adherence	CASM vs. Enhanced UC	8	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.9 Commitment 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 6.2 Social comparison 10.3 Non-specific reward	0	NI	2	Social-ecological theory Social cognitive theory	Theory/predictors used to select/develop intervention techniques
	CASM + vs. Enhanced UC	9	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.9 Commitment					

(*Continued*)

Table 3. Continued.

Authors (year) Behaviours	N.o BCTs IG	BCTs IG	N.o BCTs CG	BCTs CG	N.o of Theories	Theories that informed intervention development	
		2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 6.2 Social comparison 10.3 Non-specific reward					
Jansink et al. (2013) *Lifestyle* – Diet – Physical activity	1	2.1. Monitoring of behaviour by others without feedback	0	NI	0	NI	N/A
Eakin et al. (2014) – Diet – Physical activity	7	1.1 Goal setting (behaviour) 1.2 Problem solving 1.3 Goal setting (outcome) 2.3 Self-monitoring of behaviour 8.7 Graded tasks 10.3 Non-specific reward 12.5 Adding objects to the environment	0	NI	1	Social cognitive theory	Theory/predictors used to select/develop intervention techniques
Griffin et al. (2014) – Diet – Physical activity – Smoking – Medication Adherence	7	1.1 Goal setting (behaviour) 1.2 Problem solving 1.3 Goal setting (outcome) 1.4 Action planning 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome (s) of behaviour 12.5 Adding objects to the environment	2	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome)	5	Leventhal's common-sense model Theory of planned behaviour Operant theory Carver and Scheier's control theory Relapse prevention theory	Theory/predictors used to select/develop intervention techniques
Kim et al. (2014) – Diet – Physical activity	5	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment	0	NI	0	NI	N/A
Shahid et al. (2015)	2	2.2 Feedback on behaviour 2.3 Self-monitoring of	1	2.3 Self-monitoring of behaviour	0	NI	N/A

– Diet – Physical activity – Medication adherence			behaviour					
Swoboda et al. (2016) – Diet – Physical activity	Multiple-goal group vs.Single-goal group	5	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.5 Review behavioural goal(s) 2.1 Monitoring of behaviour by others without feedback	5	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.5 Review behavioural goal (s) 2.1 Monitoring of behaviour by others without feedback	0	NI	N/A
	Multiple-goal group vs. Control group			0	NI			
Hypertension								
Korhonen et al. (2003) – Diet – Physical activity – Smoking – Alcohol consumption		3	1.1 Goal setting (behaviour) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour	0	NI	0	NI	N/A
Hyman et al. (2007) – Diet – Physical activity – Smoking	Simultaneous group vs. Usual care	1	1.1 Goal setting (behaviour)	0	NI	1	Transtheoretical model	Theory/predictors used to select/develop intervention techniques
	Sequential group vs. Usual care	1	1.1 Goal setting (behaviour)					
Han et al. (2010) – Diet – Physical activity – Smoking – Alcohol consumption		4	1.2 Problem solving 1.3 Goal setting (outcome) 1.7 Review outcome goal(s) 2.7 Feedback on outcome(s) of behaviour	4	1.2 Problem solving 1.3 Goal setting (outcome) 1.7 Review outcome goal(s) 2.7 Feedback on outcome(s) of behaviour	0	NI	N/A
Mendis et al. (2010)		0	NI	0	NI	0	NI	N/A

(*Continued*)

Table 3. Continued.

Authors (year) Behaviours	N.o BCTs IG	BCTs IG	N.o BCTs CG	BCTs CG	N.o of Theories	Theories that informed intervention development	
– Diet – Physical activity – Smoking							
Tobari et al. (2010) – Diet – Physical activity – Smoking – Alcohol consumption	3	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome (s) of behaviour	0	NI	0	NI	N/A
Drevenhorn et al. (2012) – Physical activity – Smoking – Alcohol consumption	0	NI	0	NI	1	Transtheoretical model	Extent unclear
Migneault et al. (2012) – Diet – Physical activity – Medication adherence	6	1.1 Goal setting (behaviour) 1.2 Problem solving 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome (s) of behaviour 12.5 Adding objects to the environment	0	NI	2	Social cognitive theory Transtheoretical model	Theory/predictors used to select/develop intervention techniques
Kim et al. (2016) – Physical activity – Smoking – Alcohol consumption	3	2.4 Self-monitoring of outcome (s) of behaviour 7.1 Prompts/cues 12.5 Adding objects to the environment	0	NI	0	NI	N/A
Liu et al. (2018) Expert-driven e-counselling vs.Control – Diet – Physical activity	8	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 2.3 Self-monitoring of behaviour	2	5.1 Information about health consequences 12.5 Adding objects to the environment	1	Transtheoretical model	Theory/predictors used to select/develop intervention techniques

		2.4 Self-monitoring of outcome (s) of behaviour 4.1 Instruction on how to perform the behaviour 6.1 Demonstration of the behaviour 8.7 Graded tasks 12.5 Adding objects to the environment					
User driven e-counselling vs. Control	3	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome (s) of behaviour				NI	N/A
Jafar et al. (2022) – Diet – Physical activity – Smoking – Alcohol consumption – Medication adherence	1	1.1 goal setting (behaviour)	0	NI	1	Transtheoretical model	Extent unclear
Cancer and Cancer survivors							
Demark-Wahnefried et al. (2006) – Diet – Physical activity	4	1.1 Goal setting (behaviour) 1.6 Discrepancy between current behaviour and goal 2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment	1	12.5 Adding objects to the environment	2	Transtheoretical model Social cognitive theory	Theory/predictors used to select/develop intervention techniques
Demark-Wahnefried et al. (2007) – Diet – Physical activity	2	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour	0	NI	2	Transtheoretical model Social cognitive theory	Theory/predictors used to select/develop intervention techniques
Ibfelt et al. (2011) – Diet – Physical activity	0	NI	0	NI	0	NI	N/A

(*Continued*)

Table 3. Continued.

Authors (year) Behaviours	N.o BCTs IG	BCTs IG	N.o BCTs CG	BCTs CG	N.o of Theories	Theories that informed intervention development	
Hawkes et al. (2013) – Diet – Physical Activity – Smoking – Alcohol consumption	4	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 7.1 Prompt/cues 12.5 Adding objects to the environment	0	NI	0	NI	N/A
Bantum et al. (2014) – Diet – Physical activity	6	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified)	0	NI	0	NI	N/A
Lee et al. (2014) – Diet – Physical activity	5	1.1 Goal setting (behaviour) 1.4 Action planning 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 5.1 Information about health consequences	0	NI	1	Transtheoretical model	Theory/predictors used to select/develop intervention techniques
Kanera et al. (2016) – Diet – Physical Activity – Smoking	7	1.1 Goal setting (behaviour) 1.2 Problem solving 1.6 Discrepancy between current behaviour and goal 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 9.1 Credible source 9.2 Pros and cons	0	NI	2	Self-regulation theory I-Change Model	Theory/predictors used to select/develop intervention techniques
One or more chronic conditions							
Eakin et al. (2009) – Diet – Physical Activity	2	1.1 Goal setting (behaviour) 12.5 Adding objects to the environment	0	NI	1	Social cognitive theory	Extent unclear
Rosenberg et al. (2014)	7	1.1 Goal setting (behaviour) 1.2 Problem solving	0	NI	0	NI	N/A

– Diet – Physical activity – and/or – Smoking		1.3 Goal setting (outcome) 2.3 Self-monitoring of behaviour 11.1 Pharmacological support 11.2 Reduce negative emotions 12.5 Adding objects to the environment					
Potempa et al. (2023) *Health goals* – Diet – Physical activity – Medication adherence	3	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 1.4 Action planning	0	NI	1	Transtheoretical model	Extent unclear
Multiple conditions							
Zgibor et al. (2017) – Physical activity – Smoking	2	1.1 Goal setting (behaviour) 5.1 Information about health consequences	1	5.1 Information about health consequences	0	NI	N/A

Abbreviations: BCTs, behaviour change techniques; IG, intervention group; CG, control group; N/A, not applicable; NI, no information.

Table 4. Links between behaviour change techniques of intervention groups and the behaviours targeted.

Matrix	Physical activity	Diet	Smoking cessation	Alcohol consumption	Medication Adherence	Unclear which behaviour is being targeted
Cardiovascular diseases						
Haskell et al. (1994)	1.1 Goal setting (behaviour) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform the behaviour	1.1 Goal setting (behaviour) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform the behaviour	1.1 Goal setting (behaviour) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform the behaviour	N/A	N/A	1.3 Goal setting (outcome)
Allison et al. (2000)	X	X	X	N/A	N/A	N/A
VHSG (2003)	1.1 Goal setting (behaviour) 1.4 Action planning 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified)	3.1 Social support (unspecified) 4.1 Instruction on how to perform the behaviour 6.1 Demonstration of the behaviour 8.1 Behavioural practice/ rehearsal	1.1 Goal setting (behaviour) 3.1 Social support (unspecified)	N/A	N/A	N/A
Jiang et al. (2007)	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome(s) of behaviour 3.1 Social support (unspecified) 10.7 Self-incentive	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome(s) of behaviour 3.1 Social support (unspecified) 10.7 Self-incentive	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome(s) of behaviour 3.1 Social support (unspecified) 10.7 Self-incentive	N/A	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome(s) of behaviour 3.1 Social support (unspecified) 10.7 Self-incentive	1.3 Goal setting (outcome)
Jolly et al. (2007)	1.1 Goal setting (behaviour)	N/A	X	N/A	N/A	N/A
Wister et al. (2007)	1.1 Goal setting (behaviour) 1.5 Review behaviour goal(s)	1.1 Goal setting (behaviour) 1.5 Review behaviour goal(s)	1.1 Goal setting (behaviour) 1.5 Review behaviour goal(s)	N/A	N/A	1.3 Goal setting (outcome) 1.7 Review outcome goal(s)
Charlson et al. (2008)	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	N/A	1.1 Goal setting (behaviour)	N/A

Lindsay et al. (2008)	X	X	X	X	N/A	12.5 Adding objects to the environment
Naser et al. (2008)	1.1 Goal setting (behaviour) 2.2 Feedback on behaviour 4.1 Instruction on how to perform the behaviour	2.2 Feedback on behaviour	N/A	2.2 Feedback on behaviour	N/A	1.3 Goal setting (outcome) 2.7 Feedback on outcome(s) of behaviour
Pischke et al. (2008)	1.1 Goal setting (behaviour) 3.1 Social support (unspecified)	1.1 Goal setting (behaviour) 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behaviour 6.1 Demonstration of the behaviour 8.1 Behavioural practice/ rehearsal	N/A	N/A	N/A	N/A
Wood et al. (2008)	1.1 Goal setting (behaviour) 1.5 Review behaviour goal(s) 2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment	X	1.2 Problem solving 1.4 Action planning	N/A	N/A	1.3 Goal setting (outcome)
Lindsay et al. (2009)	X	X	X	X	N/A	12.5 Adding objects to the environment
Neves et al. (2009)	X	X	X	N/A	N/A	N/A
Redfern et al. (2009)	X	X	X	N/A	N/A	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 1.5 Review behaviour goal(s) 1.7 Review outcome goal(s)
Wolfe et al. (2010)	N/A	N/A	X	X	N/A	N/A
Eckman et al. (2012)	X	X	X	N/A	N/A	5.1 Information about health consequences 12.5 Adding objects to the environment
Ijzelenberg et al. (2012)	1.1 Goal setting (behaviour)	X	1.1 Goal setting (behaviour)	N/A	N/A	N/A

(*Continued*)

Table 4. Continued.

Matrix	Physical activity	Diet	Smoking cessation	Alcohol consumption	Medication Adherence	Unclear which behaviour is being targeted
	2.1 Monitoring of behaviour by others without feedback 4.1 Instruction on how to perform the behaviour 6.1 Demonstration of the behaviour 8.1 Behavioural practice/ rehearsal		2.1 Monitoring of behaviour by others without feedback			
Sher et al. (2014)	1.2 Problem solving 3.2 Social support (practical) 3.3 Social support (emotional)	1.2 Problem solving 3.2 Social support (practical) 3.3 Social support (emotional)	N/A	N/A	1.2 Problem solving 3.2 Social support (practical) 3.3 Social support (emotional) 12.1 Restructuring the physical environment	N/A
Chow et al. (2015)	5.1 Information about health consequences 7.1 Prompts/cues. 8.7 Graded tasks	8.2 Behaviour substitution	1.2 Problem solving 4.1 Instruction on how to perform the behaviour	N/A	X	N/A
Pfaeffli Dale et al. (2015)	1.1 Goal setting (behaviour) 1.4 Action planning 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 8.7 Graded tasks 12.5 Adding objects to the environment	1.2 Problem solving 6.1 Demonstration of the behaviour	5.1 Information about health consequences	X	5.1 Information about health consequences	1.5 Review behaviour goal(s) 3.1 Social support (unspecified) 6.2 Social comparison 10.9 Self-reward
Park et al. (2015)	X	X	3.1 Social support (unspecified) 12.4 Distraction	N/A	N/A	N/A
Kadda et al. (2016)	1.1 Goal setting (behaviour) 8.7 Graded tasks	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	X	N/A

Xavier et al. (2016)	1.2 Problem solving 3.1 Social support (unspecified) 5.1 Information about health consequences	1.2 Problem solving 3.1 Social support (unspecified) 5.1 Information about health consequences	1.2 Problem solving 3.1 Social support (unspecified) 5.1 Information about health consequences	1.2 Problem solving 3.1 Social support (unspecified) 5.1 Information about health consequences	1.2 Problem solving 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 5.1 Information about health consequences 7.1 Prompts/cues	N/A
Wan et al. (2016)	1.1 Goal setting (behaviour) 1.4 Action planning 10.4 Social reward	1.1 Goal setting (behaviour) 1.4 Action planning 10.4 Social reward	1.1 Goal setting (behaviour) 1.4 Action planning 10.4 Social reward	1.1 Goal setting (behaviour) 1.4 Action planning 10.4 Social reward	1.1 Goal setting (behaviour) 1.4 Action planning 10.4 Social reward	N/A
Duan et al. (2018)	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.5 Review behaviour goal(s) 2.2 Feedback on behaviour 3.1 Social support (unspecified)	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.5 Review behaviour goal(s) 2.2 Feedback on behaviour 3.1 Social support (unspecified)	N/A	N/A	N/A	N/A
Type 2 Diabetes						
Agurs-Collins et al. (1997)	1.1 Goal setting (behaviour) 1.2 Problem solving 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behaviour	1.1 Goal setting (behaviour) 1.2 Problem solving 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behaviour	N/A	N/A	N/A	1.3 Goal setting (outcome)
Gæde et al. (2003)	X	1.1 Goal setting (behaviour)	X	N/A	N/A	N/A
Clark et al. (2004)	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	N/A	N/A	N/A	N/A

(*Continued*)

Table 4. Continued.

Matrix	Physical activity	Diet	Smoking cessation	Alcohol consumption	Medication Adherence	Unclear which behaviour is being targeted
	1.2 Problem solving 1.6 Discrepancy between current behaviour and goal 2.1 Monitoring of behaviour by others without feedback 3.1 Social support (unspecified) 8.2 Behaviour substitution 12.1 Restructuring the physical environment 13.2 Framing/reframing	1.2 Problem solving 1.6 Discrepancy between current behaviour and goal 2.1 Monitoring of behaviour by others without feedback 3.1 Social support (unspecified) 8.2 Behaviour substitution 12.1 Restructuring the physical environment 13.2 Framing/reframing				
Toobert (2010)	1.1 Goal setting (behaviour) 3.3 Social support (emotional) 4.1 Instruction on how to perform the behaviour 8.1 Behavioural practice/ rehearsal 8.7 Graded tasks	1.1 Goal setting (behaviour) 3.3 Social support (emotional) 8.2 Behaviour substitution	3.3 Social support (emotional)	N/A	N/A	N/A
Koo et al. (2010)	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour	N/A	N/A	N/A	N/A
Griffin et al. (2011)	X	X	X	N/A	N/A	N/A
Shetty et al. (2011)	X	X	N/A	N/A	X	N/A
Toobert et al. (2011)	1.1 Goal setting (behaviour) 1.2 Problem solving 3.1 Social support (unspecified)	1.1 Goal setting (behaviour) 1.2 Problem solving 3.1 Social support (unspecified)	1.1 Goal setting (behaviour) 1.2 Problem solving 3.1 Social support (unspecified)	N/A	N/A	N/A
Glasgow et al. (2012) i. CASM	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.9 Commitment 2.2 Feedback on	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.9 Commitment 2.2 Feedback on	N/A	N/A	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.9 Commitment 2.2 Feedback on	N/A

	behaviour 2.3 Self-monitoring of behaviour 6.2 Social comparison 10.3 Non-specific reward	behaviour 2.3 Self-monitoring of behaviour 6.2 Social comparison 10.3 Non-specific reward			behaviour 2.3 Self-monitoring of behaviour 6.2 Social comparison 10.3 Non-specific reward	
i. CASM +	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.9 Commitment 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 6.2 Social comparison 10.3 Non-specific reward	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.9 Commitment 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 6.2 Social comparison 10.3 Non-specific reward	N/A	N/A	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.9 Commitment 2.2 Feedback on behaviourvior 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 6.2 Social comparison 10.3 Non-specific reward	N/A
Jansink et al. (2013)	2.1 Monitoring of behaviour by others without feedback	2.1 Monitoring of behaviour by others without feedback	N/A	2.1 Monitoring of behavior by others without feedback	N/A	N/A
Eakin et al. (2014)	1.1 Goal setting (behaviour) 1.2 Problem solving 2.3 Self-monitoring of behaviour 8.7 Graded tasks 10.3 Non-specific reward 12.5 Adding objects to the environment	1.1 Goal setting (behaviour) 1.2 Problem solving 2.3 Self-monitoring of behaviour 8.7 Graded tasks 10.3 Non-specific reward	N/A	N/A	N/A	1.3 Goal setting (outcome)
Griffin et al. (2014)	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 2.3 Self-monitoring of behaviour	N/A	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 2.3 Self-monitoring of behaviour	1.3 Goal setting (outcome) 2.4 Self-monitoring of outcome(s) of behaviour
Kim et al. (2014)	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	N/A	N/A	N/A	1.3 Goal setting (outcome)

(*Continued*)

Table 4. Continued.

Matrix	Physical activity	Diet	Smoking cessation	Alcohol consumption	Medication Adherence	Unclear which behaviour is being targeted
	2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment	2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment				
Shahid et al. (2015)	X	X	N/A	N/A	N/A	2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment
Swoboda et al. (2016)	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.5 Review behaviour goal(s) 2.1 Monitoring of behaviour by others without feedback	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.5 Review behaviour goal(s) 2.1 Monitoring of behaviour by others without feedback	N/A	N/A	N/A	N/A
Hypertension						
Korhonen et al. (2003)	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour	X	1.1 Goal setting (behaviour)	N/A	N/A
Hyman et al. (2007) i. Simultaneous group	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	N/A	N/A	N/A
Hyman et al. (2007) i. Sequential group	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	N/A	N/A	N/A
Han et al. (2010)	1.2 Problem solving	1.2 Problem solving	1.2 Problem solving	1.2 Problem solving	N/A	1.3 Goal setting (outcome) 1.7 Review outcome goal(s) 2.7 Feedback on outcome(s) of behaviour
Mendis et al. (2010)	X	X	X	N/A	N/A	N/A
Tobari et al. (2010)	2.3 Self-monitoring of behaviour	X	X	X	N/A	1.1 Goal setting (behaviour) 2.4 Self-monitoring of outcome(s) of behaviour
Drevenhorn et al. (2012)	X	N/A	N/A	X	N/A	N/A
Migneault et al. (2012)			N/A	N/A		

		1.1 Goal setting (behaviour) 1.2 Problem solving 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment	1.1 Goal setting (behaviour) 1.2 Problem solving 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour			1.2 Problem solving 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour	2.4 Self-monitoring of outcome(s) of behaviour
Kim et al. (2016)		X	N/A	X	X	N/A	2.4 Self-monitoring of outcome(s) of behaviour 7.1 Prompts/cues 12.5 Adding objects to the environment
Liu et al. (2018)	i. Expert driven	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform the behaviour 6.1 Demonstration of the behaviour 8.7 Graded tasks 12.5 Adding objects to the environment	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform the behaviour 6.1 Demonstration of the behaviour	N/A	N/A	N/A	1.3 Goal setting (outcome) 2.4 Self-monitoring of outcome(s) of behaviour
	ii. User driven	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour	N/A	N/A	N/A	2.4 Self-monitoring of outcome(s) of behaviour
Jafar et al. (2022)		1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	N/A
Cancer and cancer survivors							
Demark-Wahnefried et al. (2006)		2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment	1.6 Discrepancy between current behaviour and goal	N/A	N/A	N/A	1.1 Goal setting (behaviour)
Demark-Wahnefried et al. (2007)		1.1 Goal setting (behaviour)	1.1 Goal setting (behaviour)	N/A	N/A	N/A	N/A

(*Continued*)

Table 4. Continued.

Matrix	Physical activity	Diet	Smoking cessation	Alcohol consumption	Medication Adherence	Unclear which behaviour is being targeted
	2.3 Self-monitoring of behaviour	2.3 Self-monitoring of behaviour				
Ibfelt et al. (2011)	X	X	N/A	N/A	N/A	0
Hawkes et al. (2013)	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 7.1 Prompts/cues 12.5 Adding objects to the environment	7.1 Prompts/cues	7.1 Prompts/cues	N/A	N/A	N/A
Bantum et al. (2014)	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified)	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified)	N/A	N/A	N/A	N/A
Lee et al. (2014)	1.1 Goal setting (behaviour) 1.4 Action planning 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 5.1 Information about health consequences	1.1 Goal setting (behaviour) 1.4 Action planning 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 5.1 Information about health consequences	N/A	N/A	N/A	N/A
Kanera et al. (2016)	1.1 Goal setting (behaviour) 1.2 Problem solving 1.6 Discrepancy between current behaviour and goal 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified)	1.1 Goal setting (behaviour) 1.2 Problem solving 1.6 Discrepancy between current behaviour and goal 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified)	1.1 Goal setting (behaviour) 1.2 Problem solving 1.6 Discrepancy between current behaviour and goal 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified)	N/A	N/A	N/A

	9.1 Credible source 9.2 Pros and cons	9.1 Credible source 9.2 Pros and cons	9.1 Credible source 9.2 Pros and cons			
One or more chronic conditions						
Eakin et al. (2009)	1.1 Goal setting (behaviour) 12.5 Adding objects to the environment	1.1 Goal setting (behaviour)	N/A	N/A	N/A	N/A
Rosenberg et al. (2014)	1.2 Problem solving 2.3 Self-monitoring of behaviour 12.5 Adding objects to the environment	1.2 Problem solving	1.2 Problem solving	N/A	N/A	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 11.1 Pharmacological support 11.2 Reduce negative emotions
Potempa et al. (2023)	X	X	N/A	N/A	X	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 1.4 Action planning
Multiple conditions						
Zgibor et al. (2017)	1.1 Goal setting (behaviour)	N/A	1.1 Goal setting (behaviour)	N/A	N/A	5.1 Information about health consequences

Abbreviations: N/A, not applicable; X, behaviour targeted but no BCT is attributed to it; 0, no BCT behavioural target was considered to be unclear.

Table 5. Links between behaviour change techniques and behavioural domains.

	Physical activity	Diet	Smoking cessation	Alcohol consumption	Medication adherence
1.1 Goal setting (behaviour)[a]	X	X	X	X	X
1.2 Problem solving[a]	X	X	X	X	X
1.3 Goal setting (outcome)					
1.4 Action planning[a]	X	X	X	X	X
1.5 Review behaviour goal(s)	X	X	X		
1.6 Discrepancy between current behaviour and goal	X	X	X		
1.7 Review outcome goal(s)					
1.9 Commitment	X	X			X
2.1 Monitoring of behaviour by others without feedback	X	X	X	X	
2.2 Feedback on behaviour[a]	X	X	X	X	X
2.3 Self-monitoring of behaviour	X	X	X		X
2.4 Self-monitoring of outcome(s) of behaviour					
2.7 Feedback on outcome(s) of behaviour					
3.1 Social support (unspecified)	X	X	X	X	X
3.2 Social support (practical)	X	X			X
3.3 Social support (emotional)	X	X	X		X
4.1 Instruction on how to perform the behaviour	X	X	X		
5.1 Information about health consequences[a]	X	X	X	X	X
6.1 Demonstration of the behaviour	X	X			
6.2 Social comparison	X	X			X
7.1 Prompts/cues	X	X	X		X
8.1 Behavioural practice/ rehearsal	X	X			
8.2 Behaviour substitution	X	X			
8.7 Graded tasks	X	X			
9.1 Credible source	X	X	X		
9.2 Pros and cons	X	X	X		
10.3 Non-specific reward	X	X			X
10.4 Social reward[a]	X	X	X	X	X
10.7 Self-incentive	X	X	X		X
10.9 Self-reward					
11.1 Pharmacological support					
11.2 Reduce negative emotions					
12.1 Restructuring the physical environment	X	X			X
12.4 Distraction			X		
12.5 Adding objects to the environment	X	X			
13.2 Framing/reframing	X	X			
Total number of different BCTs	**28**	**28**	**18**	**8**	**16**

[a]BCTs used for all behavioural domains.

Quality assessment

Most studies presented some concerns regarding their overall risk of bias for randomised controlled trials (49.7%) and for cluster-randomised trials (73.3%). Risk of bias assessment for randomised controlled trials and cluster-randomised trials are presented in figures 1 and 2 of supplementary materials 2.

Meta-Analyses

Of the 61 studies, 43 were included in the meta-analyses. Silva et al. (2024) reported that analyses for continuous data showed small to substantial positive effects of MHBC interventions on all

behaviours ($d = .081$ to 2.003), except for smoking at the end of the intervention timepoint ($d = -.019$). For dichotomous data, all analyses showed positive effects across all behaviours and timepoints (RR = 1.006 to 2.247). Refer to tables 1 and 2 of supplementary materials 3 for a summary of effects at the end of the intervention timepoint and the latest follow-up timepoint available across behaviours. See figures 1 to 6 of supplementary materials 3 for plots of each behaviour.

In sum, the publication bias and sensitivity analyses revealed some asymmetry in the data across various behaviours. The trim and fill methods generally identified a few potentially missing studies, which led to slight but notable adjustments in the reported effect sizes. For instance, the trim and fill analysis often reduced the effect sizes for physical activity, fruit and vegetable intake and smoking cessation when missing studies were accounted for. Sensitivity analyses demonstrated that removing studies with a high risk of bias or those with unclear behavioural targets typically resulted in modest changes in effect sizes. Specifically, removing high-risk studies generally increased effect sizes for fat intake alcohol consumption, smoking cessation and medication adherence. In contrast, the effects for physical activity and fruit and vegetable intake varied, with some analyses showing increased effects and others showing decreases, depending on the specific outcome measure. See figures 7 to 18 of supplementary materials 3 for plots.

Subgroup analyses

Physical activity

For *subjective and continuous* data, interventions targeting the cluster 'diet, physical activity and smoking' ($d = .24$, CI = .16 to .31, k = 8 vs. $d = .125$, CI = −.01 to .26, $k = 12$; $p = .16$) or 'diet and physical activity' ($d = .25$, CI = −.02 to .52, $k = 6$ vs. $d = .18$, CI = .10 to .26, $k = 14$; $p = .60$) did not have statistically significant higher effects on physical activity levels than the ones targeting other clusters.

Regarding MoD, none of the approaches assessed were significantly more effective on physical activity levels than interventions using other MoDs, i.e., those delivered entirely face to face ($d = .30$, CI = .02 to .27, $k = 10$ vs. $d = .13$, CI = .04 to .22, $k = 14$; $p = .08$), entirely through electronic means ($d = .14$, CI = .02 to .27, $k = 10$ vs. $d = .22$, CI = .09 to .34, $k = 10$; $p = .41$), combining face to face with at a distance MoD ($d = .12$, CI = −.04 to .27, $k = 4$ vs. $d = .20$, CI = .09 to .30, $k = 16$; $p = .37$), or using automated methods only ($d = .25$, CI = .05 to .46, $k = 3$ vs. $d = .16$, CI = .06 to .26, $k = 17$; $p = .41$).

Interventions where healthcare professionals were involved in their delivery ($d = .21$, CI = .11 to .32, $k = 14$) had no significant differences in physical activity levels when compared to others that used different types of interventionists ($d = .12$, CI = −.04 to .27, $k = 6$; $p = .32$).

For theory usage, interventions using theory to inform their intervention development ($d = .21$, CI = .09 to .32, $k = 10$) did not have statistically significant higher effects than those that did not use theory ($d = .14$, CI = −.01 to .28, $k = 10$; $p = .47$).

Lastly, the use of BCTs *1.1 goal setting (behaviour)* ($d = .22$, CI = .11 to .33, $k = 14$ vs. $d = .09$, CI = −.06 to .24, $k = 6$; $p = .16$), *1.2 problem solving* ($d = .20$, CI = .07 to .33, $k = 5$ vs. $d = .17$, CI = .06 to .28, $k = 15$; $p = .70$), or *2.3 self-monitoring of behaviour* ($d = .18$, CI = .07 to .29, $k = 5$ vs. $d = .17$, CI = .06 to .29, $k = 15$; $p = .96$) did not have statistically significant higher effects on physical activity than the ones that did not use them.

Please refer to table 1 of supplementary materials 4 for the differential effects of these factors on physical activity at the end of intervention for subjective and continuous data.

For *subjective and dichotomous* data, no assessments were made for behavioural clusters, as only two studies had the selected clusters as their target.

As for MoD, the positive effects on physical activity were not as strong in interventions delivered entirely face to face (RR = 1.28, CI = 1.07 to 1.54, $k = 3$) when compared to other approaches (RR = 1.80, CI = 1.46 to 2.22, $k = 9$; Q = 5.74, $p = .02$). No statistically significant differences were found on physical activity levels for interventions delivered entirely through electronic MoD (RR = 1.67, CI = 1.00 to 2.80, $k = 4$ vs. RR = 1.63, CI = 1.39 to 1.91, $k = 8$; $p = .93$), nor combining in person and at a

distance MoD (RR = 1.86, CI = 1.49 to 2.33, $k = 4$ vs. RR = 1.53, CI = 1.14 to 2.06, $k = 8$; $p = .30$). No comparisons were made for automated MoD as only two studies used this approach.

No statistically significant differences in physical activity levels were found for interventions delivered by healthcare professionals than the ones delivered by other types of interventionists (RR = 1.53, CI = 1.27 to 1.83, $k = 5$ vs. RR = 1.83, CI = 1.35 to 2.48, $k = 7$; $p = .32$).

Interventions that were theory informed had no significant differences from atheoretical interventions (RR = 1.84, CI = 1.38 to 2.46, $k = 6$ vs. RR = 1.54, CI = 1.19 to 1.99, $k = 6$; $p = .36$).

Use of the BCTs *1.1 goal setting (behaviour)* (RR = 1.57, CI = 1.35 to 1.82, $k = 9$ vs. RR = 1.87, CI = .93 to 3.75, $k = 3$; $p = .63$), *1.2 problem solving* (RR = 1.62, CI = .99 to 2.64, $k = 3$ vs. RR = 1.66, CI = 1.37 to 2.02, $k = 9$; $p = .92$), *or 2.3 self-monitoring of behaviour* (RR = 1.74, CI = 1.08 to 2.81, $k = 4$ vs. RR = 1.62, CI = 1.33 to 1.98, $k = 8$; $p = .79$) also led to no statistically significant differences between groups.

Please refer to table 2 supplementary materials 4 for differential effects of these factors on physical activity at the end of the intervention for subjective and dichotomous data.

Fat intake

For *subjective and continuous* data, interventions that targeted the cluster 'diet, physical activity and smoking' ($d = .53$, CI = .09 to .98, $k = 3$ vs. $d = .39$, CI = .09 to .68, $k = 7$; $p = .59$) and those that targeted 'diet and physical activity' ($d = .42$, CI = .04 to .80, $k = 6$ vs. $d = .49$, CI = .02 to .80, $k = 4$; $p = .77$) had no statistically significant higher effects in reducing fat intake compared to other clusters.

Regarding MoD, interventions delivered entirely face to face had no statistically significant differences compared to other approaches ($d = .52$, CI = .19 to .84, $k = 6$ vs. $d = .34$, CI = −.07 to .76, $k = 4$; $p = .52$). Subgroup analyses for other MoDs could not be conducted due to the limited number of studies available.

No subgroup analysis was performed for the source of the interventions, as only two studies used an interventionist who was not a healthcare professional.

Interventions that were theory informed did not have statistically significant different effects on reducing fat intake compared to interventions that were not theory informed ($d = .26$, CI = .15 to .37, $k = 5$ vs. $d = .71$, CI = .19 to 1.23, $k = 5$; $p = .10$).

Lastly, no subgroup analysis was conducted for the BCTs *1.1 goal setting (behaviour)* and *1.2 problem solving* due to the limited number of studies available. Interventions that used the BCT *2.3 self-monitoring of behaviour* had no significant differences on fat intake reduction compared to interventions that did not use it ($d = .53$, CI = .12 to .94, $k = 4$ vs. $d = .37$, CI = .08 to .66, $k = 6$; $p = .54$).

Please refer to table 3 of supplementary materials 4 for differential effects of these factors on fat intake at the end of intervention for subjective and continuous data.

Smoking cessation

For *subjective and dichotomous* data, interventions that targeted the cluster 'diet, physical activity and smoking' had no statistically significant differences regarding smoking cessation than those targeting other behaviours (RR = 1.10, CI = .95 to 1.27, $k = 4$ vs. RR = 1.11, CI = 1.00 to 1.24, $k = 8$; $p = .86$).

Regarding MoD, interventions fully delivered face to face (RR = 1.08, CI = .89 to 1.29, $k = 4$ vs. RR = 1.12, CI = 1.02 to 1.23, $k = 8$; $p = .70$) and those using a combination of face to face and at a distance (RR = 1.19, CI = .95 to 1.49, $k = 6$ vs. RR = 1.04, CI = .97 to 1.13, $k = 6$; $p = .27$) did not have statistically significant higher effects achieving smoking cessation when compared to other approaches. No other MoD was assessed due to the limited number of studies.

As for the source of the intervention, interventions involving healthcare professionals did not have statistically significant different effects in achieving smoking cessation compared to interventions without their involvement (RR = 1.05, CI = .95 to 1.16, $k = 8$ vs. RR = 1.19, CI = 1.03 to 1.38, $k = 4$; $p = .17$).

Theory-based interventions did not have statistically significant higher effects achieving smoking cessation compared to interventions without a theoretical basis (RR = 1.05, CI = .94 to 1.18, $k = 4$ vs. RR = 1.13, CI = 1.02 to 1.26, $k = 8$; $p = .38$).

Lastly, positive effects for smoking cessation were more strongly associated with interventions not using the BCT *1.1 goal setting (behaviour)* (RR = 1.40, CI = 1.11 to 1.76, $k = 3$) than with those using it (RR = 1.03, CI = .98 to 1.08, $k = 9$; Q = 6.73, $p = .01$), whereas interventions using *1.2 problem solving* did not show a significant difference in effects (RR = 1.09, CI = .89 to 1.34, $k = 4$ vs. RR = 1.10, CI = 1.02 to 1.19, $k = 8$; $p = .94$).

Please refer to table 4 of supplementary materials 4 for the differential effects of these factors on smoking cessation at the end of intervention for subjective and dichotomous data.

Regression analyses

Physical activity

For the *continuous and subjective* data, longer intervention duration ($\beta = .00$, CI = −.00 to .00, $k = 20$; $p = .49$, $R^2 = 0\%$) and targeting more behavioural domains ($\beta = -.06$, CI = −.16 to .04, $k = 20$; $p = .27$, $R^2 = 0\%$) were not significantly associated with higher physical activity levels. Please refer to table 5 of supplementary materials 4 for the differential effects of these factors on physical activity at the end of intervention for subjective and continuous data.

For the *dichotomous and subjective* data, longer intervention duration was associated with higher levels of physical activity ($\beta = .00$, CI = .00 to .00, $k = 12$; $p = .01$, $R^2 = .11\%$), but no association was found for number of behaviours targeted by the interventions ($\beta = -.00$, CI = −.18 to .17, $k = 12$; $p = .98$, $R^2 = 0\%$). Please refer to table 6 of supplementary materials 4 for the differential effects of these factors on physical activity at the end of intervention for subjective and dichotomous data.

Fat intake

For the **continuous and subjective** data, no significant associations were found between reducing fat intake and longer intervention duration ($\beta = .00$, CI = −.00 to .01, $k = 10$; $p = .05$, $R^2 = .35\%$), nor with targeting more behavioural domains ($\beta = .04$, CI = −.33 to .41, $k = 10$; $p = .84$, $R^2 = 0\%$). Please refer to table 7 of supplementary materials 4 for differential effects of these factors on fat intake at the end of the intervention for subjective and dichotomous data.

Smoking cessation

For the *subjective and dichotomous* data, no significant associations were found between smoking cessation and longer intervention duration ($\beta = .00$, CI = −.00 to .01, $k = 12$; $p = .23$, $R^2 = 0\%$), nor with targeting more behavioural domains ($\beta = .08$, CI = −.05 to .20, $k = 12$; $p = .17$, $R^2 = 0\%$). Please refer to table 8 of supplementary materials 4 for the differential effects of these factors on physical activity at the end of intervention for subjective and dichotomous data.

Discussion

Sixty-one interventions aiming to change two or more health-related behaviours of individuals with chronic conditions were identified in Silva et al.'s (2024) systematic review. When looking at the characteristics of these studies and components of the interventions, we verified that most MHBC included interventions focused on supporting individuals with cardiovascular diseases, aimed to change the behavioural clusters 'physical activity, diet and smoking' and 'physical activity and diet', used some form of human MoD, were delivered in an individual format, lasted for up to a year, were not theory informed, and frequently used the BCTs *1.1 goal setting (behaviour), 1.2 problem* solving and *2.3 self-monitoring of behaviour*.

Looking at the specific behavioural clusters targeted by these interventions can be an important factor to understand their success and dynamics. Among the interventions analysed, 'physical

activity, diet and smoking' was the most frequently targeted behavioural cluster. Our findings found no evidence that targeting specific clusters ('physical activity, diet and smoking' or 'diet and physical activity') led to significant differences on the effects of any behaviour (physical activity, fat intake, or smoking cessation). Despite considerable research focusing on specific behaviours isolated or specific clusters – mostly diet and physical activity (e.g., Cradock et al., 2017; Duan et al., 2021; Spark et al., 2013) – , there remains limited information regarding the potential dynamics of targeting specific behaviours together (van Allen et al., 2023).

Regarding the MoD of these interventions, a wide range of methods were used, including face to face sessions, remote delivery through electronic means, a combination of both, and even automated approaches without any human contact. Our analyses indicated that for promoting physical activity delivering the interventions entirely in-person might not yield the best results. Previous research has highlighted the effectiveness of less demanding delivery methods (e.g., passive interventions and face-to-face presentations) in targeting multiple behaviour changes (Wilson et al., 2015). When looking specifically at electronic MoDs, traditional approaches (e.g., SMS and telephone) have shown greater effectiveness in promoting healthy dietary habits (Duan et al., 2021). Understanding the methods used to deliver the intervention to its target population can give us important insights into its impact on the reception of intervention techniques and their influence on the intervention effects (Marques et al., 2020). Moreover, this understanding can also shed light on the variability of these dynamics based on the behavioural cluster targeted.

The source of interventions is another important factor to consider. In our analyses we looked for associations between having a healthcare professional delivering the intervention as opposed to other interventionists, and found no significant differences. Cradock et al. (2017) found that to change diet and physical activity, using experts in these areas (e.g., exercise physiologists and dietitians) was more effective than non-experts (e.g., doctors or nurses) for better clinical outcomes. It would be valuable to further examine whether different types of professionals, potentially through multidisciplinary teams, are better suited for targeting specific behavioural clusters. More, having access to more detailed information regarding the source of the intervention (e.g., type of expertise, training received), can provide us a more in-depth understanding of the key characteristics of those delivering the interventions and eventually contribute to maximize its impact (Norris et al., 2021).

In relation to intervention duration, our findings suggest that longer interventions may lead to slightly better results in increasing physical activity levels. This is in line with previous studies that have shown that interventions with longer durations are associated with better behavioural outcomes (Meader et al., 2017; Wilson et al., 2015). Still, the insufficient reporting in most studies regarding intervention duration, as well as number and frequency of interventions, hampers our ability to make comprehensive interpretations. The reporting was particularly limited regarding the timing of specific BCTs within the intervention and the duration specific behaviours were targeted.

In terms of theory usage, it is important to note that most interventions in this review did not report using a theory to inform their development. When a theory was mentioned, the TTM and SCT were most commonly reported. These findings are consistent with previous reviews that also observed a low utilisation of theories in MHBC interventions (e.g., Alageel et al., 2017; Cradock et al., 2017). Interestingly, Duan et al. (2021) found that most of the eHealth interventions they examined were theory-based, which raises the question of whether digital interventions tend to use theories more frequently. Our analysis indicated no statistically significant differences between theory-based interventions and atheoretical ones. Duan et al. (2021) on the other hand, reported greater effects of theory-based interventions on physical activity outcomes. Similar to our review, other studies have highlighted the inadequate reporting of the extent to which theory tends to be employed in interventions (Alageel et al., 2017; Cradock et al., 2017), which hinders our understanding and analysis of the role of theory in these interventions. Also, the results might be more influenced by the choice of theory, than by the mere presence or absence of using a theory to inform intervention development. Theories need to be advanced to consider the dynamics of

multiple behaviour change, rather than applying 'single behaviour change theories' to multiple behaviour change. Theoretical explanations for the dynamic processes of targeting multiple behaviours through which MHBC interventions may be effective have been proposed, namely through specific 'carry-over mechanisms', i.e., where resources such as experiences, skills, knowledge, and self-efficacy, are carried over from one domain to another (Geller et al., 2017). Alongside, there is also the concern that by targeting multiple behaviours we incur in the risk that it becomes too burdensome for individuals and, as a result, ineffective (Nigg et al., 2002; Sweet & Fortier, 2010). More research is also needed to fully understand the role of compensatory cognitions, i.e., beliefs that unhealthy behaviours can be compensated for by engaging in other healthy behaviours (e.g., believing that physical activity can compensate for an unhealthy diet; Geller et al., 2017). Still, none of these theoretical approaches have been identified in the included studies. Further understanding of these dynamics is necessary in chronic disease management, particularly in multimorbidity, where patients are often required to make multiple behavioural changes in addition to complying with complex treatment plans.

Among the identified BCTs, the most commonly used ones were *1.1 goal setting (behaviour)*, *1.2 problem solving* and *2.3 self-monitoring of behaviour*. However, it was not always clear if these techniques were used to target specific behaviours or if they were applied to all behaviours addressed by the interventions. Moreover, the links between theory and the use of BCTs were sometimes unclear, even in theory-based interventions. Findings from our subgroup analyses suggest that not using the BCT *1.1 goal setting (behaviour)* tended to be more effective for promoting smoking cessation. To our knowledge, previous reviews of MHBC interventions have not examined the effects of specific BCTs on behavioural outcomes extensively. However, in the context of type 2 diabetes, *8.7 graded tasks* have been associated with a reduction in HbA1c (Cradock et al., 2017), and in cardiovascular risk management, the inclusion of *1.4 action* planning was associated with greater weight loss (Alageel et al., 2017). Interestingly, despite the extensive use of BCT *1.1 goal setting (behaviour)* simultaneously targeting different behavioural domains in the included trials, as well as existing evidence indicating that processes associated with multiple-goal pursuit can be effective in achieving multiple behavioural changes (e.g., by exploring goal facilitation, Presseau et al., 2013; or goal prioritisation, Conner et al., 2022), no study included in this review specifically addressed the dynamics of multiple-goal pursuit. Further research is needed to gain a clearer understanding of the direct impact of BCTs on behavioural outcomes rather than indirect measures, and on the potential contribution, multiple-goal pursuit approaches can have to the MHBC field.

Limitations

One of the limitations of this study relates to the scope of the literature search. Only electronic databases were searched, and no grey literature was consulted. Additionally, our inclusion criteria were limited to studies published in English. While these decisions were made due to practical considerations, they might have resulted in missing studies and introduced a risk of publication bias. Future reviews should consider expanding their search to gray literature and different languages.

The search terms used might have also led to some missing studies, by using 'chronic conditions'-related terms rather specific conditions' names (e.g., type 2 diabetes). To address this concern, included studies in previous reviews of MHBC interventions were assessed for inclusion. This limitation also emphasises the importance of using of a shared language to facilitate dissemination of findings.

We also had a relatively small number of eligible studies available to conduct further analyses. Moreover, the underspecified reporting of aspects of studies poses challenges to their interpretability. In particular, as most studies did not use taxonomies or ontologies to comprehensively describe their intervention content in a standardised way, some bias may have been introduced during the data extraction process. To mitigate this issue, a second coder extracted information for twenty percent of the included studies, in order to assess inter-rater reliability, and uncertainties were resolved through discussions.

Strengths

This review makes an important contribution to the field by using the most up to date ontologies and taxonomies to guide the data extraction process and by establishing connections among various intervention components. This approach enables the creation of cumulative data, which holds the potential to inform future interventions and reviews within this context. In addition, the adoption of a standardised language through the use of existing taxonomies and ontologies enhances clarity and fosters a more nuanced comprehension of MHBC interventions. This work facilitates mapping these interventions to any framework that can be used for its improvement or optimisation.

Conclusion

This review provides valuable insights into MHBC interventions targeting individuals with chronic conditions and their key components. To advance the quality of MHBC interventions, future research should focus on employing established taxonomies and ontologies to accurately describe intervention components. Additionally, conducting comprehensive testing of theories can enhance the understanding of the underlying mechanisms through which these interventions impact behaviour change. Having clear descriptions of the 'active ingredients' of these interventions becomes paramount, as certain BCTs might be effective for specific behaviours but not for others, making the links between BCTs and their behavioural targets essential. Providing clear and standardised information on intervention components can help us understand not only if interventions are working, but also the underlying mechanisms (the 'how') through which they operate. This contribution can help us optimise both current and future interventions and facilitate their potential dissemination.

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Data availability statement

An early version of this manuscript was uploaded to PsyArXiv (10.31234/osf.io/yfmjx). All data relevant to the study are included in the article or available at Open Science Framework (https://osf.io/abe92/). Any other data from this review is available from the corresponding author upon request.

ORCID

Justin Presseau http://orcid.org/0000-0002-2132-0703

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