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Mediators of Physical Activity Behavior Change Interventions among Adults: A Systematic Review and Meta-Analysis

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Abstract

Background: An understanding of physical activity through mediators of behaviour change is important to evaluate the efficacy of interventions. The purpose of this review is to update prior reviews with meta-analysis in order to evaluate the state of physical activity interventions that include proposed mediators of behaviour change. **Methods**: Literature was identified through searching of five key databases. Studies were eligible if they described a published experimental or quasi-experimental trial in English examining the effect of an intervention on physical activity behaviour and mediators in non-clinical adult populations with the necessary statistical information to be included in the meta-analytic structural equation modelling analysis. **Results**: Fifty-one articles (49 samples) met the eligibility criteria. Small overall effects were identified for mediation paths a (r = .16; 95% CI = .10 to .22), b (r = .21; 95% CI .16 to .27), and c (r = .24; 95% CI .12 to .35), c' (r = .05 to .19) and ab (r = .02 to .07) that showed similar findings by theory and construct. **Conclusion**: The effect sizes seen in physical activity interventions are mediated by our current theories, but the effects are very small and no one construct/theory appears to be a critical driver of the mediated effect compared to any other. Innovation and increased fidelity of interventions is needed.

Key Words: Exercise Interventions, Exercise Social Cognitive Theory, Transtheoretical Model, Theory of Planned Behaviour, Self-determination Theory

Regular physical activity (PA) is linked to the reduced chances of acquiring numerous health conditions and chronic diseases (Lee et al., 2012; Rhodes, Bredin, Janssen, Warburton, & Bauman, 2017), yet much of the adult population is failing to participate in the 150 minutes of moderate or vigorous PA recommended to reap these benefits (Hallal et al., 2012). Thus, the promotion of regular PA is of clear importance to public health. Interventions to modify PA behavior have had modest success (Conn, Hafdahl, & Mehr, 2011; McEwan et al., 2019; Murray et al., 2017). For example, a recent review of 27 PA intervention meta-analyses positioned the overall effectiveness of behavior change at d =.27 (95% CI = .17 to .37; Rhodes et al., 2017), which suggests this effect size is in the small but meaningful range (Cohen, 1992). Still, all of these meta-analyses demonstrated generally large heterogeneity among behavior change studies. Thus, there is a need to understand what is working in interventions and what is not working in order to inform future intervention design.

Mediators of behavior change are the intermediary variables in the causal process between an intervention and the behavior change effect (Baron & Kenny, 1986; MacKinnon, Fairchild, & Fritz, 2007). Specifically, mediators help us understand “why” or “why not” a PA intervention may have worked (Baranowski, Anderson, & Carmack, 1998). Knowledge of mediators will allow for the effective design of interventions; PA promotion initiatives constructed to change important target variables should then lead to behaviour change, while those interventions used to target ineffective variables can be discarded (Rhodes & Pfaeffli, 2010). Mediators also provide the best test of the internal validity of PA theories (Baranowski et al., 1998). While many different variables are correlated with PA (Bauman et al., 2012),

theoretical variables that have been targeted in interventions are validated when they can link that intervention and behavior change through the change of that variable. Mediation is achieved with evidence of a significant and substantive product-of-coefficient estimate (*ab* effect) where the independent variable (e.g., intervention) has its effect on the outcome (e.g., change in PA) via the mediator (Cerin & Mackinnon, 2008; Mackinnon, Lockwood, Hoffman, West, & Sheet, 2002).

To our knowledge, there have been five reviews of PA mediators among the adult population (Baranowski et al., 1998; Lewis, Marcus, Pate, & Dunn, 2002; Murray et al., 2018; Rhodes & Pfaeffli, 2010; Teixeira et al., 2015). An early scoping review by Baranowski et al. (1998) and an update by Lewis et al. (2002), noted a very limited literature that had actually tested the proposed mediating mechanisms (i.e., 10 studies). Lewis et al. noted in their evaluation that the behavioural processes of change from the transtheoretical model (Prochaska & DiClemente, 1982) had the most convincing and reliable evidence as a mediator from interventions, with very mixed results from all other potential variables. They also found that mediation tests had only been conducted using social cognitive theory (Bandura, 1986) and the transtheoretical model of behavior change. Rhodes and Pfaeffli (2010) updated this literature with six additional studies that also showed evidence for self-regulation behaviors, such as the behavioral processes of change, and indeterminate effects of other possible mediators of PA. Two more narrowly focused reviews have updated this literature. Teixeira et al. (2015) reviewed six studies in weight loss interventions with a PA component and found good mediation evidence for the autonomous motivation construct from self-determination theory (Deci & Ryan, 1985), and some evidence for self-efficacy and self-regulation behaviors from social cognitive theory (Bandura, 1998) and the transtheoretical model (Prochaska & Velicer, 1997). Finally, Murray et

al. (2018) reviewed 12 studies that involved mediation tests of interventions longer than six-months in duration. The results also showed that self-regulation behaviors from the behavioral processes of change had the most evidence of mediation with mixed or limited evidence for any other variable.

Taken together, the collection of these reviews represents a rather fragmented understanding of PA mediators, given the series of selected review updates and focused aims. A systematic review of all possible tests of mediation in PA research among adults is warranted to provide a more fulsome understanding of contemporary literature. Furthermore, given the length of time since any general update (i.e., >nine years since Rhodes and Pfaeffli's review), there is likely a larger body of literature now available to appraise the findings that would be inclusive of additional variables and theories that have gained in popularity and use since social cognitive theory and the transtheoretical model (Rhodes, McEwan, & Rebar, 2019). Finally, all of these prior reviews have involved vote-counting procedures of various kinds, which depend on testing a hypothesis by counting the total of significant versus non-significant findings and are subject to high levels of type II error (Hedges & Olkin, 1980). It would therefore be helpful to include point-estimates of mediated effects via meta-analysis. This would provide greater information on the size of the effects and their heterogeneity.

Thus, the purpose of this paper was to systematically review studies among adult nonclinical populations that have employed formal mediation tests in PA interventions and engage in a meta-analysis of these results. We subsequently sought to explore any potential moderators of the meta-analytic results, subject to the available number of tests for any given variable.

Method

This review followed PRISMA guidelines for meta-analyses (Moher, Liberati, Tetzlaff, & Altman, 2009).

Inclusion Criteria

Articles were eligible for this meta-analysis if they met the following criteria: (1) The study examined the effect of an intervention on PA behavior and mediator change. (2) The study did not recruit participants on the basis of an unhealthy weight (i.e., BMI > 30) or clinical condition (i.e., participants did not suffer from chronic illnesses, require regular treatment). Clinical samples were excluded because of the unique factors that can contribute to physical (in)activity during disease treatment and thus require more focused analyses (e.g., Courneya, 2014). (3) The study was a published experimental or quasi-experimental trial with a comparison condition. (4) The study provided PA measurements as the outcome variables. Studies which exclusively measured PA variations through the stages of change construct as a proxy for PA change did not meet this criteria (Adams & Nettle, 2009). (5) The mean age of participants was between the age of 18 and 65 years old. (6) The article provided sufficient statistical information. Specifically, studies needed to provide the results of a mediator analysis with effect sizes for the indirect effect (*ab* path) and the direct (*c'*-path) and total effect (*c*-path).

Literature Search

Literature searches were conducted by one author for articles published between January, 1970 and December, 2018. The following databases most relevant to the topic of psychology and PA were searched: Web of Science (previously known as Web of Knowledge), PsycINFO, MEDLINE, and SPORTDiscus. An extensive search strategy was based on a previous review conducted by Rhodes and Pfaeffli (2010). The search strategy used a combination of the keywords Mediat* AND (random OR intervention OR experiment) AND 46 synonyms for the

terms ‘PA’ and ‘behavioral research’ (please see Appendix A for more details on the search terms used). In addition, the reference list of five previous reviews of PA mediators (Baranowski et al., 1998; Lewis et al., 2002; Murray et al., 2018; Rhodes & Pfaeffli, 2010; Teixeira et al., 2015) were consulted for additional pertinent articles. Original article selection was performed by one reviewer (PB). For all articles where necessary information to calculate Pearson’s *r* coefficients were missing, an e-mail was sent to the corresponding author. In the e-mail the authors were asked to, if possible, provide necessary information needed to calculate the correlation coefficients. A total of eight of 31 authors responded.

Data Extraction

Data were extracted by two independent reviewers (AI, PB) for intervention, measurement, and participant characteristics. Effect sizes for the a-path, b-path, indirect effect (*ab* path), the direct (*c’*-path), and total effect (*c*-path) were extracted by three authors (PB, RR, AI). Intervention characteristics included: use of theory, intervention duration, description of intervention, presence of baseline data, and the type of intervention used (e.g., individual counselling, support group, or print). Measurement characteristics included: PA measurement, PA measurement type (i.e., frequency, duration, and/or intensity), mediator measurement tool, and the mediator test used (e.g., Sobel test). Participant characteristics included: sample size, percentage of dropouts, control sample size, mean age, gender, and location.

Risk of Bias

Two reviewers assessed study quality using the following criteria from the revised Cochran risk-of-bias tool for randomized trials (Sterne et al., in press). The RoB 2 was used to assess the risk of bias of studies based on five domains: (1) Risk of bias arising from the randomization process (2) Risk of bias due to deviations from the intended interventions (effect

of assignment to intervention) (3) Risk of bias due to missing outcome data (4) Risk of bias in measurement of the outcome (5) Risk of bias in selection of the reported result. When discrepancies between author ratings regarding quality scores occurred, the authors discussed the article with regard to these differences until they agreed on a common score (see Appendix B). An inter-rater reliability of .73, which according to McHugh (2012), represents a moderate-to-strong level of agreement between authors was found. We expressed study quality through tertiles of 'low risk', 'some concern', and 'high risk'.

Data Analysis

All calculations were performed using the Comprehensive Meta-Analysis software (Borenstein, Hedges, Higgins, & Rothstein, 2013). For all analyses, Pearson's *r* correlation coefficients were used as effect size estimates. To obtain the Pearson's *r* correlation coefficients, all collected effect sizes were first transformed to Fisher's *z* correlations. Second, to correct for sampling errors, all Fisher's *z* correlations were weighted for sample size. Third, we used the weighted average Fishers's *z* correlations for the relationships between the included variables. Fourth, we transformed the calculated average Fisher's *z* correlation estimates into Pearson's *r* correlation coefficients. To handle the dependence of effect sizes within our selected studies (i.e., studies that had more than one effect size in one psychological variable) we followed the recommendations of Borenstein, Hedges, Higgins, and Rothstein (2009) and computed one composite score for each study (on each variable). This composite score where then used in the analysis. For more information about the equations and calculation see Borenstein et al. (2009).

I^2 statistics and Tau^2 statistics were calculated to illustrate the magnitude of heterogeneity for all relationships. The I^2 statistic is represents the degree of inconsistency in magnitude of

effects across studies (Higgins, Thompson, Deeks, & Altman, 2003). The scale ranges from 0-100% where low numbers indicate small inconsistencies between studies.

For the effect sizes representing the relationship between the intervention and mediators (i.e., *a* path) as well as for the effect sizes representing the relationship between the mediators and PA (*b* path), moderator analyses were performed. More specifically, in the two separate analyses, the effect sizes were classified into; (a) theory based domains (e.g., self-determination theory, theory of planned behaviour), and (b) construct based domains (e.g., beliefs about capabilities, intention). Theory-level categorization was based on the explicit statement that a particular theory was applied (e.g., that the study applied SDT). Categorization at the construct level was achieved using an adapted theoretical domains framework (Cane, O'Connor, & Michie, 2012), which provides an overview template of most major constructs used in behavioral science (see Appendix C). The specific adaptation was to include affective judgments (enjoyment, affective attitude, and intrinsic motivation) within the emotion categorization because, while distinct from core affect/emotion, these constructs are within the larger taxonomy of affect-related constructs (Rhodes, Williams, & Conner, 2018) and are both conceptually and operationally different than beliefs about instrumental consequences in PA (Rhodes, Fiala, & Conner, 2009).

For the relationship between the intervention and PA (i.e, *c* path) the following moderators were included; (a) type of measure for PA (objective vs. subjective), (b) theory underpinning the intervention (e.g., SDT, TTM, TPB), (c) gender distribution within study, (d) BMI at baseline, (e) age, (f) quality score, and (g) length of the intervention.

All results are reported using mean effect sizes, *p* values, and 95% Confidence Interval (CI). A result of $p < 0.05$ was considered statistically significant.

Mediation Analyses. To test the mediation hypotheses the two-stage structural equation modelling (TSSEM; Cheung & Chan, 2005; Cheung & Hong, 2017) method was used. In the TSSEM method meta-analytical techniques and structural equation modelling (SEM) is combined. At the first step if the TSSEM method a pooled correlation matrix is produced by synthesizing correlation matrices from all include samples. In the TSSEM method the covariances between the included correlations are accounted for. At the second step the structural model (i.e., mediation model) are fitted based on the pooled correlation matrix. For more information about the TSSEM method see, for example, Cheung and Hong (2017). The TSSEM analyses were estimated within the metaSEM package (Cheung, 2015) in R (R Core Team, 2013). Because samples, and the magnitude of effect sizes were expected to vary between studies a random-effect model was selected. Indirect effects (Sobel method) with 95% CI were calculated within each model (MacKinnon, 2008). If the 95% CI did not include 0 the effect was considered as statistically significant. All data and code can be found at: https://osf.io/h589d/?view_only=002b2f3ef9d040ae8469f018622f9d42

Publication bias. Publication bias was assessed by inspecting the funnel-plots for each main analysis. Also, the Egger's test (Egger, Smith, & Phillips, 1997) was calculated to complement the visual inspection of the funnel-plots, because our analyses contained more than the recommended lowest number of studies (k = 10; Sterne et al., 2011) to obtain adequate power for this test.

Results

Literature Search

We identified 5470 articles via the database search Web of Science, PsycINFO, MEDLINE, and SPORTDiscus. An additional 57 articles were identified through a search of

previous reviews. Following title and abstract elimination, 269 articles were subjected to full-text review. Through preliminary assessment, 218 articles were excluded because participants were chosen from a clinical population ($N = 6$), articles were not relevant ($N = 30$), the study did not examine mediators of PA ($N = 36$), the study did not include a control group ($N = 19$), the study did not include measures of PA ($N = 16$), the study did not conduct a mediator analysis ($N = 37$), the population was considered obese ($N = 7$), the article was not an intervention ($N = 32$), the population studied was older than 65 years old ($N = 6$), the population studied was younger than 18 years old ($N = 6$), or articles lacked statistical information for calculating effect sizes ($N = 23$). Ultimately, 51 articles, consisting of 49 unique trials, met all inclusion criteria. Three sets of two articles utilised identical samples and one article included two unique samples. Please see the PRISMA flow chart (Figure 1) for an outline of the search and screening steps. References for all papers used in the meta-analyses can be found in Appendix D.

Study Characteristics

Overall, the 51 included articles examined a variety of types of interventions on PA behaviour (see Supplementary Table 1 and Table 1). Based on the RoB-2 criteria (Sterne et al., in press), we identified 13 articles as having a high risk of bias and deemed 38 articles as having some concerns regarding risk of bias (see Appendix B). The design of the interventions were either randomized controlled trials *(*$N = 43$), group randomized control trials *(*$N = 5$), or quasi experimental designs *(*$N = 4$). Trials ranged from two to four arms, with the majority using a two-arm design comparing a high theoretical fidelity intervention to a control group *(*$N = 40$). Eleven other articles compared a high-fidelity intervention to one or two secondary interventions and a control group.

The settings of the studies included universities *(N* = 20), hospital/clinic *(N* = 6), community settings *(N* = 8), worksites *(N* = 6), homes *(N* = 4), religious settings *(N* = 3), or the internet *(N* = 4). Collectively, 20,647 participants were sampled and sample sizes ranged from 32 to 3089. Participants were of both genders *(N* = 37), of women only *(N* = 10), or of men only *(N* = 4). PA was most commonly assessed using the Godin Leisure-Time Exercise Questionnaire *(N* = 12), 7-day PA Recall (*N* = 10), and the International PA Questionnaire *(N* = 6).

The interventions were based on the theories of social cognitive theory *(SCT; N* = 13), theory of planned behavior *(TPB; N* = 8), self-determination theory *(SDT; N* = 7), the transtheoretical model *(TTM; N* = 5), multiple theories (*N* = 6), no specified theories (*N* = 5), or other theories (*N* = 7). Categorization of the eligible theories and constructs for our analyses were delimited to those categories that received at least three independent studies per group. This is acknowledged as an arbitrary distinction but it provides some triangulation of findings and prevents the interpretation of findings arising from a single study, which is not the intention of a review or synthesis (Rhodes, Kaushal, & Quinlan, 2016). There were sufficient numbers to examine six constructs from the theoretical domains framework (see Appendix C). Our analyses at the construct level included beliefs about capabilities (*N* = 39), beliefs about consequences (*N* = 17), social influences (*N* = 25), emotions (*N* = 18), intentions (*N* = 10), and behavioral regulation (e.g., planning, self-monitoring) (*N* = 9). The interventions ranged in length from one session to 24 months. Most studies did not mention a PA target, however, fourteen trials set a PA target goal of 150 minutes of moderate-to-vigorous PA per week. Nine trials set a PA target goal of 30 minutes of moderate-to-vigorous PA for most days of the week and four trials set individually-tailored PA recommendations.

Main Analyses

Intervention effects on the proposed mediators (path *a*). Results of the intervention on the proposed mediators (*a*-path) can be found in Table 2. The overall effect of the interventions on the proposed mediators were small (r = .16, 95% CI = [.10, .22]). There was large heterogeneity in the magnitude of effect sizes between studies (I^2 = 97.76, Tau^2 = .029).

The estimates for the interventions'effects on the proposed mediators from the different theoretical models were all small (rs ranged between .09 and .24). All effects, except the one for the interventions based on the TTM (and TTM + SCT), were statistically significant. The TPB interventions had, in comparison to the other theories, the largest effect of the theory specific mediators (r = .24, 95% CI = [.004, .45]).

For the construct based mediators, the effects estimates were more heterogeneous (See Table 2). More specifically, the effects of the interventions on the different construct based mediators ranged from .10 to .28. The strongest significant intervention effect was on behavioral regulations (r = .22, 95% CI = [.14, .29]).

Relationship between the mediators and physical activity (Path *b*). Path *b* analyses of the effect of the putative mediator on PA can be found in Table 2. The overall effect of the relationship between the proposed mediators and PA was small (r = .21, 95% CI = [.16, .27]). There was large heterogeneity in the magnitude of effect sizes between studies (I^2 = 93.16, Tau^2 = .012).

The effect estimates for the relationship between the proposed mediators from the different theories and PA were considered to be small to medium (rs ranged between .17 and .40). The strongest relationship was between the mediators from the TTM and PA (r = .40, 95% CI = [.17, .60]). For the construct based mediators the effects estimates ranged from .15 to .29. The largest effect estimates were between PA and the following mediators: beliefs about

capabilities (r = .26, 95% CI = [.21, .32]), intentions (r = .27, 95% CI = [.20, .33]) and behavioral regulations (r = .29, 95% CI = [.14, .43]).

Intervention effects on physical activity (Path *c*). Path *c* analyses of the effect of the intervention on PA can be found in Table 2. The overall effect of the interventions on PA was small to moderate (r = .24, 95% CI = [.12, 35]). There was large heterogeneity in the magnitude of effect sizes between studies (I^2 = 97.75, Tau^2 = .13). Interventions based on SCT, TPB as well as TTM all had moderate effects on PA, while SDT had a small effect.

The moderator analyses of these effects showed no statistically significant relationship for study quality scores (β = .09, p = .30), age (β = -.003, p = .38), gender distribution (β = -.003, p = .11), BMI at baseline (β = .008, p = .50), or length of the intervention (β = -.001, p = .46). Furthermore, similar effects were found when PA was measured with objective (r = .23, 95% CI = [.10, .36]) as well as self-reported (r = .22, 95% CI = [.08, .35]) measures.

Direct effect of the intervention after controlling for the mediator (Path *c'*)

Results of *c'* in path analyses can be found in Table 3. SDT (*c'* = .11), TTM (*c'* = .05), Beliefs about Consequences (*c'* = .08), and Intention (*c'* = .19) were non-significant. All other theories and analyses at the construct level showed evidence for significant path (*c'* = .07 to .19), thus suggesting some relationship between the intervention and changes in PA that was not accounted for by the putative mediator.

Indirect effect (Path *ab*)

Results of the mediated effect of the intervention through the putative theories and their respective constructs can be found in Table 3. The results from the mediation analyses showed that the independent variable (intervention) in combination with the different domains of proposed mediators could explain between five and 10% of the variance in PA. Nearly all

analyses (except two) showed statistically significant indirect effects of the intervention on PA through mediating constructs. These effects were via SCT, SDT, TPB, TTM, beliefs about capacities, beliefs about consequences, intention, and social Influences, respectively. All effects were very small (*ab* = .02 to .07). For estimates and 95% Confidence Intervals see Table 3.

Publication bias

The inspection of the funnel-plots and Eggers regression analyses indicated high risk of publication bias for the effect of the interventions on the proposed domains of mediators (*b* = -1.13, *p* = .03). For the effect of the intervention on PA (*b* = 0.04, *p* = .98), as well as for the relationship between the mediator and PA (*b* = 1.03, *p* = .08) low risk of publication bias was present.

Discussion

While PA interventions have been effective in changing behavior, there is considerable heterogeneity in the results across studies (McEwan et al., 2019; Rhodes et al., 2017). As a result, research has attempted to parse the critical behavior change techniques and theoretical elements associated with successful behavior change (Gourlan et al., 2016; Michie, Abraham, Whittington, McAteer, & Gupta, 2009) and the mixed findings have generated considerable recent debate (Dalgetty, Miller, & Dombrowski, 2019; Hagger & Weed, 2019; McEwan et al., 2019). The purpose of this paper was to add to this collective information through a systematic review of studies among adult nonclinical populations that have employed formal mediation tests in PA interventions and engage in a meta-analysis of these results. We subsequently explored potential demographic and study design variables as moderators of the findings. The results add the first quantitative summary statistics and updated results to an aging evidence base of PA mediators in interventions (Baranowski et al., 1998; Lewis et al., 2002; Rhodes & Pfaeffli, 2010).

Collectively, this review represents 51 articles that met inclusion criteria. Our analyses allowed a broad assortment of mediators of PA interventions to be explored, including core constructs from SDT, TTM, SCT, and TPB. The articles collectively represented unique samples of over 20,000 participants. The majority of articles were assessed as having some concerns for risk of bias and 13 articles were assessed as having a high risk of bias. Thus, the available sample of studies represents a rich data-set to appraise the state of current evidence in an attempt to organize findings and propose areas for future research. Of particular importance, there were no statistically significant relationships between the magnitude of effects and study quality/bias, sample participant age, gender distribution, BMI, or length of the intervention allowing for robust generalization of the findings.

In mediation analyses, one of the critical pathways is to understand the relationship between the mediator and its proposed antecedent intervention (MacKinnon et al., 2007). To this end, we analyzed the overall relationships between PA interventions and their corresponding theory and constructs applied within each study. Overall, interventions were significantly linked to changes in theoretical variables within the small effect size range (r = .16) and a disaggregated sub-analysis by theory or specific construct yielded similar findings. Thus, interventions have proven capable of making small changes to the key variables within SDT, TPB, SCT, and to a more varied extent, the TTM; although this sub-analysis should be treated with caution because it contained a small sample size.

At the construct level of analyses, the only non-significant path *a* finding was with the intention construct, where our results identified considerable heterogeneity. This is interesting because intention is the foundational variable within most social cognitive models (Sniehotta, 2009). The finding may have occurred because intention is among the only variables in our

analyses that has no direct intervention mechanism, and is conceived as being entirely reliant on changes among its purported antecedents (e.g., perceptions of capabilities, social influences, outcome expectations) (Rhodes & Blanchard, 2007). This could explain the heterogeneity of these findings in the *a*-path coefficients compared to other constructs. It was also interesting to note that the largest path *a* coefficient was behavioral regulation, which was closer to a medium effect size, while expectations about outcome and social influence had associations with the intervention that were closer to the small-trivial range. The findings support the premise of action control theories, where participants may arrive at interventions with good intentions and expectations, and thus benefit most from interventions to change self-regulation strategies (Gollwitzer, 1990; Schwarzer, 2008).

Path *b* analyses overview the connections of the proposed mediator construct to PA change (Baron & Kenny, 1986; MacKinnon et al., 2007). We found reliable evidence that our current theories predict behavior change in the upper range of a small effect size. For the most part, no theory was particularly more effective than the other with the exception of the TTM, which had medium-sized effects. The findings overall mimic meta-analyses based on specific theories (Conn et al., 2011; Gourlan et al., 2016; McEwan et al., 2016) showing minimal differences in effectiveness, but an overall capability to explain behavior change. We have no readily apparent explanation as to why the TTM proved to have a larger coefficient in these analyses because more fulsome meta-analyses of this model compared to other theoretical approaches has not shown this outcome (Conn et al., 2011; Gourlan et al., 2016; McEwan et al., 2016; Prestwich et al., 2014). It may be a function of the specific inclusion criteria of our study and the small sample size.

Interestingly, all of the underlying theoretical constructs were also significant predictors of PA change in sub-analyses. The predictive capability of beliefs about capability, intention, behavioral regulation, and emotion were expected because these variables are well established predictors of PA (McEachan et al., 2016; Rhodes et al., 2009; Williams, Anderson, & Winett, 2005; Young, Plotnikoff, Collins, Callister, & Morgan, 2014). It was interesting, however, that social influences and beliefs about consequences were also significant predictors of PA change because these constructs have typically not been reliably associated with PA (Bauman et al., 2012; McEachan, Conner, Taylor, & Lawton, 2011; Williams et al., 2005; Young et al., 2014). One potential explanation is that our coding with the theoretical domains framework (Cane et al., 2012) included a breadth of different assessments of these constructs. For example, in the case of beliefs about outcomes, this included high quality autonomous sources of regulation, such as identified regulation (Deci & Ryan, 2000), and this has been consistently linked to PA change (Teixeira, Carraça, Markland, Silva, & Ryan, 2012). In terms of social influence, while subjective norm (McEachan et al., 2011) and relatedness (Teixeira et al., 2012) have not been reliable predictors of PA, social support has been a stronger predictor (Rhodes, Jones, & Courneya, 2002). The amalgam of these constructs in our analyses may explain these minor deviations from past research.

Path *c* analyses (Baron & Kenny, 1986; MacKinnon et al., 2007) between the intervention and PA change showed a small effect overall, suggesting that most PA interventions were able to change behavior. This finding also aligns with past meta-analyses of PA interventions, which typically report overall effectiveness in the high end of the small effect size range (see Rhodes et al., 2017 for a review). Overall all theory-based interventions, with the

exception of SCT, which had the highest heterogeneity, had significant effects on PA that ranged from small (SDT) to the bottom criterion of medium (TPB, TTM).

The analysis of the mediated relationship, known as path *ab* (Baron & Kenny, 1986; MacKinnon et al., 2007) between the intervention and PA change proved particularly interesting and represents the crux of the analyses. Overall, all the theories were able to mediate the covariance between the intervention and change in PA, with very small effects throughout (.03 to .07). Relatedly, significant path *c'* analyses were found for SCT and TPB, that showed the intervention was still significantly associated with PA after controlling for the various putative mediators. At the construct level, only behavioral regulation did not have a significant *ab* path, although its effect size was comparable to the other constructs and the finding is likely due to more heterogeneity among the small number ($k = 4$) of studies to assess the b-path for this construct. Overall, the effects ranged from .02 to .06, suggesting small effects across the constructs with little discernable variation. Collectively, the results show that current constructs in TPB, SCT, TTM, and SDT mediate our interventions but the effects are very small and no one construct appears to be a critical driver of the mediated effect compared to any other. This finding provides some contrast to prior narrative reviews on the mediators of PA where mainly self-regulation behaviors (plans, self-monitoring) were reliable explanations for how interventions bestow behavior change (Murray et al., 2018; Rhodes & Pfaeffli, 2010; Teixeira et al., 2015).

Taken together, this meta-analysis assists in future PA intervention planning. For example, it is readily apparent that the modest mediation capabilities of our current theories is from relatively equal *a* and *b* paths that produce a subsequently weak *ab* path. Our results did not show a single "weak link" in the chain as much as modest links across the chain that produced an

overall weak effect. Furthermore, in contrast to what Murray et al. (2018) had found in their review, the majority of interventions ($N = 39$) reviewed in this meta-analysis were designed to affect change in the mediators. This means that improvements in the fidelity of interventions to match theories in the *a*-path (Prestwich et al., 2014) and the overall improvements to theories for explaining PA in the *b*-path (Rhodes et al., 2019) should improve the overall effectiveness of behavior change. From a pragmatic perspective, this means that researchers should continue to strive to use different/augmented theories and behavior change techniques in interventions to maximize the effectiveness of changing behavior while carefully documenting randomized controlled trials used to target the constructs of each theory.

Despite notable findings in this review, there are limitations to our evidence at present. First, the available studies mixed a large complement of adult populations, interventions, and study design aspects into the same analysis. We saw few differences in our moderator analyses but future research with formal testing of potential differences is warranted to provide evidence that is more conclusive. Next, our review focused on the available literature of interventions that applied mediators of PA change and this was primarily social cognitive in nature, with some additional research in the humanistic (SDT) and stage-based (TTM) paradigms. Other policy, environmental, social, and non-conscious factors are considered important within PA theory (Rhodes et al., 2019) and these may yield different findings. Indeed, much of the similarities of the findings across the theories in this review likely result from the homogeneity of the theories and constructs applied.

There were also some limitations of the review methods. This literature review is limited by the search terms and search engines employed as well as studies in English. Also, we had to exclude some of the identified articles due to lack of reporting statistics that could be used to

calculate the Pearson's *r* correlation coefficients. Our use of specific terms (e.g., specific theories) and low return-rate from authors who had missing statistical information has likely narrowed the available studies for this analysis. A future review may be able to acquire more data by searching through all studies of experimental designs and asking the authors for mediator-related data that may have not been presented in these publications. The initial search and paper selection was also only performed by one author and thus subject to potential error.

In summary, to our knowledge, this was the first meta-analysis of PA intervention mediators and the first collection and appraisal of all adult PA mediation studies. Our findings showed that small overall effects were identified for mediation paths *a*, *b* and *c, c'* and *ab* that showed relatively similar findings by theory and construct. The small effect sizes seen in PA interventions are thus not explained well by our current theories. This effect appears to be mainly because of small *a* and *b* pathways rather than a particularly weak link in the causal chain. Innovation and increased fidelity of interventions is needed and should be a priority for future research.

Figure Caption:

Figure 1: PRISMA Flow Diagram. Caption: Source inclusion process. Adapted from PRISMA Statement, Moher et al., 2009

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Table 1
Summary of Study Characteristics

Characteristics	Sample: *N* = 49 independent samples (corresponding to *N* = 51 articles)	Percentages (based on *N* of independent samples)
Study Design		
Randomized Control Trial	40 (43 articles)	81.6
Group randomized Control Trial	5 (5 articles)	10.2
Quasi-experimental	4 (4 articles)	8.2
Number of groups		
2 Arm trial	39 (40 articles)	79.6
3 Arm trial	8 (9 articles)	16.3
4+ Arm trial	2 (2 articles)	4.1
Mean sample size, (min, max)	425.3, (32, 3089)	
Quality score median (min, max)	7 (4, 10)	
Participant population		
Both gender trial, N (%)	35 (37 articles)	71.4
All Women trial, N (%)	10 (10 articles)	20.4
All Men trial, N (%)	4 (4 articles)	8.2
Setting		
University	21 (20 articles)	42.9
Community	7 (8 articles)	14.3
Hospital/Clinic	6 (6 articles)	12.2
Worksite	6 (6 articles)	12.2
Web	3 (4 articles)	6.1
Home	3 (4 articles)	6.1
Religious setting	3 (3 articles)	6.1

Intervention

Theory		
SCT	13 (13 articles)	26.5
TPB	9 (8 articles)	18.4
SDT	6 (7 articles)	12.2
No Specified Theory	5 (5 articles)	10.2
TTM	4 (5 articles)	8.2
Multiple theories	5 (6 articles)	10.2
Action Control	2 (2 articles)	4.1
Ecological	1 (1 article)	2.0
Goal-setting theory	1 (1 article)	2.0
Group dynamics theory	1 (1 article)	2.0
Process Model for Lifestyle Behavior Change	1 (1 article)	2.0
Reasoned action	1 (1 article)	2.0
Duration of intervention		
One month or greater and less than six months	26 (28 articles)	53.1
Six months or greater and less than one year	9 (10 articles)	18.4
One week or greater and less than one month	7 (6 articles)	14.3
Less than one week	4 (articles)	8.2
One year or greater	3 (3 articles)	6.1
PA target		
None mentioned	29 (30 articles)	59.2
150 minutes MVPA/week	9 (9 articles)	18.4
30 minutes MVPA most days/week	5 (6 articles)	10.2
Individually tailored recommendation	4 (4 articles)	8.2
30 minutes MVPA 3 days/week	1 (1 article)	2.0
Walk an additional 3500 steps/day	1 (1 article)	2.0

Physical Activity Outcome measures

GLTEQ*	12 (12 articles)	24.5
PAR*	9 (10 articles)	18.4
IPAQ*	6 (6 articles)	12.2
Pedometer	5 (5 articles)	10.2
Accelerometer	3 (3 articles)	6.1
CHAMPS*	3 (3 articles)	6.1
Attendance	2 (2 articles)	4.1
Centers for Disease Control and Prevention	2 (2 articles)	4.1
Logbook	2 (2 articles)	4.1
DSQAHEOA*	1 (2 articles)	2.0
Global Physical Activity Questionnaire	1 (1 article)	2.0
National Health Interview Survey	1 (1 article)	2.0
The Behavioral Risk Factor Surveillance System	1 (1 article)	2.0
Other self-report questionnaire	1 (1 article)	2.0
Type of mediation test		
Bootstrap	14 (14 articles)	28.6
Linear regression	12 (12 articles)	24.5
Baron and Kenny	8 (8 articles)	16.3
Path analysis	6 (6 articles)	12.2
Product of co-efficient	6 (7 articles)	12.2
Structural equation modeling	2 (2 articles)	4.1
Latent growth modeling	1 (1 articles)	2.0

Notes. PAR= Physical Activity Recall; CHAMPS = Community Health Activities Model Program for Seniors Questionnaire; DSQAHEPA = Dutch Short Questionnaire to Assess Health Enhancing Physical Activity; IPAQ = International Physical Activity Questionnaire; GLTEQ= Godin Leisure-Time Exercise Questionnaire

Table 2

Results of meta-analysis for a, b, and c paths

Variable	*N (K)*	ES (*r*)	p-value	95% CI	I^2	Tau^2
a-path						
Total effect	36 (184)	.16	<.001	.10, .22	97.76	.029
Theory based						
SCT	12 (42)	.14	<.001	.08, .20		
SDT	7 (23)	.13	.007	.04, .22		
TPB	4 (27)	.24	.046	.004, .45		
TTM	2 (3)	.12	.14	-.04, .28		
TTM + SCT	2 (5)	.09	.089	-.01, .20		
Construct based						
Beliefs about Capabilities	31 (54)	.17	.003	.06, .27		
Beliefs about Consequences	13 (32)	.11	.011	.02, .19		
Intentions	6 (7)	.28	.111	-.07, .57		
Social influences	19 (40)	.10	<.001	.05, .15		
Emotions	16 (23)	.18	<.001	.09, .26		
Behavioral regulations	8 (16)	.22	<.001	.14, .29		
b-path						
Total effect	18 (68)	.21	<.001	.16, .27	93.16	.012
Theory based						
SCT	8 (13)	.21	<.001	.13, .30		
SDT	3 (7)	.21	<.001	.19, .24		
TPB	4 (10)	.17	<.001	.10, .23		
TTM	2 (8)	.40	.001	.17, .60		
Construct based						
Beliefs about capabilities	15 (19)	.26	<.001	.21, .32		
Beliefs about consequences	7 (14)	.19	<.001	.09, .29		

Intentions	3 (3)	.27	<.001	.20, .33		
Social influences	8 (11)	.15	.003	.05, .24		
Emotion	5 (6)	.15	.017	.03, .27		
Behavioral regulation	4 (5)	.29	<.001	.14, .43		
c-path						
Total effect	34 (37)	.24	<.001	.12, .35	97.75	.13
Subjective	26 (29)	.23	.002	.09, .37		
Objective	8	.23	.001	.10, .36		
SCT	10 (11)	.33	.10	-.06, .63		
SDT	9 (10)	.13	.006	.04, .23		
TPB	6 (7)	.35	<.001	.20, .48		
TTM	2	.27	.001	.12, .41		

Note: SCT = Social Cognitive Theory, SDT = Self-Determination Theory, TPB = Theory of Planned Behavior, TTM = Transtheoretical Model, N = Number of studies, K = number of effect sizes.

Table 3

Estimates and confidence intervals for the indirect effects (c' and ab path)

Mediation model			Explained variance of PA
	c'	*ab*	R^2
Int – SCT - PA	.07 [.01, .14]	.04 [.02, .08]	0.05
Int – SDT - PA	.11 [-.04, .26]	.03 [.01, .06]	0.05
Int – TPB - PA	.19 [.01, .37]	.05 [.03, .07]	0.15
Int – TTM -PA	.05 [-.08, .19]	.07 [.03, .12]	0.06
Int – BACa- PA	.10 [.04, .34]	.04 [.03, .06]	0.05
Int – BACo - PA	.08 [-.02, .17]	.03 [.01, .07]	0.06
Int – Intention - PA	.19 [-.05, .43]	.06 [.03, .10]	0.11
Int – SI - PA	.09 [.02, .16]	.03 [.01, .06]	0.06
Int – Emot - PA	.15 [.03, .26]	.02 [.00, .04]	0.05
Int – BR – PA	.19 [.11, .26]	.03 [-.01, .08]	0.06

Note: Int = Intervention condition; PA = Physical Activity; SCT = Social Cognitive Theory; SDT = Self Determination Theory; TPB = Theory of Planned Behavior; TTM = Transtheoretical Model; BACa = Beliefs about Capabilities; BACo = Beliefs about Consequences; SI = Social Influences; Emot = Emotions; BR = Behavioral regulation; c' = the effect of X on Y controlling for M