Original article

Matched or nonmatched interventions based on the transtheoretical model to promote physical activity. A meta-analysis of randomized controlled trials

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The aim of this study was to examine whether the efficacy of transtheoretical model (TTM)–based interventions on physical activity (PA) varied according to the following criteria: (1) interventions targeted the actual stages of change (SOCs) or did not; (2) participants were selected according to their SOC or were not; and (3) its theoretical constructs (decisional balance, temptation, self-efficacy, processes of change). Thirty-three randomized controlled trials assessing TTM-based interventions promoting PA in adults were systematically identified. The between-group heterogeneity statistic (Qb) did not reveal any differential efficacy either in interventions targeting the actual SOC compared with those that did not ($Qb = 1.28$, $p = 0.22$) or in interventions selecting participants according to their SOC compared with those that did not ($Qb = 0.01$, $p = 0.91$). TTM-based interventions enhanced PA behavior whether they targeted the actual SOC (Cohen's $d = 0.36$; 95% confidence interval (CI): 0.22–0.49)) or not ($d = 0.23$; 95% CI: 0.09–0.38) and whether they selected their participants according to their SOC ($d = 0.33$; 95% CI: 0.13–0.53) or not ($d = 0.32$; 95% CI: 0.19–0.44). The moderators of the efficacy of TTM-based interventions were the number of theoretical constructs used to tailor the intervention ($Qb = 8.82$, $p = 0.003$), the use of self-efficacy ($Qb = 6.09$, $p = 0.01$), and the processes of change ($Qb = 3.51$, $p = 0.06$). TTM-based interventions significantly improved PA behavior, and their efficacy was not moderated by SOC but by the TTM theoretical constructs.
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1. Introduction

Over the past decades, physical activity (PA) was found to be low in most countries.[1,2] Future projections indicate a continuous decline,[3] along with an increasing prevalence of major noncommunicable diseases.[4] Numerous studies have been designed based on theoretical models to shed light on the processes generating significant changes in PA behavior.[5] Among them, the transtheoretical model[6] (TTM) has been widely used.

The TTM is a stage-based model of behavior change developed by Prochaska and DiClemente[6] based on the assumptions that (1) no single theory can account for the complexity of behavior change; (2) behavior change is a process that unfolds over time through several stages; (3) stages are stable and open to change; and (4) specific processes and principles of change should be used at specific stages to maximize the efficacy of behavior change.[7] In the TTM, each stage of change (SOC) describes the individual's current intention and engagement toward a targeted health-related behavior. The stages are precontemplation (no intention to change the behavior), contemplation (individual starts to consider a possible behavior change), preparation (the individual is preparing to change),

action (the individual is working on behavior change), and maintenance (the behavior change is consolidated). The TTM was initially developed for tobacco cessation[6] to understand how people change their behavior. However, given its success and efficacy in addictive behaviors, the TTM was further applied and extended to modify positive behaviors such as PA.[8] The TTM posits that there is no linearity in the evolution through the different stages, and that the progression or regression is influenced by its theoretical constructs, namely the decisional balance, temptation, self-efficacy, and processes of change (POCs).[9] Decisional balance is defined as a multidimensional set of values perceived as advantages and/or disadvantages associated with the decision to change a behavior. Temptation is described as an urge to engage in a specific habit in the midst of difficult situations.[10] Self-efficacy refers to the people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances.[11] Finally, POCs are experiential and are behavioral strategies that people use to change a given behavior.[7]

The efficacy of TTM intervention in promoting PA in adults has been assessed in 2 meta-analyses. First, Conn et al.[12] showed that TTM-based interventions had a small but significant effect on PA ($d = 0.15$), but their conclusions remain limited owing to the inclusion of different study designs (e.g., randomized trials, nonrandomized trials, controlled trials). Moreover, Conn et al.[12] did not define what a TTM-based intervention was (e.g., to what extent the TTM was cited when the intervention was described) and did not consider the theoretical implementation (e.g., to what extent the development and evaluation of the intervention are explicitly based on the TTM).[13]

More recently, Gourlan et al.[5] conducted a meta-analysis on the effects of theory-based interventions on PA promotion and further found an overall significant efficacy of TTM-based interventions with a medium effect size ($d = 0.31$, 95% CI: 0.11–0.32). However, although those previous works have highlighted the efficacy of TTM-based interventions in promoting PA among adults, important issues remain to be resolved, notably concerning some of the characteristics (i.e., moderators) associated with their efficacy. Indeed, both meta-analyses[5,12] have exhibited a high level of heterogeneity, with an I^2 equal to 64%[12] and 80%,[5] respectively, highlighting an important variability in individual studies' effect sizes[a] and indicating the necessity to further explore the sources of heterogeneity.

The exploration of the moderators associated with the efficacy of TTM-based intervention is an important issue because this model has the particularity to offer various implementation strategies. For instance, it is possible to deliver an intervention specifically targeting the participants' SOC (i.e., stage-matched intervention).[8] Over the past years, systematic reviews have

examined the impact of stage-matched interventions promoting PA on stage progression[14–18] and pointed out inconsistent findings. Although the authors of those articles suggested that stage-matched interventions have more impact on PA compared with non–stage-matched interventions, none of these studies statistically tested this hypothesis. Another strategy to implement TTM-based interventions is to select participants based on their specific SOCs (i.e., selection related to stage). For instance, Fahrenwald et al.[19] selected only participants in contemplation and preparation stages and applied the same material to all participants. The rationale behind these approaches is that each SOC is characterized by its specific motivational characteristics, and thus TTM-based interventions must be adapted to each SOC and its features (stage-matched interventions) to avoid mismatches resulting from different SOCs (non–stage-matched intervention). Moreover, these interventions are more effective in homogeneous groups (selected by stage strategy) compared with interventions with mixed SOCs (not selected by stage). However, there were no attempts to examine whether these strategies generate more important PA changes than the inclusion of participants whatever their SOC.

Lastly, another important issue is to determine whether a better theoretical implementation of TTM-based interventions, which integrates the theoretical constructs of the model (i.e., decisional balance, temptation, self-efficacy, POC), is associated with higher intervention efficacy. Indeed, as those constructs are hypothesized to influence behavior change,[9] it seems reasonable to hypothesize that interventions that would explicitly target the theoretical constructs (decisional balance, temptation, self-efficacy, POC, and the number of theoretical constructs used) would report a higher impact. However, to our knowledge, no previous research has explored the moderating impact of the integration of those theoretical constructs on the efficacy of TTM-based interventions.

From those reports, the aim of the present meta-analysis was to examine whether the impact of TTM-based interventions on PA behavior varied according to (1) whether interventions were based on SOC or not (stage-matched interventions *vs*. non-stage-matched intervention), and (2) selection by stage *vs*. not selected by stage (i.e., participants were selected according to their SOC or not). The second aim was to examine the moderator effect of the theoretical constructs (decisional balance, temptation, self-efficacy, POC, and the number of theoretical constructs used) on the efficacy of TTM-based interventions on PA level.

2. Methods

This meta-analysis has been conducted following a strict protocol by using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[20]

2.1. Literature search

A systematic search was done on PubMed and PsycINFO until March 2016 using appropriate terms. We used keywords similar to those used by Gourlan et al. (2016)[5] for exercise: "exercise" OR "exercise therapy" OR "exercise movement

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[a] The I^2 statistic quantifies the heterogeneity between collected studies and describes the proportion of variance in effect size due to heterogeneity. I^2 between 0% and 30% is considered a not important heterogeneity; between 30% and 60% it is moderate; between 50% and 90% it is substantial; and 75% to 100% is considerable heterogeneity.[49]

techniques" OR "resistance training" OR "muscle stretching exercises" OR "breathing exercises" OR "sports" OR "motor activity" OR "relaxation" OR "physical fitness" OR "physical activity" OR "walk." Those keywords were used in interaction with the following theory-relevant construct keywords to identify studies using the transtheoretical model: (1) SOC, (2) self-efficacy, (3) decisional balance, (4) POC, (5) temptation, and (6) TTM. The limits of search were ages above 18 years and randomized controlled trial (RCT) design. Then the references of 3 systematic reviews[17,21,22] were also scanned to be more exhaustive and improve the search strategy. All the included trials are available online in the supplementary file (Table A1).

The titles and abstracts found were screened by 2 trained reviewers (PB and CB). The final selection was based on full-text reading and performed by 4 trained reviewers. Any disagreements were resolved by discussion with AJR (PhD) (anonymized for peer review).

2.2. Inclusion and exclusion criteria

For the present meta-analysis, studies were included if (1) they had a randomized controlled design, (2) they concerned adult participants (healthy or with a chronic disease), (3) the intervention was explicitly depicted as based on the TTM in the text, (4) at least 1 TTM construct was mentioned, and (5) PA was a primary or secondary outcome. Studies were further separated into stage-matched interventions *vs.* non–stage-matched interventions and selected by stage *vs.* not selected by stage interventions based on the information provided in each study.

2.3. Coding of characteristics

Two independent reviewers gathered the following data: authors, years of publication, sample characteristics, intervention characteristics, number of TTM constructs used, and outcomes. Regarding studies with several PA indicators (steps count, metabolic equivalents per week, PA duration) and/or those involving multiple methods to measure PA (accelerometer and questionnaire), the data were averaged to generate a single summary effect size.[23] Regarding the TTM, information about the theoretical constructs used was collected. To be considered as used, the theoretical construct had to be explicitly mentioned in the text.

2.4. Statistical analyses

Concerning the overall effect, effect sizes were calculated using Cohen's d,[24] with positive effect size indicating favorable changes in TTM-based interventions compared with the control groups. By convention, effect sizes of 0.2, 0.5, and 0.8 represent small, medium, and large effect, respectively.[24] The moderation effects of selected by stage *vs.* not selected by stage interventions and stage-matched interventions *vs.* non–stage-matched interventions criteria were separately assessed with a meta-analytical analogue of analysis of variance, using the between-group heterogeneity statistic (Qb).[25] The same analyses were performed for the TTM constructs. Summary effects of interventions were computed by pooling subgroups of RCTs based on "matching" criteria. Given the expected high level of heterogeneity, statistical analyses were performed using a random effect. The publication bias was evaluated using a funnel plot.

Statistical analyses were performed by using Comprehensive Meta-analysis (v. 2.2.064) (Biostat, Englewood, NJ, USA).[25]

3. Results

3.1. Study selection

Database research led to the screening of 334 potentially relevant articles by applying the inclusion and exclusion criteria, and 33 articles focusing on the effects of TTM-based RCTs on PA were included in the present study (the flow chart is available online in the supplementary file Fig. A.1).

3.2. Study characteristics

A total sample of 10,350 participants (median: 186.5; range: 22–1369) was included in the present meta-analysis. Among included participants, 5400 (median: 81; range: 11–688) were in the control group and 4950 (median: 102; range: 11–681) in the intervention group. Most of studies used mixed-sex samples, and 8 of the 33 studies were exclusively performed among women. The included population was aged 47.27 ± 9.48 years old (mean ± SD) (median: 47; range: 26.48–70.3).

Regarding the included RCTs, 4 studies were performed on workers, 7 on specific populations (e.g., low-income mothers), 8 on sedentary people, and 14 on adults with chronic diseases (e.g., type 2 diabetes). These interventions had mean duration of 22.33 ± 21.13 weeks (median: 14; range: 2–100). RCTs are detailed online in supplementary file Table A.1.

3.3. Bias of publication

The funnel plot of TTM-based interventions (as compared with controls) was found to be asymmetrical, which indicated the presence of a publication bias for these data (Fig. 1).

3.4. Overall intervention effects

Regarding the overall effect of TTM-based interventions on PA, a significant effect was found (d = 0.33; 95% CI: 0.22, 0.43).

3.5. Moderator analyses

All statistical results are available in Table 1.

3.5.1. Stage-matched interventions *vs.* non–stage-matched interventions

Twenty-two studies of 33 (67%) implemented a stage-matched intervention. The moderation analyses did not reveal any differential efficacy in stage-matched interventions compared with non–stage-matched interventions (Qb = 1.48, p = 0.22). TTM-based interventions enhanced PA behavior whether they were stage matched (d = 0.36; 95% CI: 0.22–0.49) or non–stage-matched (d = 0.23; 95% CI: 0.09–0.38) (Fig. 2).

3.5.2. Selected by stage *vs.* not selected by stage interventions

Thirteen studies of 33 (39%) selected their participants according to their SOC membership. The moderation analyses
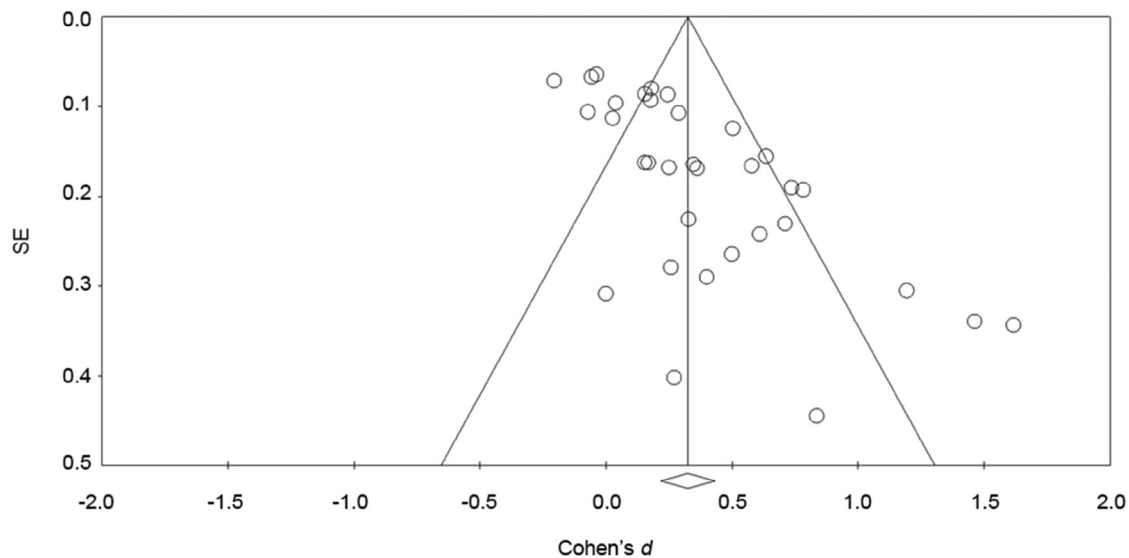
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Fig. 1. Funnel plot of publication bias. SE = standard error.

did not reveal any differential efficacy in selected by stage interventions compared with not selected by stage interventions (Qb = 0.01, p = 0.91). TTM-based interventions significantly improved PA behavior whether participants were selected by stage (d = 0.33; 95% CI: 0.13–0.53) or not selected by stage (d = 0.32; 95% CI: 0.19–0.44) (Fig. 3).

3.5.3. Decisional balance

Seventeen studies of 33 (52%) used decisional balance in their intervention. No statistical difference was found according to the use of the decisional balance (Qb = 2.26, p = 0.13). TTM-

based interventions increased PA whether decisional balance was used or not.

3.5.4. Temptation

Three studies of 33 (9%) used temptation in their intervention. No statistical difference was found according to the use of the temptation construct (Qb = 0.86, p = 0.35). TTM-based interventions increased PA whether temptation was used or not.

3.5.5. Self-efficacy

Sixteen studies of 33 (48%) used self-efficacy in their intervention. A significant moderation effect of self-efficacy on PA

Table 1

Analyses of moderators of TTM-based interventions as its constructs.

Moderator	No. of RCTs	d (95% CI)	I^2	Qb	p
Stage-matched interventions				1.48	0.22
Yes	22	0.36 (0.22–0.49)	85.32		
No	11	0.23 (0.09–0.38)	41.27		
Selected by stage interventions				0.01	0.91
Yes	13	0.33 (0.13–0.53)	84.35		
No	20	0.32 (0.19–0.44)	75.84		
Decisional balance				2.26	0.13
Yes	17	0.41 (0.22–0.61)	86.42		
No	16	0.25 (0.14–0.35)	59.21		
Temptation				0.86	0.35
Yes	3	0.57 (0.02–1.11)	69.10		
No	30	0.30 (0.19–0.41)	80.47		
Self-efficacy				6.09	0.01
Yes	16	0.48 (0.27– 0.69)	87.47		
No	17	0.19 (0.09–0.29)	60.55		
POCs				3.51	0.06
Yes	21	0.41 (0.24–0.67)	83.68		
No	12	0.21 (0.07–0.34)	70.88		
Number of theoretical constructs				8.82	0.003
Low (score = 1–2)	15	0.16 (0.06–0.25)	53.96		
High (score = 3–5)	18	0.49 (0.29–0.69)	86.74		

Notes: Total score for TTM refers to the number of constructs used to tailor the intervention. d (95 % CI): Cohen's d with 95% confidence intervals; I^2: heterogeneity statistic; Qb: between-group heterogeneity statistic.

Abbreviations: POCs = processes of change; RCTs = randomized controlled trials; TTM = transtheoretical model.
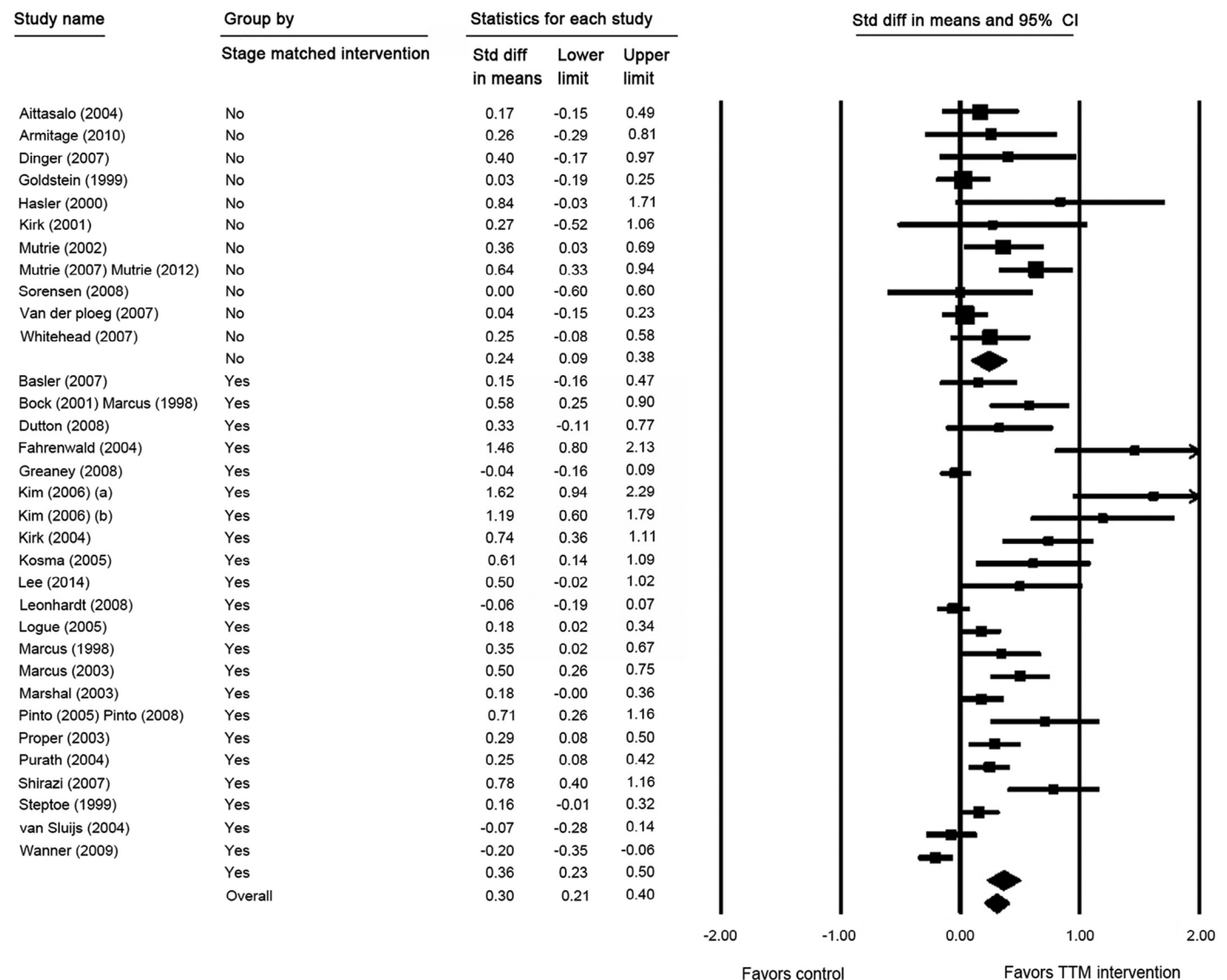
Fig. 2. Forest plot of stage-matched interventions. Full references for the study names appear in the online supplemental material. Std diff: xxx; TTM = transtheoretical model.

behavior was observed (Qb = 6.09, $p = 0.01$), with studies using self-efficacy being more likely to increase PA behavior ($d = 0.48$, 95% CI: 0.27–0.69) compared with studies that did not use this construct ($d = 0.19$, 95% CI: 0.09–0.29).

3.5.6. Processes of change

Twenty-one studies of 33 (64%) used the processes of change in their intervention. A moderation effect of processes of change on PA behavior was suggested with borderline significance (Qb = 3.51, $p = 0.06$), meaning that studies using processes of change were twice as likely to increase PA ($d = 0.41$, 95% CI: 0.24–0.67) compared with those that did not ($d = 0.21$, 95% CI: 0.07–0.34).

3.5.7. Number of TTM theoretical constructs

Eighteen studies of 33 (55%) used at least 3 of the 5 TTM constructs (e.g., SOC, decisional balance, temptation, self-efficacy, processes of change) to tailor their intervention. A

significant moderation effect of the number of implemented constructs on PA behavior was observed (Qb = 8.82, $p = 0.003$), with studies using at least 3 constructs being 3 times more likely to increase PA ($d = 0.49$, 95% CI: 0.29–0.69) compared with studies that used less than 3 constructs ($d = 0.16$, 95% CI: 0.06–0.25).

4. Discussion

The overall goal of this meta-analysis was to analyze the moderation effect of TTM theoretical constructs. The first objective was to investigate whether the impact of TTM-based interventions on PA behavior varied according to, on the one hand, stage-matched interventions *vs.* non–stage-matched interventions (i.e., the interventions were based on SOC or not), and, on the other hand, selected by stage *vs.* not selected by stage interventions (i.e., participants were selected according to their SOC or not). The second objective was to investigate the

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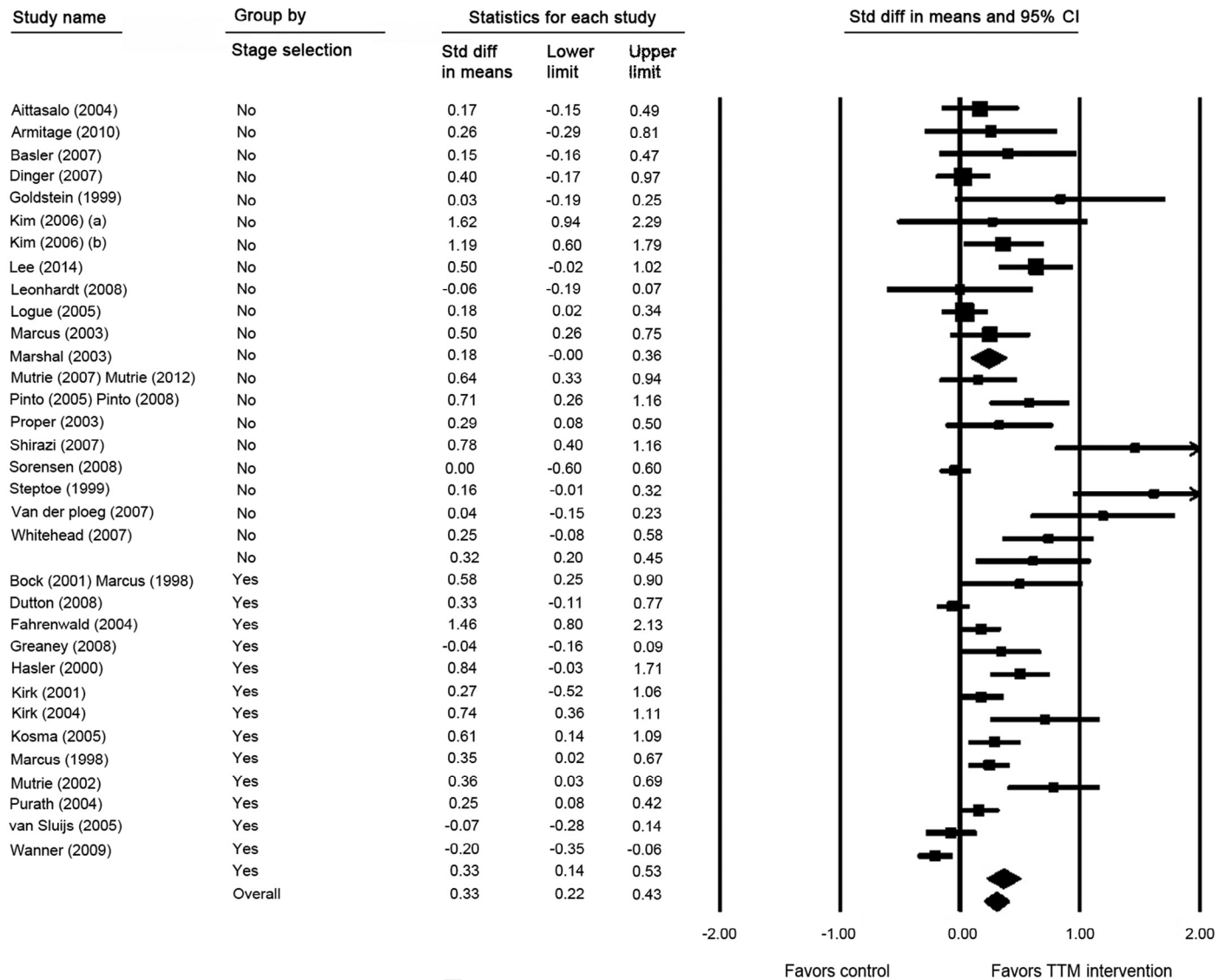| Study name	Group by	Statistics for each study			Std diff in means and 95% CI
	Stage selection	Std diff in means	Lower limit	Upper limit	
Aittasalo (2004)	No	0.17	-0.15	0.49	
Armitage (2010)	No	0.26	-0.29	0.81	
Basler (2007)	No	0.15	-0.16	0.47	
Dinger (2007)	No	0.40	-0.17	0.97	
Goldstein (1999)	No	0.03	-0.19	0.25	
Kim (2006) (a)	No	1.62	0.94	2.29	
Kim (2006) (b)	No	1.19	0.60	1.79	
Lee (2014)	No	0.50	-0.02	1.02	
Leonhardt (2008)	No	-0.06	-0.19	0.07	
Logue (2005)	No	0.18	0.02	0.34	
Marcus (2003)	No	0.50	0.26	0.75	
Marshal (2003)	No	0.18	-0.00	0.36	
Mutrie (2007) Mutrie (2012)	No	0.64	0.33	0.94	
Pinto (2005) Pinto (2008)	No	0.71	0.26	1.16	
Proper (2003)	No	0.29	0.08	0.50	
Shirazi (2007)	No	0.78	0.40	1.16	
Sorensen (2008)	No	0.00	-0.60	0.60	
Steptoe (1999)	No	0.16	-0.01	0.32	
Van der ploeg (2007)	No	0.04	-0.15	0.23	
Whitehead (2007)	No	0.25	-0.08	0.58	
	No	0.32	0.20	0.45	
Bock (2001) Marcus (1998)	Yes	0.58	0.25	0.90	
Dutton (2008)	Yes	0.33	-0.11	0.77	
Fahrenwald (2004)	Yes	1.46	0.80	2.13	
Greaney (2008)	Yes	-0.04	-0.16	0.09	
Hasler (2000)	Yes	0.84	-0.03	1.71	
Kirk (2001)	Yes	0.27	-0.52	1.06	
Kirk (2004)	Yes	0.74	0.36	1.11	
Kosma (2005)	Yes	0.61	0.14	1.09	
Marcus (1998)	Yes	0.35	0.02	0.67	
Mutrie (2002)	Yes	0.36	0.03	0.69	
Purath (2004)	Yes	0.25	0.08	0.42	
van Sluijs (2005)	Yes	-0.07	-0.28	0.14	
Wanner (2009)	Yes	-0.20	-0.35	-0.06	
	Yes	0.33	0.14	0.53	
	Overall	0.33	0.22	0.43	

Fig. 3. Forest plot of stage-selection interventions. Full references for the study names appear in the online supplemental material. Std. diff: xxx; TTM = transtheoretical model.

moderation effect of the theoretical constructs (decisional balance, temptation, decisional balance, processes of change) on TTM-based interventions aimed at promoting PA.

Regarding the first objective, the moderation analyses did not reveal any differential efficacy in interventions according to these moderators. TTM-based interventions showed significant improvement of PA behavior whether they were stage matched or non–stage matched, and whether participants were selected by stage or not selected by stage.

Indeed, this result can be explained by the fact that SOCs have been defined differently across trials of PA promotion. In the literature, several staging algorithms have been used. For example, whereas some studies defined regular PA as 30 min per session at least 4 times per week,[26,27] other studies defined regular PA as 20 min per session or longer performed 3 to 5 times per week,[8,28] or as 30 min or more per day on 5 days per week.[29,30] So it is possible that this difference across RCTs

could account for the failure of SOC to moderate outcomes in the present meta-analysis. However, another explanation is also possible. In fact, the present results suggest that SOC may not be the better way to implement TTM-based interventions to improve PA. As theoretically described, it is likely that TTM-based interventions are moderated by the other constructs. We therefore compared studies using at least 3 TTM constructs to tailor their interventions compared with those using less than 3 constructs. The first observation was that barely 50% of interventions used at least 3 TTM constructs. Then, as assumed by the TTM,[7] studies using more TTM constructs to tailor their interventions were 3 times more likely to increase PA than others. Indeed, studies that rightly implemented the TTM had an effect size that could be considered medium to large, whereas other studies had an effect size that could be considered small. Therefore, 2 conclusions can be deduced from this result. The first point is that with 46% of included studies using

2 or fewer theoretical constructs, we can say that almost half of TTM-based studies are TTM inspired (constructs used separately) rather than really TTM driven (using all the theoretical constructs).[31] The second point is that PA interventions should use all TTM constructs to really know the efficacy of this model. Gourlan et al.[5] previously noticed that small effect size could be a result of poor implementation of a theory. This poor reporting associated with a poor implementation of theory-based interventions is not new[32] and may explain the mixed findings of previous studies using the TTM.

When we investigated more precisely the moderation effect of each of the other TTM constructs (i.e., decisional balance, temptation, self-efficacy, POC), our analyses highlighted that self-efficacy and the POC were 2 constructs of importance in the TTM. Indeed, interventions that had included self-efficacy were more than twice as likely to increase PA compared with interventions that had not. This finding confirms previous investigations highlighting that self-efficacy is well known to be a powerful predictor of behavior change, as in facilitating the transition between the SOC[33,34] notably in conjunction with the POC. In fact, self-efficacy was able to predict the transition out of preaction stage, the retention in the maintenance stage of change, as the relapse to earlier stages.[33–35]

Studies that had included POC were twice as likely to increase PA compared with studies that had not. This result is of interest because POC, the experiential/behavioral mechanisms involved in behavior change, is a core construct of the TTM. Although important in the TTM, this construct was not systematically used in the interventions but was found to be associated with PA level and the transition between SOC and was a mediator of the adherence to PA.[36–40] In fact, in the TTM, POCs "provide important guide for interventions programs, as processes are like independent variables that people need to apply to move from stage to stage."[7] Moreover, when activated during interventions, POCs can constitute a possible explanation for the results observed in stage-matched interventions *vs.* non–stage-matched interventions and selected by stage *vs.* not selected by stage interventions. Effectively, even though these interventions were not designed to do so, it is possible that some included studies have used behavior change techniques that have further led to changes in POC and PA behavior.[41]

From a methodological point of view, a bias of publication was found in our present study with a lack of symmetry in the funnel plot. When analyzed, the funnel plot indicated an intervention-shifted bias, with small sample size studies being more likely to have larger effect size, which may have inflated our results.[42] This phenomenon could be explained by the fact that studies with small sample size and small effects are less likely to be published than studies with identical sample size showing large effects.[43]

The present study has some limitations. First, given the overall weakness of the TTM construct implementation, we still do not have enough information about its precise efficacy even though our results showed that properly implemented studies had medium to large effect size. Second, it is possible that other study characteristics could have moderated the effect estimates of RCTs designed to improve PA, such as the frequency of contact with participants, the presence of supervised PA sessions,[44,45] or the methodological quality criteria of RCTs.[12,46,47] For example, it is known that theory-based interventions including female participants yielded greater effect size than interventions including solely males or mixed populations.[47] Although the sex effect was no longer significant when entered into the multivariate analysis, we cannot exclude that it could probably have a role in our results, such as other demographic parameters (e.g., age, presence of chronic diseases). Nevertheless, these aspects were beyond the scope of the present study. Another limitation was the relatively small number of included studies, which probably had limited power to find differences. Indeed, our data were limited by how the moderators were distributed across trials. For example, the test for temptations as a moderator examined only 3 trials compared with the remaining 30 studies, which necessarily had an impact on power.

Consequently, and as recommended for studies with interventions,[48] other theoretical constructs of the TTM that could moderate its efficacy regarding PA should be more frequently and accurately employed and reported in publications to be analyzed in further meta-regression analyses.

Several strengths should also be acknowledged. To our knowledge, this is the first study that has statistically tested whether tailoring the intervention according to participants' SOC would lead to higher changes in PA than applying the same program to everyone. A second strength is that this meta-analysis was the first to show the evidence-based efficacy of the TTM constructs on PA behavior and to further confirm the interest in the entire model. Finally, to keep a higher level of evidence-based approach, only RCTs were included, which strengthened our results.

5. Conclusion

In conclusion, matching or not matching interventions and participants according to their SOCs did not moderate the effect of TTM-based interventions on PA promotion. TTM-based interventions significantly improved PA behavior whether interventions or participants were matched with stages of change or not. Future TTM studies should report accurately how they used TTM constructs and pay attention to the implementation of the greatest number of TTM constructs, with particular importance paid to self-efficacy and the POC.

Acknowledgment

Authors' contributions

All authors conceived of the study design. AJR, PB, JB, CB, OL, and MG did the literature review and extracted the data. AJR, PB, and MG did the literature review update. AJR, MG, PB, and MC did the statistical plan and analyses. AJR, CB, PB, and MC wrote the first draft of the manuscript. All authors did a significant revision to the manuscript. All authors have read

and approved the final version of the manuscript and agree with the order of presentation of the authors.

Competing interests

None of the authors declare competing financial interests.

Appendix: Supplementary material

Supplementary data to this article can be found online at doi:10.1016/j.jshs.2016.10.007.

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