Changes in determinants of physical activity during interventions for adults with chronic diseases: systematic review and meta-analysis of randomised controlled trials

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Abstract

A better understanding of how interventions can increase the determinants of physical activity in adults with chronic diseases is needed to improve their efficacy. The present meta-analysis aims to assess the efficacy of behaviour change interventions in impacting determinants of physical activity in adults with chronic respiratory, metabolic, and/or cardiovascular disease. In addition, this review seeks to identify clinical and intervention characteristics associated to efficacy, including disease, mode of delivery, nature of operational constructs and behaviour change techniques (BCTs). The electronic bibliographic databases consulted were PubMed, PsycINFO, Web of Science and Open Grey. Studies involving adults (≥ 18 years) with chronic cardiovascular and/or respiratory and/or metabolic diseases were included. Only randomised control trials (RCT), explicitly targeting a change in determinants of behaviour and assessing one or several operational constructs pre- and post-intervention were included. The meta-analysis was conducted on 43 studies (202 effect sizes; $N=15\ 361$); the analyses revealed a medium effect of interventions on factors associated with motivation at the end of the intervention ($d=0.5$; 95% CI $[0.283;0.716]$; $p < .001$; $k=43$; 200 effect sizes) and 3 months or more after ($d=0.69$ (95% CI $[0.038, 1.347]$; $p < .001$; $k=8$; 30 effect sizes). The presence of the technique Framing/reframing led to a higher effect on determinants of physical activity ($d=1.586$; 95% CI $[1.055;2.117]$; $p < .001$; $k=5$; 16 effect sizes). Physical activity interventions are effective to change the determinants of physical activity and the presence of framing/reframing in the intervention content leads to higher effects.

Keywords: Meta-analysis; physical activity; determinants of behaviour; chronic disease; behaviour change techniques; M-PAC approach

Introduction

Chronic cardiovascular, metabolic and respiratory conditions are among the most prevalent non-communicable diseases (Assurance Maladie, 2020; World Health Organization, 2014), and contribute directly and indirectly towards majority of deaths worldwide with major financial costs to society (Ding et al., 2016; Soriano et al., 2020). Moreover, hypertension, type 2 diabetes, obesity, and chronic obstructive pulmonary diseases often coexist within one person (Einarson et al., 2018; Melo et al., 2014; Seicean & Punjabi, 2008; Vos et al., 2015), and are common comorbid conditions studied together (Bricca et al., 2020; Cheen et al., 2019; Doos et al., 2014; Kastner et al., 2018; Wang et al., 2020). These diseases share inactivity as risk factor, and inflammation appears to be aetiologically linked to the pathogenesis of all of them (Gleeson et al., 2011; Pedersen & Saltin, 2015). The anti-inflammatory effects of exercise and its many benefits make physical activity a non-drug therapeutic strategy used for the treatment of these diseases (Boulé et al., 2001). Indeed, participating in physical activity is associated with positive health effects in adults with these conditions, with benefits for mortality, disease-specific outcomes, quality of life, physical functioning, and fatigue (Carroll et al., 2014; Garcia-Aymerich et al., 2008; Garcia-Rio et al., 2009; Taylor et al., 2004; Thomas et al., 2006; Zanuso et al., 2010). As a consequence, similar physical activity recommendations (in terms of time per week, intensity, number of set and repetition) are formulated in the prevention of these conditions (Turner-Moss et al., 2021).

Yet, despite the well-known health benefits, adults living with those conditions are still characterized by more sedentary and physically inactive lifestyles than those without chronic disease (Morrato et al., 2007; Valero-Elizondo et al., 2016). These low adherence rates are not altogether surprising, as individuals with chronic disease have specific physical activity barriers for instance, related to health, fatigue, pain and disease complications (Baillot et al., 2021; Kang et al., 2021; Prior & Suskin, 2018). Health-enhancing physical activity is a particularly difficult behaviour to integrate. Indeed, it has to be performed several times per week, takes the body out of rest and induces variable affective responses, requires appropriate clothes, equipment and facilities, and takes substantial time to achieve, organize,

and regulate (Rhodes & Nigg, 2011). In many prospective studies, a positive association between factors associated with motivation and physical activity behaviour was found in persons with chronic disease (Parschau et al., 2014; Plotnikoff et al., 2010; Scholz et al., 2005). Thus, increasing the level of determinants of physical activity seems necessary to increase the patients' level of physical activity. Moreover, studies have shown that intention to perform a behaviour is necessary (McEachan et al., 2011; Rhodes & Nigg, 2011; Weinstein, 2007) but not sufficient to initiate a new behaviour (Rhodes & de Bruijn, 2013a; Rhodes & Dickau, 2012), and that the psychological processes associated with behaviour change were manifold. Indeed, many behaviour change determinants participate in the initiation of physical activity (Bélanger-Gravel et al., 2013; Conn et al., 2011; Knittle et al., 2018; Kwasnicka et al., 2013; McEwan et al., 2016; Sheeran et al., 2020; Zhang et al., 2018) as well as its maintenance (Gardner et al., 2011; Kwasnicka et al., 2016; Rebar et al., 2016; Rhodes et al., 2016; Rhodes & de Bruijn, 2013b). In this literature, these constructs are associated with a small to large effect sizes for explaining behaviour change.

These results indicate that focusing specifically on the effects of interventions toward the determinants of physical activity, developed among adults with chronic disease, is paramount to understand how to develop more effective physical activity interventions. Moreover, prior systematic reviews and meta-analysis examined the role of factors that vary among interventions including the presence and nature of behaviour change theories underpinning their content (Bélanger-Gravel et al., 2013; Conn et al., 2011; Knittle et al., 2018; Kwasnicka et al., 2013; McEwan et al., 2016; Sheeran et al., 2020; Zhang et al., 2018), behaviour change techniques (BCTs) implemented (Dombrowski et al., 2012), and their mode of delivery (Samdal et al., 2017). This meta-analysis aims to assess the efficacy of behaviour change interventions on determinants of physical activity, by identifying which parameters influence them.

Operational constructs

Several theories of behaviour change have been used to provide a framework for understanding physical activity behaviour and to guide physical activity interventions for adults with chronic disease.

These include the socio-cognitive approaches - such as the theory of planned behaviour (Ajzen, 1991), the social cognitive theory (Bandura, 1977, 1998), the transtheoretical model (Prochaska & DiClemente, 1982), or the health action process approach (Schwarzer et al., 2008) - and dual process frameworks (Strack & Deutsch, 2004).

The Multi-Process Action Control (M-PAC) approach (Rhodes, 2017) is a recent integrative model which aims at understanding physical activity. It brings together the relevant operational constructs present in several streams of contemporary research in physical activity (see Figure 1). Schematically, the M-PAC framework is composed of three articulated levels, all linked together. The first level corresponds to the phases of behaviour and include intention formation, adoption of action control and maintenance of action control. The second is related to behaviour change processes, called initiating reflective processes, ongoing reflective processes, regulation processes and reflexive processes. Finally, the third level corresponds to the determinants of behaviour, also called operational constructs. Concretely, the reflective and regulation processes refers to constructs that are conscious reasoned and deliberate, while reflexive processes refers to constructs that are nonconscious and automatic (Rebar et al., 2021). In the M-PAC conceptualization, the first processes – i.e., the initiation of reflective processes - are linked to the initiation of intention formation, while the second – i.e., ongoing reflective processes - concern the constructs having a longer action in this formation. Thus, the initiating reflective processes include perceived capability and instrumental attitude. The ongoing reflective processes include affective judgements, perceived opportunity and barriers. Next, the third processes, the regulation processes, refer to constructs that underlie goal attainment, relative to how one executes a behaviour by implementing one's intentions, adapting them to a given context. Among these constructs, there are setting goals, coping planning, action planning, social support, maintenance self-efficacy. Finally, the fourth processes, the reflexive processes, represent less reasoned constructs that influence behavioural action, most often through learned associations that are triggered through particular circumstances and stimuli (e.g., identity, habit).

To date, there are few comprehensive available data pertaining the role of operational constructs toward physical activity in adults with chronic cardiovascular, metabolic and respiratory disease. However, such evidences are needed to better understand how interventions may change physical activity levels throughout the entire process of behaviour adoption. Indeed, previous meta-analyses on determinants of physical activity (Knittle et al., 2018; Ntoumanis et al., 2020; Olander et al., 2013; Steinmetz et al., 2016) have included operational constructs mostly linked with initiating and ongoing reflective processes (i.e., self-efficacy, subjective norms, attitudes, intentions, autonomous motivation, perceived behavioural control and basic psychological needs) and associated with the formation of intentions (Hagger et al., 2003; Rhodes, 2017; Schwarzer et al., 2008). These meta-analyses consistently indicate that interventions are effective to change behavioral determinants with a significant small effect. There is however a lack of studies toward regulation processes and reflexive processes which are linked with maintenance of the behaviour. Moreover, among these meta-analyses, only two have focused on determinants of physical activity (Knittle et al., 2018; Olander et al., 2013), and only one involved adults with chronic disease specifically (Olander et al., 2013) (obesity). No meta-analyses have brought together results toward chronic cardiovascular, metabolic and respiratory disease to explore the effect of the type of disease or levels of severity in the interventions effectiveness, and to identify strategies to change determinants of physical activity in these specific populations. Thus, this meta-analysis could help to refine behavioral interventions in that context.

[Insert Figure 1 about here]

Moderators of intervention efficacy related to the determinants of physical activity

There were attempts in some meta-analyses to identify which interventions characteristics were associated with higher efficacy. In several meta-analyses, it was hypothesized that change in operational constructs could vary depending on the BCTs (i.e., an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour ; Michie et al., 2013). These studies showed greater effectiveness in changing determinants of behaviour when, for instance, the techniques action planning, self-monitoring, goal

setting, feedback on behaviour, mental rehearsal of successful performance, emotional social support, social reward, behavioural practice and self-talk are present (Knittle et al., 2018; Ntoumanis et al., 2020; Olander et al., 2013). Regarding other characteristics of interventions, the location of the intervention (community settings show a positive effect compare to universities, schools and clinics (Ntoumanis et al., 2020)), the mode of delivery (components delivered in a group session show a positive effect compare in an individual session (Steinmetz et al., 2016)), and the type of professionals involved (components delivered by a researcher were followed by more important changes, compared to sport professionals, health professionals, peers, psychologists, dieticians (Knittle et al., 2018)), for instance, were identified as significantly impacting changes in the determinants of behaviour.

The present study

The present systematic review and meta-analysis was framed by an integrative behaviour change model, called M-PAC (Rhodes, 2017). The aims were to (i) assess the effectiveness of physical activity interventions for changing the determinants of physical activity in adults with chronic respiratory, metabolic, and/or cardiovascular disease, (ii) identify which BCTs were associated with intervention effectiveness, and (iii) determine whether the effects varied depending on the nature of the operational constructs, nature of the interventions, population characteristics and contexts.

Methods

The systematic review and meta-analysis protocol was registered in PROSPERO. The present article is reported in accordance with the PRISMA guidelines (Liberati et al., 2009) and the recommendations of Lakens et al. (Lakens et al., 2016). All relevant study material (e.g, PRISMA checklist, pre-registration protocol, pre-print, data and R code) are available on the Open Science Framework.

Search strategy

The following electronic bibliographic databases were searched: PubMed, PsycINFO, Web of Science and Open Grey. Article titles, keywords and abstracts were screened with terms referring to (i) physical activity, (ii) behaviour change (theories and constructs) and (iii) chronic disease (see the supplementary

File 2 for the search strategy). There were no restrictions on publication date. Studies published, up to January 2020, in English, Spanish, Portuguese, French, and Italian were considered for inclusion.

To establish interrater reliability in the study selection, dyads identified eligible studies based on 5% of the articles. A satisfactory agreement was obtained with a kappa statistic equal of 0.83, meaning that observers were relatively agreed with each other (Landis & Koch, 1977). Next, four researchers independently screened the article titles and abstracts retrieved using the search strategy and then the retained full texts. When it was not clear whether a study fulfilled all the inclusion criteria, the content was discussed by the team until consensus was reached. For studies fulfilling all the inclusion criteria but presenting data in a way potentially unsuitable for meta-analysis, the corresponding authors were contacted up to two times by email in an effort to obtain the appropriate data.

Inclusion criteria

To be eligible for inclusion, a study had to be an RCT involving adults (≥ 18 years) with chronic cardiovascular (e.g., stroke, coronary, hypertension, heart failure), respiratory (COPD), metabolic disease (e.g., obesity, type 2 diabetes). The authors of the studies just have to evoke chronicity for it to be included. Generally, the duration of the symptoms was not provided in the studies. Furthermore, the study had to have (i) delivered an intervention explicitly targeting a change in determinants of physical activity and/or in physical activity behaviour and (ii) measured an operational construct pre- and post-intervention. Physical activity intervention was defined by an intervention which aims to encourage individuals to increase his levels of physical activity for initiate and/or maintain healthy levels of physical activity. Moreover, the physical activity practices eligible were linked with exercise, a subset of physical activity, which is planned, structured, and repetitive bodily movement with the goal of improving or maintaining physical fitness (Haskell et al., 2008). Absence of a measure at follow-up was not an exclusion criterion. All control conditions were included (i.e., no intervention, minimal intervention, attention placebo or active comparison). Studies were excluded if the intervention was limited to a pharmacological treatment, and if no differences existed between the interventional and control groups in regards of BCT related to physical activity.

Coding and data extraction

Once the final inclusion of studies was finalized, dyads extracted data based on 9% of the articles to establish interrater reliability in the data coding. An almost perfect agreement was obtained with a kappa statistic of 0.88 for the extraction of key effect sizes. Next, five researchers independently extracted relevant information into a csv file (see supplementary File 3-5, 9). Missing data that were needed to calculate effect sizes were requested from the corresponding authors and, when available, the supplementary online information (e.g., protocol study, ...) was consulted.

Sample characteristics

Information about participants age, gender, BMI/overweight status, disease (metabolic/ respiratory/ cardiovascular), initial physical activity level, context (routine care/post-acute disease-related event) and socioeconomic status were collected.

Operational constructs outcomes

As this review targeted various operational constructs, from socio-cognitive to dual process approaches, and in order to integrate a dynamic approach with markers of initiation and maintenance, this review chose the M-PAC to organize the analysis of factors associated with physical activity behaviour. Based on the M-PAC approach (Rhodes, 2017), operational constructs were categorized into four main categories (i.e., initiating reflective processes, ongoing reflective processes, regulation processes and reflexive processes) corresponding to the four behaviour change processes, and for more readability, the names of similar constructs have been standardized (see the Supplementary File 6 for more details on categorization).

The number of subjects in each randomised group, as well as the mean and standard deviation score for each operational constructs assessed pre- and post-intervention were retrieved. When available, follow-up data were coded as well as the duration between post- and follow-up measurements.

Behaviour change techniques

BCTs present in the intervention were coded following the v1 taxonomy of behaviour change techniques (Michie et al., 2013). This taxonomy comprises an extensive hierarchical classification of

clearly, distinctly (i.e., no overlap no redundancy) and precisely labeled BCTs. This hierarchical structure is composed of 16 reliable and stable groupings of BCTs, defined and labeled based on conceptual similarities and differences between BCTs, and 93 individual BCTs. The clusters and BCTs are identifiable by a number. Thus, the clusters are: 1. Goals and planning, 2. Feedback and monitoring, 3. Social support, 4. Shaping knowledge, 5. Natural consequences, 6. Comparison of behaviour, 7. Associations, 8. Repetition and substitution, 9. Comparison of outcomes, 10. Reward and threat, 11. Regulation, 12. Antecedents, 13. Identity, 14. Scheduled consequences, 15. Self-belief, 16. Covert learning. And, for instance, the BCTs for the cluster 3. Social support are: 3.1. Social support (unspecified), 3.2. Social support (practical), 3.3. Social support (emotional). Motivational interviewing was coded independently (i.e., as a specific BCT). Only the BCTs present in the intervention group and absent in the control group were coded (G.-J. Y. Peters et al., 2015). To improve consistency in this specific stage, one researcher independently coded the BCTs.

Intervention and control group characteristics

The modes of delivery of the intervention were characterized according to the following criteria: group/individual; face-to-face/mobile; apps/mail/text messages; self-guided/paper-based/web; total contact time; number of contacts, duration of the intervention; interventionist; and location of the intervention. Control groups were characterized as no intervention, minimal intervention (e.g., information or education), and active comparison.

Risk of bias

Risk of bias was evaluated using the Cochrane Risk of Bias tool 2.0 (Sterne et al., 2019) and performed by the same researchers in charge of the data extraction. This tool assess bias related to: (i) bias arising from the randomisation process; (ii) bias due to deviations from intended interventions; (iii) bias due to missing outcome data; (iv) bias in the outcome measurements; (v) bias in the selection of the reported result; and (vi) overall risk of bias. In the event of ambiguous cases, consensus was sought through team discussion. Studies were rated as showing either “low,” “high,” or “some concerns” risk of bias on each of these criteria. A study was declared to show an overall low risk of bias if at least

three criteria were rated as low. Typically, blinding of patients and treatment providers is difficult to achieve and maintain for non-pharmacological interventions (Boutron et al., 2007), resulting in a high risk of bias in this domain.

Statistical procedure

All analyses were performed with R (Version 3.2.0). Standardized mean difference was used to quantify the size of the group differences between experimental and control groups, using the R function *escalc* in the *metafor* package (Viechtbauer, 2010). Cohen's d-values with corresponding 95% confidence intervals (95% CI) were then used as the primary measure of overall effect size in the meta-analysis; the magnitude of effect sizes was interpreted as small $>.2$, medium $>.5$, or large $>.8$ (Cohen, 1988). Intention-to-treat data were used when available. The selected studies usually measured and reported more than one operational construct, and we therefore applied a multilevel approach to deal with the potential interdependency of the within-study effect sizes (Assink & Wibbelink, 2016). This approach was also empirically justified by comparing the indices of fit of the meta-analysis accounting for within-study variance with a reduced model accounting for between-study variance only. Given the superiority of the full model in comparison to the reduced one, a three-level meta-analytic model was used to calculate the combined effect sizes and perform the moderator analyses.

Multivariate and univariate outliers were spotted using a combination of techniques, including Baujat plots (Baujat et al., 2002) and residual Cook's distances. Outliers detected with these methods were compared and used to inform the sensitivity analyses. For the sensitivity analysis, we therefore estimated the average effect using only the studies with low risk of bias. Contour-enhanced funnel plots were used to assess publication bias (Peters et al., 2008) together with an Egger's test to assess funnel plot asymmetry (Egger et al., 1997). In order to analyse the possible publication bias, we performed a trim and fill procedure (Duval & Tweedie, 2000) by drawing a trim-and-fill plot using the *trimfill* function of the *metafor* package.

Heterogeneity was quantified using the I^2 indicator. Three sources of variance were modelled. Level 1 included the sampling variance for the observed effect sizes. Level 2 was the variance between effect

sizes from the same study. Lastly, level 3 refers to the variance between studies (Cheung, 2014). An I^2 value of 25 was interpreted as having a low dispersal, 50 as moderate, and 75 as high dispersal (Higgins et al., 2003). To prevent potential type I error, an α level of 0.01 was used.

Follow-up analyses were performed on operational construct when a measure was available at least 3 months after the end of the intervention.

Moderator analyses

Moderator analyses were conducted according to Assink and Wibbelink (Assink & Wibbelink, 2016) using distinct strategies for binary moderators (e.g., interventions delivered at the group *versus* the individual level), categorical moderators (i.e., clusters of BCTs) and continuous moderators (e.g., intervention duration). Significant moderator effects were discussed only when a minimum of 4 effect sizes were available and $p < .01$ to prevent potential Type I error occurring with the multiple moderator analyses performed.

Risk of bias assessments were conducted with the the robvis package (McGuinness & Kothe, 2019). The code and analyses were initially developed and performed by GC and then managed by CL. The dataset and script used for the analyses are available as Supplemental Materials (see Supplementary Files 3-5, 9, 10, 12 and 13).

Results

Identification of studies

The search and study selection procedure identified 51 studies that met the inclusion criteria, 43 of which reported complete data at baseline and post-intervention. Among the authors contacted, eight did not respond or were unable to provide the data needed to conduct the meta-analysis. The flow diagram in Figure 2 provides more detail on the process. Overall, these studies involved 202 study arms and 4,262 participants.

[Insert Figure 2 about here]

Descriptive sample characteristics

The mean age of the participants was 54.3 ($SD = 10.2$) years and ranged from 30 to 70 years. The mean BMI was 31.6 ($SD = 4.3$) kg/m² and ranged from 25 to 45 kg/m². A few interventions were specifically designed for women (25.5%) and only one for men. A total of 27 studies out of 51 (53%) focused on individuals diagnosed with metabolic disease (mainly type 2 diabetes or obesity), 16 studies (31%) included participants with cardiovascular diseases (mostly hypertension or coronary diseases), four studies (8%) included participants with respiratory diseases (COPD exclusively), and four included a mixed sample of participants with concomitant metabolic and cardiovascular disease. The presence of risk factors or co-morbidities was rarely mentioned (22%; 11 studies).

Twenty-seven trials were physical activity-specific (53%), whereas in the others cases physical activity was combined with diet (43%; 22 studies), medication management, reducing sedentary behaviour or smoking cessation. Regarding the control groups, most of the studies made comparisons with no intervention (61%; 31 studies), 16 (31%) with minimal intervention (e.g., booklet, educational session), and seven (14%) with another physical activity intervention differentiated by the type of physical activity, frequency or number of physical activity educational session. More detail on the descriptive characteristics of the selected studies is provided in Supplementary Files 3 and 4.

Descriptive intervention characteristics

On average, the intervention phases lasted 4.75 ($SD = 3.3$) months and ranged from 1 to 12 months, with five contacts of 52 minutes per month. Of the 51 trials, one proposed three interventions and six delivered two interventions to reach a total of 59 distinct interventions. Regarding the intervention location, most took place in a single location (76%; 45 interventions). Nineteen (32%) were delivered in a health establishment (e.g., hospital, health centre), 17 (29%) in the patient's home, five (8%) in a sports establishment (e.g., gymnasium, sports centre), and four (7%) in universities (in the principal investigator's research department). The other trials were delivered in two locations.

Of the 59 interventions, 48 (81%) involved an interventionist providing face-to-face sessions (75%; 36 interventions), phone sessions or both (21%; 10 interventions). Face-to-face contact was provided for groups (41%; 19 interventions), individuals (33%; 15 interventions) or both (11%; 5 interventions). Interventionists were health professionals (29%; 14 interventions), sports professionals (23%; 11 interventions), researchers (13%; 6 interventions) or, more rarely, a lifestyle coaches or sports science students (7%; 3 interventions). Twenty-five (52%) of the interventions included the supervision of physical activity practice.

Only six interventions (13%) with an interventionist combined the use of technology (e.g., web site, email, text messages or mobile application). Ten interventions (17%) were exclusively technology-based. Not much information regarding the technological aspect of the interventions was reported. The omitted information mostly concerned the time using mobile apps or web sites and the number of contacts with these tools. More detail on the descriptive characteristics of the interventions is provided in Supplementary File 4.

Behaviour change theories

Most trials cited at least one theory (68%, 35 studies). Among the 12 theories identified, the most cited were as follows: the social cognitive theory (39%; 20 studies), the self-determination theory (12%; 6 studies), the transtheoretical model (12%; 6 studies), the self-efficacy theory (10%; 5 studies), the health action process approach (8%; 4 studies) and the theory of planned behaviour (8%; 4 studies).

Operational constructs outcomes

Following M-PAC approach, no outcome of the 228 classified operational constructs belonged to the fourth behaviour change processes: reflexive processes, with the associated identity and habit subgroups. Of these 228 outcomes, 35 had no match with any category in the classification (i.e., amotivation, locus of causality, needs satisfaction) and were excluded of the analysis. Table 1 shows the number of effect sizes concerning by groups and subgroups. On average, interventions assessed four operational constructs (range 1-11). Eight interventions assessed at least one subgroups of each

group. A total of 27 distinct operational constructs were identified. The most frequently assessed were “instrumental attitude”, “task self-efficacy”, “social support”, “intrinsic motivation” and “intention”. The first two constructs refer to initiating reflective processes, while the next two correspond to ongoing reflective processes, and the last one are regulation processes. More detail on the classification of operational constructs is provided in Supplementary Files 6-8.

Few studies reported maintenance-related operational constructs (20%; 12 studies), but these 12 studies nevertheless accounted for 49 effect sizes (21.5%). The assessed timeframes were less than 6 months for seven studies (27 effect sizes) and between 6 and 9 months for three studies (20 effect sizes), with two effect sizes corresponding to 10 months. More detail on the operational constructs is provided in Supplementary File 9.

[Insert Table 1 about here]

Taxonomies and behaviour change techniques

BCT taxonomies were mentioned in seven studies (14%). Three studies referred to the taxonomy of behaviour change techniques (Abraham & Michie, 2008), two to the Coventry Aberdeen London REfined (CALO-RE) taxonomy (Michie et al., 2011), and two to the v1 taxonomy of behaviour change techniques (Michie et al., 2013).

Across the 59 interventions, 15 of the 16 clusters were identified as present in at least one study arms (no BCT from cluster 14). The most used clusters were as follows: 1. goals and planning (66%; 39 interventions), 4. shaping knowledge (64%; 38 interventions), 2. feedback and monitoring (63%; 37 interventions), 6. comparison of behaviour (58%; 34 interventions), 8. repetition and substitution (54%; 32 interventions), 5. natural consequences (47%; 28 interventions) and 3. social support (44%; 26 interventions). When clusters 1, 2 and 10 were involved, the average number of distinct BCTs was, respectively, three (range: 1 to 6), two (ranged from 1 to 4), and two (ranged from 1 to 3). For the 12 clusters, one BCT was used (ranged from 1 to 3). In total, an average of seven BCTs (ranged from 2 to 21) were involved in each intervention and associated with five clusters (ranged from 1 to 10). Overall,

seven interventions included motivational interviewing. More detail on the BCT clusters is provided in Supplementary File 5.

Risk of bias

Twenty-one articles (48.8%) received a low risk of bias rating on ≥ 3 criteria. These were coded as studies of higher quality. The overall quality was suboptimal for a high proportion of these RCTs. Twenty studies (46.5%) met ≤ 1 criteria, and no study met all the criteria. In Supplementary File 12, the summary barplot presents the overall percentages of studies with high, low, or some concerns of bias on each of the criteria. Regarding the eight studies assessing the determinants of physical activity for at least 3 months after the end of intervention, six articles (75%) received a low risk of bias rating on ≥ 3 criteria. In Supplementary File 13, the summary barplot presents the percentages of studies (assessment at least 3 months after) with high, low, or some concerns of bias on each of the criteria. Full information on the risk of bias of each study is available in Supplementary File 10.

Meta-analysis and sensitivity analyses

Meta-analysis indicated a medium effect of the interventions on post-intervention's motivation $d=0.52$ (95% CI [0.277;0.771]; $p < .001$; $k=43$; 202 effect sizes; result without outliers ($d=0.50$; 95% CI [0.283;0.716]; $p < .001$; $k=43$; 200 effect sizes). Between-study heterogeneity was high ($I^2 = 79\%$). Sensitivity analysis including only low risk of bias studies leads to higher effect of the interventions on the determinants of physical activity ($d=0.68$; 95% CI [0.254;1.114]; $p < .001$; $k=21$; 91 effect sizes). We found indications of publication bias. Egger's test was statistically significant ($p=0.01$). Duvall and Tweedie's trim-and-fill procedure imputed five missing studies. After adjustment, the average effect size was $d=0.48$ (95% CI [0.44, 0.60]; $p<.001$; $k=48$; 207 effect sizes). The script R in the supplementary File 12 present all the post-intervention statistical analysis.

Effect size for follow-up analyses 3-month post intervention was medium to large ($d=0.74$; 95% CI [0.031;1.452]; $p < .001$; $k=8$; 36 effect sizes). Between-study heterogeneity was moderate ($I^2 = 53\%$).

In the sensitivity analysis in which outliers were removed, the results were in line with the main finding $d = 0.69$ (95% CI [0.038;1.347]; $p < .001$; $k=8$; 30 effect sizes). The pooled effect estimate was statistically not significant when only low risk of bias studies were included ($d=0.51$; 95% CI [-0.155;1.175]; $k=6$; 24 effect sizes). We found indications of publication bias. Egger's test was statistically significant ($p<.0001$). Duvall and Tweedie's trim-and-fill procedure imputed 19 missing studies. The adjusted average effect size declined to $d=0.09$ (95% CI [-0.384 0.567]; $p<.0001$; $k=27$; 55 effect sizes), which was no longer statistically significant due to the 95% CI. More detail on the follow-up statistical analyses can be found in Supplementary File 13. Additional meta-analyses on the effect of interventions on specific operational constructs (e.g., task self-efficacy, action planning) have been added to provide more information (see Supplementary File 14).

Moderator analyses

Because heterogeneity was detected, various moderator analyses were computed. For stake of parsimony, only significant results are presented here. Full presentation on the moderator analyses are presented in Supplementary Files 11-13.

At the end of intervention, only one moderator was statistically significant. The presence of cluster 13, “identity”, was associated with large changes in operational constructs ($d=1.586$; 95% CI [1.055;2.117]; $p < .001$; $k = 5$; 16 effect sizes) compared to interventions that did not include BCTs related to identity change. At least 3 months after the end of intervention, cluster 10, “reward and threat”, was the only one to be statistically significant ($d=1.487$; 95% CI [0.965;2.008]; $p < .001$; $k = 3$; 18 effect sizes).

Discussion

This meta-analysis sought to assess the efficacy of physical activity interventions for changing the determinants of physical activity in adults with chronic cardiovascular, metabolic and respiratory disease. This meta-analysis is the first to study this issue with regard to physical activity, adopting an integrative approach (M-PAC (Rhodes, 2017)) and focusing on the specific needs of these populations. The analyses revealed a medium effect of interventions on the determinants of physical activity at the

end of the intervention and at least 3 months after the intervention. Of the potential moderators examined, only BCT clusters 13 “identity” and 10 “reward and threat” were associated with higher beneficial changes in the determinants of physical activity, at the end of the interventions and during follow-up, respectively.

Overall effect size

Compared to control groups, the intervention arms showed a medium effect on factors associated with motivation. This medium effect in the main analysis also emerged when accounting for outliers, risk of bias and publication bias, which supports the robustness of this finding. This result is consistent with previous work following a similar objective where small (French et al., 2014; Knittle et al., 2018; Rhodes & Dickau, 2012) to moderate (McDermott et al., 2016; Olander et al., 2013; Webb & Sheeran, 2006) effect sizes were found.

Regarding available follow-up data (i.e., longer than 3 months), we also found a significant, medium effect size, which still emerged when accounting for outliers. However, controlling for potential publication bias and risk of bias lead to a non-significant effect. Heterogeneity of effect sizes was moderate, but considering the small number of studies the value of I^2 still uncertain. This result was larger than the effect size noted by Ntoumanis et al. (Ntoumanis et al., 2020), $g = 0.28$, for changes in psychological need towards health behaviours. To our knowledge, this review, in non-specific sample, represents the only attempt to explore changes in operational constructs several months after the intervention (follow-up). Given the small number of studies, it remains unclear whether interventions are effective to improve the determinants of physical activity at follow-up. The maintenance in the change of operational constructs observed in patients’ regarding physical activity needs to be addressed in the future.

Moderators of interventions effectiveness on operational constructs

Beyond the overall effect of interventions, this study sought to explore potential differences in the effectiveness on various dimensions of the determinants of physical activity. Following the M-PAC, we assessed whether the effects observed were more pronounced for initiating reflective processes,

ongoing reflective processes, regulation processes and reflexive processes, at the end of the intervention. By doing this, we found firstly that no study included in this meta-analysis integrated a measurement of reflexive processes such as habit (i.e., process by which a stimulus automatically generates an impulse towards action, based on learned stimulus-response associations; (Gardner, 2015)) or identity (i.e., multi-dimensional self-concept, hierarchically organized by how one views him/herself in a given role; (Burke, 2006)). As a consequence, it was not possible to examine the effectiveness of interventions on this aspect of patients' factors associated with motivation. This focus on reflective and regulatory processes is consistent with previous research on behaviour change interventions (Carraro & Gaudreau, 2013; Knittle et al., 2018; McDermott et al., 2016; Olander et al., 2013). As such, this represent a blind spot in contemporary interventional research because of the significant role played by identity, habit and, more broadly, non-conscious processes as a catalyst for physical activity maintenance (Kwasnicka et al., 2016; Rebar et al., 2020). More globally, this scarcity of available results is consistent with the lack of studies regarding the study of maintenance of behaviour itself (Murray et al., 2017). Thus, more studies are needed to improve knowledge regarding operational constructs associated with reflexive processes, linked to the maintenance phase of behaviour, in adults with chronic cardiovascular, metabolic and respiratory disease.

The moderator analyses pertaining operational constructs did not include those associated with reflexive processes. The data available indicate no moderating effect on the behaviour change processes at the end of the intervention, suggesting that the interventions are equally effective in improving the different processes. These results are in line with previous work indicating a small- to medium-sized effect of the interventions. Indeed, for self-efficacy, a construct referring to initiating reflective processes, prior studies shown, a small effect size was revealed ($d=0.23$ (Olander et al., 2013) ; $d=0.16$ (Williams & French, 2011)). Regarding subjective norms, a construct associated with ongoing reflective processes, small-to-medium effects were observed ($d=0.14$ (Steinmetz et al., 2016) ; $d=0.62$ (Sheeran et al., 2016)). Last for intentions, a construct linked with regulation processes, small-to-medium effects emerged ($d=0.17$ (Knittle et al., 2018) ; $d=0.64$ (McDermott et al., 2016)).

Another explanation for differences in the effectiveness of physical activity interventions on operational constructs is to examine the Behaviour Change Techniques (BCTs) implemented during an intervention. The clusters of technique most used in the studies included in this meta-analysis were the following: 1. Goals and planning, 2. Feedback and monitoring, 3. Social support, 4. Shaping knowledge, 5. Natural consequences, 6. Comparison of behaviour, and 8. Repetition and substitution. These results were also noted in previous research indicating that those techniques are significantly related to operational constructs (i.e., self-efficacy, intention, action plans, coping planning and implementation intentions) in the case of physical activity (Bélanger-Gravel et al., 2013; Carraro & Gaudreau, 2013; Knittle et al., 2018; McEwan et al., 2016).

Regarding the moderator analyses per type of BCT cluster, we found that “identity” was the only cluster associated with a higher effect on the determinants of physical activity. Our examination of the studies that included this cluster showed that framing/reframing was the only BCT that used (BCT 13.2). According to the v1 taxonomy, this BCT, which includes cognitive structuring, is defined as the suggestion of the deliberately adopting a new perspective on a behaviour in order to change cognitions or emotions about performing the behaviour. This technique was implemented in various ways into the included studies. It consists, for example, in educating patients about how to reinterpret unhelpful or demoralizing thoughts, feelings, and opinions (Olson & McAuley, 2015) ; in identifying patient’s positive perceptions about physical activity and correct their negative thoughts (Alsaleh et al., 2016) ; in asking them to say stop in a commanding manner, either out loud or to themselves whenever they had a negative thought about exercise and to replace that thought with a positive one (Buckley, 2016). To illustrate, the professional can suggest concentrating on decreasing the sedentary behaviour as opposed to increasing the levels of physical activity (Michie et al., 2013). Very few studies in the context of a tailored intervention promoting physical activity has successfully used cognitive restructuring and framing techniques (Larsen et al., 2019; van ’t Riet et al., 2010), and this represents a fruitful area for future interventional research (Rhodes, 2017). This is all the more important as, in the M-PAC approach, this technique is linked with identity formation, which has received very little research

attention to date. Similarly, it was not possible to examine the role played by the cluster “associations”, because of a lack of studies. This constitutes a detrimental blind spot in the literature, as this techniques are highly linked with habit formation, which in turn has proven to be a key factor in the long-term adoption of physical activity (Lally & Gardner, 2013; Rebar et al., 2020).

With regard to these results, the studies that used the framing/reframing technique and measured identity are crucial to confirm our assumptions. Moreover, further evaluation of habits using the technique cluster “associations” is needed to better understand the differences in physical activity intervention effectiveness regarding the initiating reflective processes, the ongoing reflective processes, the regulation processes and the reflexive processes and thus our understanding of intention formation, adoption and maintenance of physical activity.

None of the sample characteristics, including body mass index or type of pathology, significantly moderated the changes observed in operational constructs. This result is consistent with previous work (Knittle et al., 2018). Moreover, the type of disease was never coded in previous meta-analyses, and effect of the interventions appear to be independent from this feature. Taking the example of COPD, a study showed that among physical activity barriers, changing health status (i.e., exacerbations of disease, fluctuation in symptoms, or experience of comorbid conditions) and personal issues (i.e., expressions of fear, anxiety or uncomfortable feelings regarding exercise and presence of depression) are reported (Thorpe et al., 2012). These indicators, associated with the consequences of the disease on the life of the patient, are rarely used to describe the characteristics of the sample in the studies. In line with these results, a study showed that patients with different motivational profiles towards physical activity did not differ significantly in terms of age, BMI and exercise tolerance. The only significant indicator identified was the degree of severity of the respiratory disease (Chevance et al., 2019). Thus, to go further in understanding the influence of disease on changes in patient's factors associated with motivation for physical activity, studies coding clinical parameters, functional limitations, anxiety and quality of life could be relevant.

Interventions that were identified as having used more techniques, implemented higher frequency/duration of contact and duration of intervention, or for having carried out by a specialist, were not associated with more substantial changes in operational constructs. These results are consistent with previous work toward attitude, subjective norms, perceived behavioural control and competence (Ntoumanis et al., 2020; Steinmetz et al., 2016). Nevertheless, Knittle et al. (Knittle et al., 2018) and Ntoumanis et al. (Ntoumanis et al., 2020) have identified, respectively, that interventions delivered by a researcher and which encompassed an higher number of BCTs were associated with more favorable change on intention. Globally, these results show that quantity is not enough, and suggest an examination of how the quality and content of BCTs impact change on factors associated with motivation and which BCTs work best for which patients.

Interventions including individual sessions, phone contacts, home-based contents, without physical activity supervision have shown an equivalent effectiveness compared to group sessions, face-to-face contacts, center-based contents, with physical activity supervision. Among these moderators, only effect of the location was explored in previous studies on operational constructs, with consistent results toward intention (Knittle et al., 2018) and competence (Ntoumanis et al., 2020). Moreover, interventions delivered by an interventionist were not associated with more changes on factors associated with motivation in comparison with interventions followed only through text messages, site web or apps. Despite mHealth interventions perspectives, too few studies were included in this meta-analysis to explore effectiveness of the various implemented supports.

Limitations and perspectives

This systematic review and meta-analysis has several strengths. First, all the included studies followed the RCT design, which decreased the risk of bias in our results. Indeed, it has been argued that quasi-experimental studies are more susceptible to bias, and may show larger effects than RCT-studies (MacLehose et al., 2000). Second, the current study is the first to investigate the effectiveness of physical activity intervention components on the determinants of physical activity by considering a variety of constructs and by using the M-PAC model as a guide for organizing the literature. More

studies using a contemporary approach for assessing physical activity operational constructs are needed to guide interventions and orient conclusions in a pragmatic way for physical activity intervention practitioners. Finally, this meta-analysis focused on adults with chronic metabolic, cardiovascular and respiratory disease to improve our understanding of the effect of the interventions on the determinants of physical activity for these populations.

This systematic review and meta-analysis also suffers from several limitations. Some limitations concerned the research strategy and the coding method. First, regarding the research strategy, even if a double search was carried out and a large number of words was selected in order to prevent relevant articles from being not retained, we cannot assure the absence of loss of relevant paper due to the lack of wildcard use and due to the restriction of studies to categorised publication type (RCTs) rather than validated search filters for experimental studies/randomized trials. Also, concerning the screening part, four peoples (six distinct dyads) carried out a double coding of 5% of the articles on the basis of the title/abstract so that each evaluator appropriates the inclusion and exclusion criteria. Nevertheless, for the screening of the complete articles, and for the moderators coding, we did not do double coding. These may have introduced biases. To minimize them, a solicitation of the team was carried out in case of doubt during these steps. In addition, the risk of bias assessment is mandatory by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009). Nevertheless, the risk-of-bias assessments in Cochrane Reviews should be performed independently by at least two people. Indeed, doing so can minimize errors in assessments and ensure that the judgement is not influenced by a single person's preconceptions (Higgins et al., 2020). This procedure has not been implemented within our team and, so, we can't assure the absence of bias introduce into the analyses by the risk of bias coding.

More specifically, some limitations concerned the BCT coding and the behaviour change interventions. First, we examined whether certain techniques or interventions parameters are associated with more successful effects on the determinants of physical activity. It is nevertheless important to bear in mind that the meta-analysis methodology conducted cannot isolate the effect of a single technique or

parameter. Indeed, interaction between techniques and the co-occurrence with other features of an intervention are likely. Thus, the absence of effect could actually reflect an absence of effect, but also counterbalanced effects or masked positive effects (Dombrowski et al., 2012). Therefore, the main interest of a meta-analysis is to bring hypotheses to the fore, which can then be tested in experimental studies, in which the inclusion of a specific component is evaluated. Also, some BCT content may have been missed due to incomplete intervention descriptions. Indeed, this coding was limited by the lack of information from the study authors. This point concerning quality of the intervention report, highlighted for many years, still needs to be improved (Albrecht et al., 2013). Moreover, this procedure does not inform about the actual use of the techniques within participants, and about his application level (Kok et al., 2016). Future studies using more fidelity checks and log data, as well as providing information on practical application are needed.

Moreover, about half of the included studies showed a high risk of bias. These biases may have inflated the overall effect size of the interventions, and the results should therefore be interpreted with caution. The significance of this meta-analysis is also limited due to the scarcity of research related to certain populations or objects. In this line, among all studies included in this meta-analysis, only three were linked to respiratory disease. Future interventions for patients with respiratory disease should further assess physical activity operational constructs. Regarding these factors, no study met our inclusion criteria for identity and habit. Our conclusions on the effectiveness of interventions regarding physical activity operational constructs therefore cannot be considered definitive due to the current lack of robust interventions based on all the relevant constructs. Finally, long-term effect data were in only a small proportion of the included studies, and the follow-up periods varied considerably. The robustness of these results is thus weak. As the mean follow-up period was only 5.25 months, studies with longer follow-ups are now needed to provide a better understanding of the long-term effects of interventions on factors associated with motivation.

Finally, we have tried to formulate common conclusions studying groups of individuals (i.e., nomothetic approach). This approach not allows to take into account individual differences and intra-

individual variations (i.e., idiographic approach). Indeed, few experimental studies have looked on trajectories and clusters identification based on operational constructs (Blanchard et al., 2015; Chevance et al., 2019), and show that during an intervention, within the same intervention group, different needs can be detected. This change in the way of approaching intervention design - from a nomothetic to an idiographic approach – may well advance the field of behaviour change towards physical activity (Dunton, 2017; Rhodes et al., 2019). Several methods can be used to direct people towards an intervention adapted to their needs based on the results of such evaluations as measurement-based care (Lewis et al., 2020) or the more dynamic and contextual ecological momentary assessment (Shiffman et al., 2008). In these approaches, evaluation is a central decision-support tool. It is crucial to measure the operational constructs that represent all the motivational levels associated with the behaviour change process.

Conclusion

Physical activity interventions, towards adults with chronic metabolic, cardiovascular and respiratory disease, show a medium effect on global the determinants of physical activity at the end of the interventions and more than 3 months post-interventions. Interventions that integrate the framing/reframing BCT lead to the most positive effects. In the M-PAC approach, this technique is linked to the identity construct, a part of the reflexive processes thought to influence the continuation of action control. In the past, too little research attention has been paid to this technique and how a physical activity-related identity is formed. To clarify the connection between initiation and maintenance, intervention designs have to adopt a comprehensive assessment of operational constructs at different time points after the end of the intervention. To improve our understanding of the influence of disease on changes in patient's constructs for physical activity, studies coding clinical parameters, functional limitations, anxiety and quality of life are needed. Thus, the results of this meta-analysis suggest that future studies should both use framing/reframing techniques and measure

identity to assess the effectiveness of changing the determinants of physical activity for adults with chronic metabolic, cardiovascular and respiratory disease.

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Figure 1 The multi-process action control schematic (« adapted from Rhodes (2017) »)

Figure 2 Flow diagram of inclusion process

Behaviour change processes	Operational constructs	Number of effect sizes
Initiating reflective processes		115
	Perceived capability	68
	Instrumental attitudes	47
Ongoing reflective processes		47
	Affective judgements	12
	Perceived opportunity	26
	Barriers control	9
Regulation processes		31
	Behavioural regulation	26
	Intention	5

Table 1 - Effect sizes per groups and subgroups

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