

Predictors of Physical Activity Change Among Adults Using Observational Designs

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Abstract

Background Regular physical activity (PA) is foundational to human health, yet most people are inactive. A sound understanding of the determinants of PA may be instructive for building interventions and/or identifying critical target groups to promote PA. Most research on PA correlates has been biased by cross-sectional or passive prospective designs that fail to examine within-person analysis of PA change.

Objective The purpose of this review was to collect and appraise the available literature on the predictors of PA change conceived broadly in terms of increases/decreases from baseline assessment as well as specifically in terms of adoption and maintenance.

Methods Eligible studies were from English, peer-reviewed published articles that examined predictors of natural change of PA over 3 months + using observational (non-experimental) data in adult samples. Searches were performed from June 2012 to January 2014 in eight databases.

Results Sixty-seven independent data-sets, from 12 countries, primarily of medium quality/risk of bias, were identified with 26 correlates spanning demographic, behavioral, intra-individual, inter-individual, and environmental categories. Only intention and the onset of motherhood could reliably predict overall PA change. Among

datasets configured to predict PA adoption, affective judgments and behavioral processes of change were the only reliable predictors, although both only have a small number of available studies. There were no reliable predictors of maintenance when compared to PA relapse.

Conclusion The results underscore the importance of individual-level motivation and behavioral regulation in PA change, but also denote critical social variables. These findings, however, are constrained by PA measurement bias and limited studies that employed time-varying covariation between predictor variables and PA.

Key Points

Intention and the onset of motherhood reliably predicted overall physical activity (PA) change.

Affective judgment and behavioral processes of change reliably predicted PA adoption but there were no reliable predictors of maintenance.

Future research using objective measures of PA and employing time-varying covariation among predictors and PA is warranted.

1 Introduction

Regular moderate- to vigorous-intensity physical activity (PA) has been linked to numerous health benefits through the reduction of risk in more than 25 chronic medical conditions [1]. These include, but are not limited to, decreases in the risk of cardiovascular disease, diabetes mellitus, several cancers, several musculoskeletal conditions, and depression. Despite the impressive benefits of

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regular PA, more than 80 % of North Americans fail to meet recommended public health guidelines [2, 3], suggesting that reduced health risks from PA are largely unattained. Similar low PA rates are identified in almost all of the developed countries in the world [4]. Thus, the promotion of PA is paramount to public health.

Understanding specific factors that may influence or predict PA behavior change is important so that they can be used to help fine-tune interventions. To achieve this aim, contemporary literature has focused heavily on the correlates of PA using cross-sectional designs or passive prospective designs [5]. For example, in a recent 20-year analysis of PA research practices, Rhodes and Nasuti [6] showed that more than 80 % of research has utilized this descriptive approach. While it is valuable to understand what variables describe physically active and inactive people, a major limitation to this approach, if this information is then used to guide promotion efforts, is the assumption that between-sample differences can be considered a good proxy for within-person change [7].

Obviously, experimental research is an excellent test of the assumption that constructs accounting for between-participant differences can produce change within the same participant [8]. Critical variables can be manipulated and changes in mediators and behavioral outcomes can be evaluated through this experimental frame [9–11]. Still, contemporary interventions are often limited in duration and scope. Most interventions in our contemporary literature use short timeframes for change and involve factors that can be manipulated with relative ease by investigators (i.e., downstream intervention) such as persuasive communications to change attitudes and skill training to improve behavioral self-regulation [12–14].

It would seem highly applicable to policy-level (i.e., upstream) promotion efforts, however, to also understand a larger array of variables that could change over time. These include resource-intensive factors such as environmental/neighborhood change or non-modifiable factors such as aging or changes to marital status which may represent critical health promotion targets. To examine these factors requires longitudinal analyses of observational (non-experimental) change. Observational analyses of change studies also complement experimental studies in our understanding of PA promotion by having a greater reach of populations, as experimental trials often result in selection biases of highly motivated people with low ethnic, economic, and health diversity [15]. That is, although experimental trials provide strong internal validity, analysis of change research may allow for greater external validity as they can potentially account for observations of a greater diversity of participants in a variety of settings.

Thus, experimental trials and longitudinal change studies are complementary and highly valuable to our contemporary understanding of PA behavior change. While many

reviews and overviews of intervention research have been conducted (e.g., Conn et al. [12–14], Foster et al. [12–14], Prestwich et al. [12–14]), predicting PA change in observational designs has seen less attention. Van Stralen et al. [16] reviewed a small literature on the predictors of PA in older adults using experimental and non-experimental data but analysis of inter-individual change was not a requirement of the inclusion criteria. Amireault et al. [17] reviewed psychological and select demographic predictors of PA maintenance (i.e., factors that can account for lapses in previously active individuals) among adults and found that self-efficacy and intention could account for the differences in people who dropped versus maintained PA. Still, an assessment of the predictors of general increases/decreases in PA as well as specific adoption (from inactivity to sustained PA) and maintenance factors may be prudent. In addition, factors that extend the scope of PA beyond psychological predictors may also be helpful in order to understand PA change. Finally, these reviews did not specify a substantive time allotment between repeated assessments, thereby allowing change to occur. Past behavior can act as a very good proxy of future behavior, suggesting that behavior change takes time [18]. Allowing for longer periods of time between assessment points may be crucial to capture long-term change. Given this gap in scholarship, the purpose of this review was to collect and appraise the available literature on PA change conceived broadly in terms of increases/decreases from baseline assessment as well as specifically in terms of adoption and maintenance to inform future interventions and provide direction for future research. The socio-ecological framework was used as a categorical template to organize the review findings [19, 20]. This framework allows for a broad approach to understanding different factors contributing toward PA change under demographic, behavioral, intra-individual, inter-individual, and environmental categories.

2 Methods

2.1 Evidence Acquisition

2.1.1 Inclusion Criteria

Eligible studies were from English language, peer-reviewed published articles that examined predictors of natural change of PA over 3 months or longer using observational (non-experimental) data. PA change was considered the critical inclusion dependent variable. Change was not restricted by any particular method of analysis (e.g., residual scores, time-varying covariation scores, dichotomous change scores around a guideline, simple difference scores). Predictor variables included any independent variables

delimited to people aged 18–64 years. We chose to restrict our analyses to this age group because populations under the age of 18 years are undergoing developmental changes, and adults older than 64 years are more likely to be experiencing degenerating health; both of these factors may impact natural PA change, and both of these groups require their own focused reviews.

2.1.2 Exclusion Criteria

Studies were excluded from this review based on pre-established criteria. Excluded studies were those that:

1. had interventions present (or not controlled for) or were randomized controlled trials (RCTs) (thus not natural change). For example, changes that occurred during an intervention or RCT would likely be due to treatment effects and therefore not be reflective of changes that might have occurred naturally. Although assessing the effectiveness of interventions and RCTs on behavior change is important, in this particular review we were interested in exploring factors that may predict change without any intervention;
2. investigated PA as a predicted outcome rather than a predictor;
3. examined clinical populations, because the results may deviate from the general population as a result of the health condition. For example, studies involving participants who have been diagnosed with type 2 diabetes or cardiovascular disease may be influenced to change their PA due to their condition;
4. had follow-up intervals of less than 3 months. The decision to exclude studies shorter than 3 months was arbitrary, and health-related fitness benefits can be derived in shorter time; however, it is important to ensure enough time for change to occur. Short timeframes where little change has occurred reduces the available variability in the PA change measure, which could lead to null findings merely because no one changed behavior and not because a given predictor is unimportant. Although 6 months may be considered a prior published standard [21], it does not represent an empirical standard and considerable change could occur before 6 months; and
5. did not evaluate leisure-time PA. Occupational- and transport-related PA are clearly important but may represent different antecedents than PA spent during free time and require a separate focused review.

2.2 Search Strategy

Database searches were performed from June 2012 to January 2014 in eight databases: Academic Search

Complete, Age Line, Alt HealthWatch, Health Source—Nursing/Academic Edition, Health Source—Consumer Edition, SPORTDiscus, PsycINFO, and MEDLINE. Search terms included a combination of physical activity, exercise, adults, predictor, longitudinal, behaviour, and change. The search strategy was not restricted by language, study design, year of publication, or population. An example of the search strategy is provided in Electronic Supplementary Material Appendix S1. Manual cross-referencing of relevant articles was completed to ensure saturation of the literature.

2.3 Screening and Evidence Synthesis

Citations were initially screened by one reviewer based on title and abstract according to pre-established inclusion criteria. Full-text of relevant articles was then obtained and screened by two independent reviewers. Potential studies were discussed and agreed upon by both reviewers. Studies that were eliminated during the full-text screening phases have been recorded with reasons in Fig. 1 in the PRISMA systematic flow chart of the literature search.

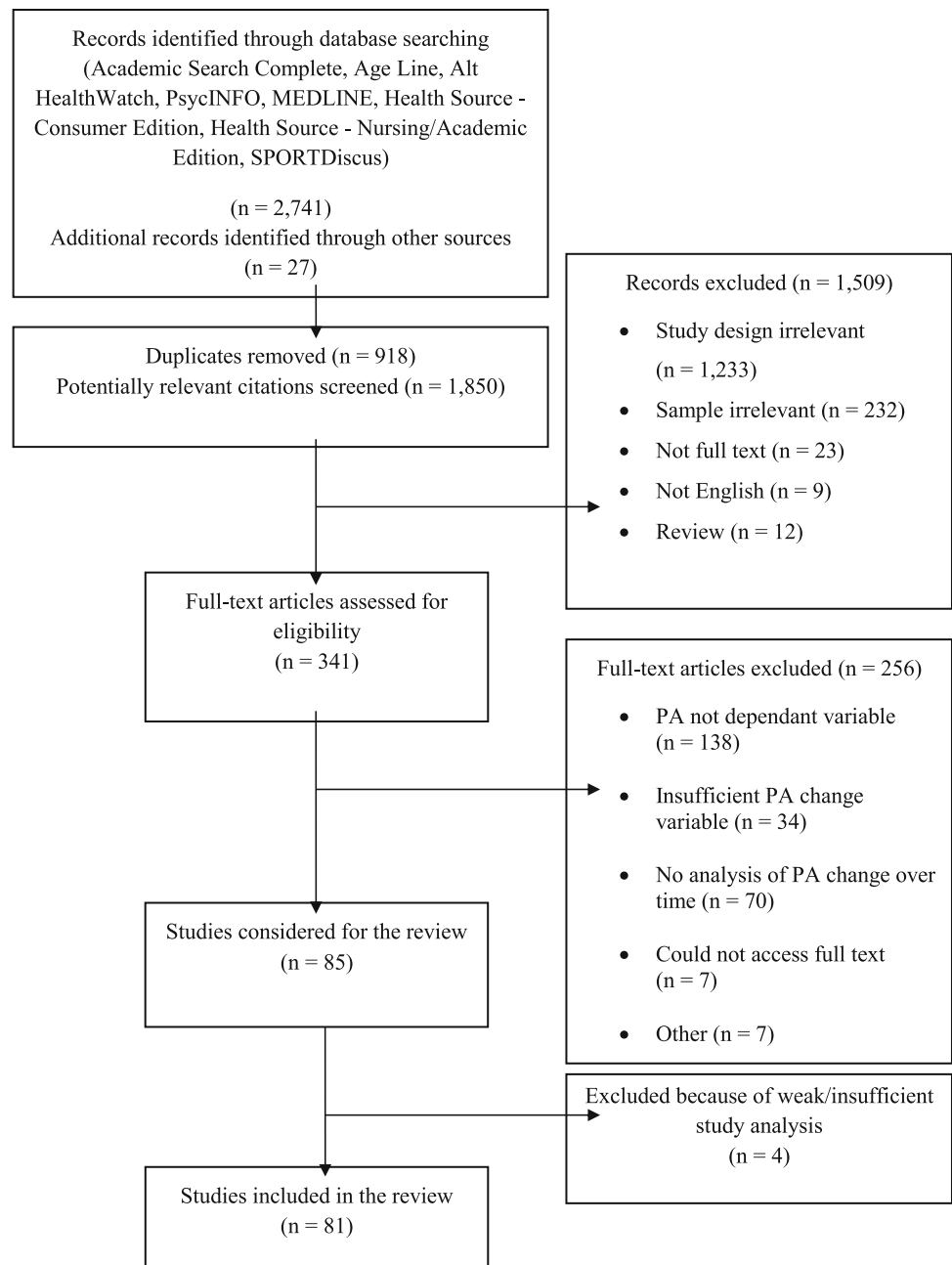
2.4 Risk-of-Bias Assessment

A modified version of Downs and Black's [22] 22-item assessment tool was used to assess the risk of bias and methodological quality. Items pertaining to RCTs were excluded, resulting in a possible maximum score of 15. Both authors independently assessed the studies and discrepancies were discussed until a consensus was reached. Eventual consensus was reached for all studies. A study was considered high quality if it scored 14–15, moderate quality if it scored 10–13, and low-quality studies were those that scored below 10. Studies were deemed weak or insufficient to be appraised in the review if they scored a 6 or less. These cut-offs have been previously established in a review by Kirk and Rhodes [23]. The scoring results can be found in Electronic Supplementary Material Appendix S2.

2.5 Data Abstraction and Analysis

Electronic Supplementary Material Appendix S3 shows an 8-item data abstraction table which included author and year of publication, participant characteristics, study length, predictor variables, PA measure, statistical results and effect sizes, time-varying covariation, and quality rating of the study. Following initial read-throughs of the studies, themes and sub-themes were developed. Themes were appraised within the socio-ecological framework and at least three studies investigating predictors of PA change were required to establish a theme. This has been

Fig. 1 PRISMA systematic flow chart of literature search. PA physical activity



previously used in reviews by Kirk and Rhodes [23] and Rhodes et al. [24]. Predictors were grouped by demographics (age, sex, ethnicity, income, education, employment), health behaviors (smoking, alcohol consumption), intra-personal factors (personality (neuroticism), attitude/outcome expectation, affective judgment, knowledge of PA, perceived behavioral control/self-efficacy, intention, behavioral/cognitive processes of change, affective response), inter-personal factors (marriage/cohabitation, divorce/separation, parenthood, social support, subjective norm, social isolation), and environment (accessibility and convenience/connectivity, safety, and aesthetics). Although

there were sufficient studies examining body mass index (BMI) and perceived health to be included as themes, we excluded these two predictors due to the influence they may have on a person's ability to change their PA. For example, a person with extremely low perceived health may be limited in their ability to be active, thus impacting the possibility for natural change to occur. Based on Sallis et al.'s [25] rubric for determining an association among studies, a theme was considered to have a positive association (+) if greater than 59 % of studies supported an increase in PA; a negative association (−) if greater than 59 % of studies supported a decrease in PA; be

inconclusive (?) if 34–59 % of studies found any association; and no association (0) if less than 34 % of studies showed any association. When analyzing the variables, both statistical significance ($p < 0.05$) and a meaningful effect size [26, 27] [$d > 0.19$; $r > 0.09$; odds ratio (OR) > 1.49] needed to be present in order for a predictor to have either a positive or negative association with PA. Studies where effect size could not be determined were scored on significance value alone. We chose not to conduct a meta-analysis for two main reasons. First, early in the evidence synthesis process it became apparent that studies had enormous heterogeneity in the PA measures (e.g., format of measurement, mode), statistical tests used to assess change, definitions of predictors (e.g., baseline, change), and study designs (e.g., length of time assessment, criterion cut-offs used); all of which impact the ability to accurately pool the studies for quantitative synthesis [28]. Second, a verbal expansion allows for a description of caveats or other idiosyncrasies specific to some studies that otherwise could possibly impact the outcome in a meta-analysis. This review followed the PRISMA Checklist [133] which can be found in Electronic Supplementary Material Appendix S4.

3 Results

3.1 Study Characteristics

Table 1 highlights the study characteristics of the 81 studies included in this review and Table 2 provides an overview of the results by theme. There were 67 independent datasets used in the results. Three studies met our inclusion criteria but did not contain enough similar studies to create themes [29–31]. Overall, five studies met the criteria to be considered of high quality (14–15), the majority of the studies ($n = 57$) were of moderate quality (10–13), and 19 were identified as low quality (< 10). The length of studies ranged from 3 months to 40 years, with an average length of 4.6 years. The 67 independent datasets represented a total of 264,187 participants with the sample sizes ranging from 32 [32] to 80,944 [33]. The majority of the studies were comprised of both males and females ($n = 54$). Two studies investigated males only [34, 35] and 11 studies investigated females only [32, 33, 36–44]. The geographical representation was broad with the majority of samples being from the USA ($n = 34$), with the remainder being from Canada ($n = 9$), the UK ($n = 6$), Australia ($n = 4$), Finland ($n = 3$), The Netherlands ($n = 5$), Austria ($n = 1$), Denmark ($n = 1$), France ($n = 1$), Germany ($n = 1$), Greece ($n = 1$), and Spain ($n = 1$).

Table 1 Characteristics of included study reports ($n = 67$ independent datasets from 81 studies)

Characteristic	Value
Location, n [independent datasets (total studies)]	
Australia	4 (6)
Austria	1
Canada	9 (12)
Denmark	1
Finland	3
France	1
Germany	1
Greece	1
Netherlands	5 (6)
Spain	1
UK	6 (7)
USA	34 (41)
Study length, years [mean (SD)], range	4.6 (6.2), 3 months–40 years
Sample size, n [mean (SD)], range	3,943.1 (11,188.6), 32–80,944
Study quality score [mean (SD)], range	11 (1.80), 7–14
Participant ethnicity, n (studies)	
Not reported	15
Diverse	50
Caucasian	1
Black	1
Participant sex, n (studies)	
All females	11
All males	2
Both sexes	54
Physical activity measures, n (studies)	
Objective (accelerometer, pedometer, number of times gym card swiped)	3
Study created questions	26
PAH	2
PAR	5
IPAQ	5
MLTPAQ	3
MAQ	2
Other/adapted from (uncategorized, CHAMPS, NPAQ2, SQUASH, BAECKE, PASE, LTEQ, LASA, PAQ, PPAQ, EHHQ)	21
Physical activity classification, n (studies)	
Total PA based on activities and/or energy expenditure	19
MVPA	28
Recreational walking	4
Exerciser/non-exerciser	3
Running	2

Table 1 continued

Characteristic	Value
Vigorous	2
Biking	1
Uncategorized and miscellaneous (i.e., inactive/active, attainment of PA guidelines)	8

BAECKE Measurement of a person's habitual physical activity questionnaire, *CHAMPS* Community Health Activities Model Program For Seniors, *EHHQ* Exercise and Health History Questionnaire, *IPAQ* International Physical Activity Questionnaire, *LASA* Longitudinal Aging Study Amsterdam, *LTEQ* Leisure Time Exercise Questionnaire, *MAQ* Modifiable Activity Questionnaire, *MLTPAQ* Minnesota Leisure Time Physical Activity Questionnaire, *MVPA* moderate-vigorous physical activity, *NPAQ2* Netherlands Physical Activity Questionnaire, *PA* physical activity, *PAH* physical activity history, *PAQ* Physical Activity Questionnaire, *PAR* Physical Activity Recall, *PASE* Physical Activity Scale for the elderly, *PPAQ* Paffenbarger Activity Questionnaire, *SD* standard deviation, *SQUASH* Short Questionnaire to Assess Health

The studies varied greatly in how they assessed PA. Only three studies used an objective measure of PA, which included the use of an accelerometer across all timepoints [45], accelerometer at one timepoint [46], and number of times a gym card was swiped [47]. The majority of the studies created their own questions for PA assessment ($n = 26$), yet the most frequently used validated PA instruments were the International Physical Activity Questionnaire (IPAQ) [48] ($n = 5$) and the 7 day Physical Activity Recall (PAR) ($n = 5$). There was also heterogeneity in the way PA was defined [i.e., moderate-to-vigorous PA (MVPA), biking, running, recreational walking, exerciser/non-exerciser, inactive/active, total energy expenditure]. The most common classification of PA was MVPA ($n = 28$), with the second most common focusing on total activities/energy expenditure ($n = 19$).

3.2 Demographic Factors

3.2.1 Age

Nineteen independent samples were present to appraise chronological age as a predictor of PA change [41, 49–66]. Age was a delimited variable in this review, and ranged from a mean of 18 to 64 years. Thus, studies with older adults and children/adolescents are not part of the variability in this analysis. All studies were limited to measuring PA with self-report. Two studies did not provide clear results with statistical tests and were removed from weighted analyses [53, 55]. Of the remaining 17 samples, 15 showed no significant and meaningful overall relationship between age and change in PA [41, 49–52, 54, 57–64, 66] while two showed a significant and meaningful relationship between older age and

PA decline [56, 65]. Among studies where adopters versus sedentary participants could be parsed from the data, six of seven studies showed that age was not related to PA adoption [49, 54, 59, 61, 63, 66]. The only caveat to these findings was a significant age effect for men but not women in the sample from Eaton et al. [62]. In this study, older men were more likely to adopt PA over 4 years than younger men. Among studies that focused on maintainers versus relapsers, six of eight studies showed no difference by age [58, 59, 61–63, 66], while the other two studies were mixed, showing maintainers were either older [49] or younger [54] than relapsers. Taken together, however, the results do not support a relationship between age and changes in PA during adulthood.

3.2.2 Sex

The difference in PA change by men and women was examined in 20 independent samples [49, 51–55, 58, 60–63, 65–73]. Seventeen [49, 51, 53–55, 61–63, 65–73] of the 20 studies found no significant and meaningful relationship between sex and change in PA, while one study showed men had a larger decline in PA than women [52]. Of the seven studies focused specifically on adoption of PA, six also showed null or not clinically meaningful relationships between sex and PA [49, 54, 61, 63, 66, 73], while Cornelio et al. [60] identified men as more likely to adopt PA over time than women. Similar findings were present in studies designed to examine PA maintenance, where five [49, 54, 61, 63, 66] of six showed null findings, yet Weiss et al. [58] reported a larger relapse in PA for women than men. Despite a couple of mixed findings, the majority of studies suggest no relationship between sex and change in PA.

3.2.3 Ethnicity

Among the 12 studies to evaluate ethnicity and change in PA [40, 41, 43, 49–52, 65, 73–76], ethnicity was either defined as ‘white’ or ‘non-white’, or in some cases was broken down further to ‘Hispanics’, ‘Asians’, ‘African Americans’, or ‘other’. One study did not include significance or effect size results so it was removed from subsequent analyses [50]. Of the remaining 11 studies, all were from samples taken in the USA. Overall, six studies had null relationships between ethnic comparators [40, 43, 51, 52, 73, 74], one study had a clear relationship with white participants reporting more positive changes in PA than black participants [75], while another had the opposed finding where white participants declined significantly more than black participants [65]. By contrast, the three other studies had mixed to moderate findings for ethnicity. Pereira et al. [41], for example, in their study of pre- to post-partum women, showed that white, black, and Asian

Table 2 Summary of the predictors of physical activity change

Predictor	Outcome	Studies (n)	Association
<i>Demographic factors</i>			
Age	Adoption	7	0
	Maintenance	9	0
	Overall	17	0
	Change in age	0	NA
Sex	Adoption	7	0
	Maintenance	6	0
	Overall	20	0
Ethnicity (Caucasian compared with other ethnicities)	Adoption	3	0
	Maintenance	1	NA
	Overall	11	?
Income	Adoption	2	NA
	Maintenance	4	?
	Overall	13	?
	Change in income	2	NA
Education	Adoption	11	?
	Maintenance	10	?
	Overall	25	0
	Change in education	2	NA
Employment	Adoption	3	0
	Maintenance	6	0
	Overall	14	0
	Change in employment	5	0
<i>Health behaviors</i>			
Smoking	Adoption	8	?
	Maintenance	9	0
	Overall	15	0
	Change in smoking	2	NA
Alcohol consumption	Adoption	4	0
	Maintenance	5	0
	Overall	7	0
	Change in alcohol	0	NA
<i>Intra-personal factors</i>			
Personality (neuroticism)	Adoption	1	NA
	Maintenance	1	NA
	Overall	3	?
	Change in neuroticism	1	NA
Attitude and outcome expectation	Adoption	7	?
	Maintenance	5	?
	Overall	14	?
	Change in outcome expectation	3	0

Table 2 continued

Predictor	Outcome	Studies (n)	Association
Affective judgments	Adoption	3	+
	Maintenance	3	0
	Overall	4	?
	Change in affect	1	NA
Knowledge of PA	Adoption	2	NA
	Maintenance	2	NA
	Overall	3	0
	Change in knowledge	0	NA
Perceived behavioral control/self-efficacy	Adoption	6	0
	Maintenance	4	?
	Overall	16	?
	Change in self-efficacy	3	+
Intention	Adoption	4	?
	Maintenance	2	NA
	Overall	11	+
	Change in intention	2	NA
Behavioral processes of change	Adoption	3	+
	Maintenance	3	0
	Overall	3	?
	Change in processes	2	NA
Cognitive processes of change	Adoption	3	0
	Maintenance	3	0
	Overall	3	0
	Change in processes	2	NA
Affective response to moderate-intensity exercise	Adoption	0	NA
	Maintenance	0	NA
	Overall	3	+
	Change in affective response	3	+
<i>Inter-personal factors</i>			
Marriage/co-habitation	Adoption	6	0
	Maintenance	6	0
	Overall	16	0
	Initiation of marriage	6	?
Divorce/separation	Adoption	–	NA
	Maintenance	–	NA
	Overall	10	0
	Onset of divorce	6	0

Table 2 continued

Predictor	Outcome	Studies (n)	Association
Parenthood			
Women	Adoption	1	NA
	Maintenance	1	NA
	Overall	6	–
	Onset of motherhood	5	–
Men	Adoption	–	NA
	Maintenance	–	NA
	Overall	3	0
	Onset of fatherhood	3	0
Social support	Adoption	8	?
	Maintenance	7	?
	Overall	12	0
	Change in social support	2	NA
Subjective norm	Adoption	3	0
	Maintenance	3	0
	Overall	5	0
	Change in subjective norm	1	NA
Social isolation	Adoption	1	NA
	Maintenance	1	NA
	Overall	3	–
	Change in social isolation	0	NA
<i>Environmental factors</i>			
Accessibility and convenience/ connectivity	Adoption	4	0
	Maintenance	3	?
	Overall	10	0
	Change in access	3	?
Safety	Adoption	3	?
	Maintenance	3	0
	Overall	7	0
	Change in safety	0	NA
Aesthetics	Adoption	3	0
	Maintenance	3	0
	Overall	7	0
	Change in aesthetics	1	NA

At least three studies were required for a theme. The themes were then broken up between adoption of physical activity and maintenance of physical activity versus relapse and overall physical activity

+ positive association (>59 % of studies), – negative association (>59 % of studies), ? indeterminate (34–59 % of studies showing an association), 0 no association (<34 % of studies showing any association), NA not applicable

participants had no difference in changes to PA yet Hispanic women were more active over time than white women. The other studies showed differences based on adoption or maintenance of PA. In terms of PA adoption,

Boutelle et al. [49] and Margolis [73] showed no ethnic differences, yet Macera et al. [76] showed that white women were more active over time than black women but the effect was null for men. In terms of PA maintenance, however, the only study to evaluate this potential relationship found no significant difference for white participants compared with other ethnicities [49]. Clearly, the contemporary literature on ethnicity and PA change is limited to the USA and inconclusive.

3.2.4 Income

Thirteen studies evaluated an income variable (defined as a household currency earned) in relation to PA change [41, 49, 50, 52, 54, 58, 60, 64, 66, 75, 77–79]. The best study designs were from Boone-Heinonen et al. [79] and Brown et al. [50], who used a change in income variable in order to correlate this with change in PA. Eight of the 13 studies showed no significant and meaningful effect size relationship between income and change in PA [41, 50, 52, 54, 58, 60, 64, 66], three studies showed a clear relationship between decreased PA and lower income [49, 77, 78], one study showed that lower income was related to decreased PA in women but not men [75], while another study showed that decreases in income related to decreases in PA for black but not white participants [79]. Only two of these studies evaluated income and adoption of PA [49, 66]; the studies found no significant and meaningful relationship between these variables. For the four studies that addressed PA maintenance, two found no significant and meaningful association [58, 66] and two found a significant and meaningful association between lower income and relapse [49, 78]. The results suggest inconclusive evidence at present for a relationship between income and change in PA.

3.2.5 Education

Education, measured as years of formal schooling, was present in 25 independent samples for an analysis of PA change [40, 41, 43, 46, 49, 51, 52, 54–60, 62–66, 76, 78–82]. However, only Schmitz et al. [56] and Borodulin et al. [82] employed a change in education measure; the other 23 samples used baseline education as a correlate of change in PA. Overall, the results showed 17 studies with non-significant findings and/or effect sizes below a meaningful value [40, 41, 43, 51, 52, 54, 55, 57, 59, 60, 63–66, 80–82] and eight studies with significant and meaningful associations between higher education and positive change in PA [46, 49, 56, 58, 62, 76, 78, 79]. Among the 11 studies where data were specified to PA adoption, seven showed no association [49, 54, 55, 59, 63, 66, 73], one showed a significant and meaningful association between education and PA adoption [62], and the other three showed sex-

specific findings where education was related to PA for women but not men [56, 61, 76]. Among the ten studies of PA maintenance, six showed no relationship [54, 55, 59, 62, 63, 66], three showed a significant and meaningful PA decline with lower education [49, 58, 78], and Sallis et al. showed no relationship between education and PA for men but PA decline with lower education among women [61].¹ Taken together, the results suggest no overall relationship between baseline (between participant) education and subsequent (within participant) changes in PA, but specific assessments of adoption and maintenance are inconclusive.

3.2.6 Employment

Fourteen independent datasets evaluated employment status and change in PA [36, 40, 41, 43, 46, 49, 57, 59, 63, 65, 66, 75, 78, 82]. These studies coded employment as either working/not working [36, 49, 57, 63, 66, 78, 82], white collar/blue collar [46, 59, 65, 75], or total working hours [40, 41, 43]. Four studies made optimal use of the prospective design by evaluating change in employment and its relationship with change in PA [36, 41, 43, 57], and longitudinal follow-up ranged from 18 months [41] to 22 years [82]. Overall, 11 of the 14 studies showed no significant and meaningful relationship between employment and change in PA [36, 40, 41, 46, 57, 59, 63, 65, 66, 78, 82], no studies had overall effects of employment and PA, while the remaining three studies showed moderate findings. For example, Sallis et al. [43] found an increase in work hours among Hispanic mothers was related to an increase in PA across 7 years, but no relationship was present for white mothers. Kaplan et al. [75] found blue collar workers decreased PA across 9 years more than white collar workers, yet no relationship was present for women and employment. Among the three datasets that specifically focused on adoption of PA, no significant relationship with employment emerged [36, 49, 59, 63, 66]. Similarly, for studies that evaluated maintenance versus relapse of PA, five of six studies showed no significant relationship [36, 59, 63, 66, 78], while Boutelle et al. [49] found that participants maintaining PA over 4 years were more likely to be working than unemployed. Overall, the composite results suggest no relationship between employment and change in PA.

¹ Although Sallis et al. [61] (1992) and Sallis et al. [80] (1992) are from the same dataset, Sallis et al. [80] (1992) analyzed PA adoption versus just overall PA change and therefore we have included both analyses in the results.

3.3 Health Behaviors

3.3.1 Smoking

Fifteen studies had the necessary information to evaluate smoking status as a predictor of PA change [35, 42, 46, 49, 54, 58–62, 69, 76, 78, 82, 83]. Smoking was defined either by the number of cigarettes smoked in a day or as either a current smoker/non-smoker. PA measurement was self-reported with the exception of Hamer et al. [46] who used accelerometry at follow-up. The best designed studies were from French et al. [83] and Borodulin et al. [82], who used change in smoking status to evaluate subsequent changes in PA. Only one [49] of the 15 studies showed consistent (i.e., across all sub-samples) evidence that smoking status relates to change in PA. Further, among the eight studies that framed their designs to evaluate adoption of PA, five showed no significant and meaningful relationship with smoking [54, 56, 59, 63, 76], one found a significant relationship between adoption of PA and lower smoking [49], one study identified a significant relationship between adoption of PA and lower smoking in females but not males [61], and the other study found a significant effect for PA adoption and less smoking for males but not females [62]. For the nine studies that were framed in terms of understanding PA maintenance, six found no relationship with smoking [49, 54, 56, 58, 61–63], while two studies showed a significant PA relapse was associated with smoking compared with non-smokers [49, 59]. The remaining study from Droomers et al. [78] showed no relationship between smoking and PA maintenance for adults under 45 years of age, but a significant PA relapse for smokers over 45 years compared with non-smokers. The overall evidence suggests that smoking does not have an effect on PA change but sex and age may moderate this finding during PA adoption.

3.3.2 Alcohol

Alcohol use, measured as drinks per day/week, was evaluated in seven independent samples [54, 59–61, 63, 78, 82]. No study supported an overall relationship between alcohol use and PA change and this null finding extended to studies that focused on adoption [54, 59, 61, 63] and maintenance [54, 59, 61, 63, 78].

3.4 Intra-Personal Factors

3.4.1 Personality

Three studies were available to examine neuroticism [68, 78, 84], defined here as a generalized disposition of self-reproach and negative affect [85]. These studies ranged

from 6 [78] to 37 [68] years in longitudinal analyses and included overall change in PA [68, 84] as well as a comparison of maintenance versus PA dropout [78]. Overall, one study showed that high levels of neuroticism were related to dropout of PA among young middle-aged adults but not older middle-aged adults [78], another study found that neuroticism was related to a decline in PA for men but not women [68], and the third study found a significant but not meaningful relationship between decline in PA and higher neuroticism [84]. The results clearly depict mixed findings at present. Two of these studies also assessed extraversion [68, 84], defined as a disposition of sociability, positive emotion, and high energy [85]. DeMoor et al. [84] found a significant and meaningful relationship between high extraversion and increases in PA and this was also identified by Kern et al. [68], although the relationship was only for men. The evidence suggests there may be a relationship between extraversion and positive changes in PA, but more research is needed to make this conclusive.

3.4.2 Attitude/Outcome Expectations

Attitude/outcome expectations, broadly defined as a cognitive judgment about the perceived consequence of PA, were assessed in 14 samples [38, 39, 44, 55, 61, 62, 70, 72, 86–91]. Three studies assessed change in attitude/outcome expectations and its relationship with subsequent change in PA [39, 90, 91]. Of the 14 studies, only one found a relationship between attitude/outcome expectations [70], four found a non-significant/non-meaningful relationship [38, 86, 90, 91], while the remaining nine studies had mixed findings by construct, PA status, or sex. For example, Higgins and Oldenburg [39], in their analysis of pros (reasons for) and cons (reasons against) of PA, found that increased cons was associated with decreases in PA, yet no relationship was present for pros. Sallis et al. [55] found changes in total PA were associated with positive attitudes for women but this was not related to PA among men. Among the seven studies to evaluate PA adoption, one showed a positive outcome expectation and greater adoption relationship among both sexes [62], four had null findings [44, 86, 88, 91], while the other two had mixed findings. Courneya et al. [87] showed no relationship between attitude and adoption of PA in a time 1–2 (baseline to 6 months) estimate, but a significant relationship between positive attitude and adoption at time 2–3 (6 months to 1 year). Sallis et al. [61] showed that more expected PA benefits was related to adoption for men but not women, where expected barriers was unrelated for both sexes. In terms of PA maintenance, four [61, 62, 87, 88] of five studies also showed mixed findings, while Titze et al. [44] showed no relationship between attitude and PA. Courneya et al. [87] showed no effect in a time 1–2

estimate, but a significant relationship at time 2–3. Rhodes et al. [88] showed no relationship for the constructs of instrumental attitude and pros, but PA cons were higher among those who relapsed than among those who maintained PA over 6 months. Finally, Sallis et al. [61] and Eaton et al. [62] showed that more expected PA benefits was related to maintenance for men but not women, and Sallis et al. also found that expected barriers were unrelated for both sexes. Overall, the role of attitudes/outcome expectations is mixed at present with no clear factor that can account for the results.

3.4.3 Affective Judgments

Four studies were available to evaluate affective judgments, defined as the expected feelings from PA engagement (e.g., enjoyment, pleasure vs. boredom, pain) [44, 72, 88, 92]. One study identified enjoyment as a large correlate of overall PA change [72]. Two of the studies found baseline affective judgments to correlate positively with PA adoption but not maintenance [44, 92] while the third study showed no significant relationship [88]. The findings suggest some evidence for affective judgments and change in PA overall, particularly adoption of PA in this small number of studies.

3.4.4 Knowledge of Physical Activity

Three studies from the USA [55, 61, 93] and one study from The Netherlands [70] were available to assess knowledge about PA and its relationship to subsequent PA change. Knowledge was broadly defined as awareness about health-related benefits of regular PA. No significant and meaningful relationship was identified between knowledge and change in PA across all four studies.

3.4.5 Perceived Behavioral Control/Self-Efficacy

Sixteen studies have evaluated perceived behavioral control/self-efficacy, broadly defined as one's perceived ability to be physically active, in relation to PA change [38, 39, 47, 55, 58, 61, 86–89, 91, 93–97]. Three of the studies were designed to examine change in control/self-efficacy and its relationship with subsequent change in PA [39, 91, 93]. Overall, seven of the 16 studies showed support for a significant and meaningful relationship with change in PA [39, 47, 58, 89, 93, 96, 97], all showing higher perceived control/self-efficacy and a positive change in PA. Three additional studies showed partial support of a relationship between perceived control/self-efficacy and change in PA [55, 61, 88]. For example, Sallis et al. [55] showed that changes in self-efficacy were related to change in total PA in men but not women. In terms of PA adoption, four [86–

88, 91, 95] of six studies showed no significant/meaningful relationship with perceived control/self-efficacy. By contrast, among the four studies that compared maintenance versus relapse, two showed a significant relationship [58, 88], one study was null [87], and one study showed higher self-efficacy was related to maintenance for men but not women [61]. The contemporary evidence on perceived control/self-efficacy and change in PA is mixed. The results indicate an inconclusive relationship between change in self-efficacy and subsequent change in PA, yet adoption of PA from a profile of inactivity has limited evidence for a relationship.

3.4.6 Intention

Intention, defined as an overall willingness to try hard to perform PA [98], was measured in 11 samples [38, 39, 47, 70, 86, 87, 94–97, 99]. Importantly, two of these studies made the most of the longitudinal design by examining change in intention and its association with change in PA [39, 96]. Overall, seven of the 11 studies showed support for a relationship between intention and change in PA [38, 39, 94–97, 99], one study showed mixed findings [87], and the remaining three studies showed no significant result [47, 70, 86]. In terms of PA adoption, two of four studies showed no relationship between intention and behavior [86, 87], while Lippke et al. [95] and Fuchs [99] found significant and medium-sized relationships. Courneya et al. [87] and Fuchs [99] were the only authors to examine PA maintenance and found a significant relationship between those with higher intention and a greater proportion of participants who maintained PA. While there are some deviations in PA adoption and intention, the overall results suggest that positive intention, including change in intention over time, is associated with positive PA change.

3.4.7 Cognitive and Behavioral Processes of Change

Three independent samples have been used to evaluate whether the behavioral and cognitive processes of change are linked to PA change [44, 88, 100]. In terms of the behavioral processes of change, one study showed support for the relationship between the processes of change and change in PA [100] while two studies were mixed depending on whether participants were adopting or maintaining PA [44, 88]. Specifically, when the studies were divided into maintenance and adoption categories, all three studies showed that the behavioral processes predicted successful adoption of PA but only Rhodes and Plotnikoff [100] showed a significant finding for maintenance versus relapse. In terms of the cognitive processes of change, all three studies show no evidence in their ability

to predict adoption or maintenance of PA. The findings suggest mixed evidence for the behavioral processes of change and PA overall, but the use of behavioral strategies during the adoption of PA had clear support in this small number of studies. No support was found for the cognitive processes of change and change in PA.

3.4.8 Affective Responses to a Bout of Exercise

Three studies evaluated the relationship between the affective response to a single bout of exercise and subsequent change in PA [101–103]. The studies all used a basic feeling-state (displeasure–pleasure) measure taken at approximately the moderate intensity marker of a submaximal exercise test (ranging from 64 % of age-predicted maximum heart rate to 65 % of predicted maximum oxygen uptake) and controlled for pre-/incremental-test feeling state. All three studies demonstrated a significant and meaningful relationship between positive affect reported during moderate intensity exercise and change in PA.

3.5 Intra-Personal Factors

3.5.1 Marriage/Co-Habitation

Sixteen independent samples examined marital status (or common-law cohabitation) as a predictor of PA change [33, 36, 40, 41, 49, 52, 56, 59, 62, 63, 65, 73, 75, 77, 79, 104, 105]. Six studies used change in marital status as a correlate of change in PA [36, 56, 65, 79, 104, 105]. Overall, 11 of the 16 studies showed a non-significant/not meaningful relationship between marriage/cohabitation and change in PA [33, 40, 41, 49, 52, 56, 62, 63, 73, 77, 104, 105], two studies showed moderate findings [36, 59], and three studies showed a significant relationship between marriage and change in PA [65, 75, 79]. However, among these studies, the significant relationship was opposed, with two showing that married couples increased PA [65, 75] and the other showing that onset of marriage decreased PA [79] relative to single participants. Among the six studies that examined adoption of PA, no results supported a relationship with marriage [36, 49, 56, 59, 62, 63]. Similarly, marriage and PA maintenance had four of six studies with null findings [49, 56, 62, 63], but Bell and Lee [36] showed women who married were less likely to maintain PA than women who remained single. This was not supported, however, by Zimmerman et al. [59], who found no effect for women, but that married men were less likely to maintain PA. Despite these mixed findings, the overall evidence is not supportive of a relationship between marriage and change in PA.

3.5.2 Divorce/Separation

Divorce or separation, compared with married couples, was investigated in ten independent samples [33, 34, 41, 49, 56, 57, 59, 77, 104–106]. Six of these ten studies evaluated a transition from being married to being divorced and the association with change in PA [33, 34, 56, 104–106]. No study showed a significant and meaningful relationship between divorce/separation and change in PA.

3.5.3 Parenthood

For an evaluation of parenthood and change in PA, our review considered three possible designs: (1) a comparison of people with and without children and subsequent changes in PA; (2) a within-participant change in PA pre-pregnancy and post-parenthood; and (3) a hybrid of these two designs that includes pre- and post-parenthood assessment of PA with a comparison cohort of people who did not have children across time. Our review yielded eight independent datasets that fit these criteria [36, 40, 45, 52, 66, 78, 79, 107]. All used self-reported PA as a dependent variable with the exception of Rhodes et al. [45] who assessed MVPA with accelerometry. Six studies examined women exclusively [36, 40, 45, 52, 79, 107], three studies had exclusive assessments of men [45, 52, 79], and two studies contained an amalgam of men and women under “parents” [66, 78]. Among women, five of the six studies [36, 40, 45, 52, 79] showed a significant and small to medium sized effect decline in PA related to motherhood. Of interest, five of these studies had the most stringent test of parenthood as they featured baseline assessment of participants before pregnancy and tracked a comparison cohort of women without children across time. Among men, one [52] of three studies found fatherhood associated with a decline in PA. Bell and Lee [36] and Sugiyama et al. [66] categorized their data in terms of adoption and maintenance criteria while Droomers et al. [78] classified their data in terms of maintenance. Failure to adopt PA over 4 years was 1.7 times more likely for new mothers than for women without children in Bell and Lee [36], but a general “parent” compared with people without children in the home measure was not related to adopting walking in Sugiyama et al. [66]. Conversely, maintaining PA was significantly less likely for new mothers [36] and a baseline assessment of “parent” compared with people without children in one study [78] but not another [66]. Overall, the results support motherhood as a predictor of PA decline that spans at least 2–15 years post-partum, but a similar decline may not extend to fatherhood. The limited number of studies that feature exclusive male samples makes this assessment tentative.

3.5.4 Social Support

Social support, broadly defined as some encouragement or aid in PA from a social referent (e.g., friends, family), was evaluated as a correlate of PA change in 12 studies [44, 49, 58, 61, 62, 65, 67, 86, 87, 91, 99, 108]. Two of these studies assessed changes in social support and its subsequent relationship with changes in PA [65, 91]. Overall, eight of the 12 studies showed no significant and meaningful relationship between social support and change in PA [44, 49, 58, 65, 67, 86, 91, 108], one study found clear support for higher social support and subsequent adoption and maintenance in PA [99], while the other three studies showed mixed findings with moderators around adoption or maintenance. For example, Sallis et al. [61] found women with higher social support were more likely to adopt PA, but the effect was null for men. However, the four other studies focused on PA adoption showed no relationship with social support [44, 49, 62, 87]. Among the seven studies that examined PA maintenance, four also showed no relationship with social support [44, 49, 58, 61]. By contrast, Courneya et al. [87] showed no relationship between social support during one 6-month period but a significant and meaningful relationship between social support and lower relapse in a second 6-month period. Eaton et al. [62] showed that women who received more encouragement from their children were more likely to maintain PA than those with lower encouragement, but the effect had an opposite relationship with men. Despite some significant interactions between social support and factors such as sex that render specific assessments of adoption and maintenance inconclusive, the overall relationship appears negligible with PA change.

3.5.5 Subjective Norm

Five studies evaluated subjective norm and its relationship with change in PA [38, 47, 61, 87, 88]. Subjective norm was measured as perceived pressure to engage in PA in all studies. All studies featured baseline assessment of subjective norm and its subsequent relationship with change in PA. No study found a significant relationship for subjective norm and change in PA including studies that focused on adoption and maintenance behavior [61, 87, 88]. Thus, while there is a paucity of evidence to evaluate changes in subjective norm and changes in PA, between-participant subjective norm is not associated with change in PA.

3.5.6 Social Isolation

Three studies measured a variable covering perceived social disconnectedness/isolation and its relationship with

change in PA [51, 59, 75]. These studies all assessed social isolation at baseline and its relationship with change in PA over time. Overall, social isolation was significantly associated with a decline in PA in two [51, 75] of the three studies and with mixed findings in Zimmermann et al. [59]. In this case, social isolation was not associated with maintenance of PA versus relapse, but it differentiated those who adopted PA, with the people who perceived more isolation reporting they were less likely to take up PA. The results suggest that social connectedness, at least when compared between participants, can account for increases in PA.

3.6 Environmental Factors

3.6.1 Accessibility

Ten independent samples [37, 44, 64, 66, 67, 80, 86, 94, 109] were available to evaluate convenience (broadly defined as any variable that measured a form of access to recreation) as a predictor of PA change. All but one study [86] reported on the perceived environment. Of particular note, three studies evaluated the relationship of change to neighborhood access/convenience and its relationship with adoption of PA [32, 37, 86]; this is the most robust assessment of PA change. Nine of ten samples showed no overall evidence for a significant and meaningful association between convenience/accessibility and change in PA, regardless of the differences in measurement among the studies. By contrast, Wells and Yang [32] showed that improvements to access/convenience were significantly associated with decreases in objectively monitored walking. When available data were divided into adoption and maintenance considerations, three of four studies [44, 61, 66] showed no relationship between accessibility and PA. The one caveat to this finding was the Beenackers et al. [86] study which found some indicators of convenience (residential density, access to park) related to cycling adoption and other indicators not related at a meaningful effect size (connectivity, access to cycling paths, number of recreational destinations). These differences were null when considered in multivariate analyses. In terms of maintenance of PA compared with relapse, Sallis et al. [61] found men, but not women, were more likely to maintain their vigorous PA when facilities were convenient. Proximity to green space was also related to the maintenance of recreational walking [66] but the effect was not replicated in a sample of runners [44]. The results, at present, suggest no overall relationship between environmental convenience/access to recreation and changes in PA and PA adoption, but there is mixed evidence for PA maintenance.

3.6.2 Safety

Seven samples comprised perceived safety-related variables and change in PA and these assessed PA in terms of cycling [86], running [44], moderate-intensity PA [94], moderate-to vigorous-intensity PA [109], vigorous-intensity PA [80], and total PA [67, 78]. Safety included crime assessments, safety assessments, neighborhood lighting, loose dogs, and heavy traffic. Despite a large range in study characteristics, all seven samples showed no significant and meaningful overall relationship between safety measures and changes in PA. There were, however, certain specific interactions and subanalyses worthy of note. Sallis et al. [109] found that loose dogs and higher perceived crime resulted in small but significant relationships with lowered moderate- to vigorous-intensity PA among women but not men (overall test of men and women was not of meaningful effect size). Of the three studies to categorize predictors of adoption, one study was null [44], one showed that safety was associated with lower adoption for males but not significant for females [61], and the one study to evaluate change in safety and subsequent adoption of PA showed that increases in perceived crime was related to lower cycling, but not in a multivariate test of environmental factors [86]. Finally, among studies that evaluated maintenance versus relapse, Droomers et al. [78] showed that extreme neighborhood safety circumstances were associated with significant and meaningful lowering of PA over 6 years compared with ideal circumstances, but only for people over 45 years of age, while two other studies found no association between safety and PA maintenance [44, 61]. Thus, the results overall do not provide compelling evidence for a relationship between neighborhood safety and changes in PA, but the heterogeneity of the methods and some sub-sample relationships makes this a liberal interpretation.

3.6.3 Aesthetics

Seven independent samples were present to investigate aesthetics (defined broadly as sensory/perceptual-based aspects of a local environment such as scenery, exhaust fumes, etc.) as a predictor of PA change [44, 66, 67, 78, 86, 94, 109]. Clearly the highest-quality study was from Beenackers et al. [86], who evaluated change in environmental aesthetics after a neighborhood change and its association with participant's adoption of PA (cycling). Regardless of the heterogeneity among the studies, the results showed no significant and meaningful effects for aesthetics and a change in PA. The three studies to evaluate PA adoption were null [44, 66, 86]. An analysis of maintainers had two null findings [44, 66], while Droomers et al. [78] showed

that very extreme neighborhood circumstances were associated with significant and meaningful lowering of PA over 6 years compared with ideal circumstances, but only for people over 45 years of age. Overall, there is no compelling evidence for an association between aesthetics and change in PA, though there is a paucity of studies employing similar methodology to make a robust statement at present.

4 Discussion

The purpose of this review was to collect and appraise the available literature on the predictors of PA change conceived broadly in terms of increases/decreases from baseline assessment as well as specifically in terms of adoption and maintenance. Sixty-seven independent datasets, primarily of medium quality/risk of bias, were identified with correlates spanning demographic, behavioral, intra-individual, inter-individual, and environmental categories using the socio-ecological model as a basic template. The results advance a very limited prior review literature on the predictors of observed PA change in adults [16, 17].

First, one of the most striking results of the review is the fairly low yield of reliable correlates able to predict PA change despite research on 26 potential variables. This is in marked contrast to the reviews of correlates of PA in adults [5, 110] and demonstrates the bias that cross-sectional or passive prospective designs provide when not accounting for within-person change across time. The limited findings in our review map closer to the reviews of PA intervention mediators [9, 11, 111] and validate that predictors of PA change may be closer to what one might require when targeting variables for PA intervention. When considering general change in PA, the consistent correlates were intention (intra-personal) and the onset of motherhood (inter-personal). Higher intention was also identified as the critical correlate of maintenance in Amireault et al. [17]. The intention concept represents overall motivation [98], highlighting the importance of individual-level motivation in natural PA change and providing validation for intention-based models in understanding PA behavior [21, 98, 112] as well as downstream individual-level intervention approaches [12–14]. What is concerning, however, is that none of intention's purported antecedents in these theories were reliably linked to change in PA. Thus, while overall motivation can account for PA change, the sources of that motivation are more obtuse. Positive affective response to a bout of moderate-intensity exercise was also identified as a correlate of increased PA, but it is difficult to discern whether this is a reliable finding at present because of the small number of studies and additional research that has shown null findings when it has been used to predict short-

term PA [113]; additional research is needed to make firm conclusions, but this may demonstrate the importance of the hedonic response to exercise in PA.

The massive increase in domestic workload duties and subsequent fatigue due to the onset of motherhood is an established correlate of lowered PA in prior reviews, but these implemented cross-sectional designs comparing parents with women without children [114, 115]. The results in this review show strong evidence, in terms of design quality and effect size, that motherhood may be one of the most pivotal times to intervene and prevent PA decline. Intervention efforts thus far have been limited and show short-term changes that revert back to low PA within 3 months [116]; thus, sustained intervention research in this demographic would seem a priority. Social isolation/loneliness was another inter-personal variable identified as a correlate of PA decrease, but it is difficult to discern whether this is a reliable finding because of the small number of studies at present; it requires additional research and highlights that robust changes to one's perceived social standing may impact PA.

While the review identified an extremely small number of variables that were reliable predictors of PA change, it demonstrated that several variables did not link to changes in PA. These included demographic factors such as age, sex, education, and employment; behavioral factors such as smoking and alcohol; intra-individual factors such as knowledge and cognitive processes of change; inter-individual factors such as marriage, divorce, fatherhood, social support, and subjective norm; and environmental factors such as access, aesthetics, and safety. The potential caveats to this list were the cognitive processes and fatherhood due to a small number of studies, and marriage and neighborhood accessibility because the highest-quality studies show mixed results. High-quality studies that examine change in these variables with subsequent change in PA may be helpful to identify whether these findings are robust.

Several variables fell into the mixed-evidence category for PA change: these included demographic factors such as ethnicity (white participants tend to have more favorable PA change) and income (higher incomes tended to be linked to higher PA); and intra-personal variables such as personality (neuroticism linked to PA decrease while extraversion linked to PA increase), attitude/outcome expectancy, affective judgments, self-efficacy/perceived control (the highest-quality studies show change in self-efficacy is linked to increases in PA), and the behavioral processes of change. Overall, continued longitudinal research is needed to identify whether these factors are reliably linked to changes in PA. The results contrast with Amireault et al. [17], who found self-efficacy, along with intention, to be the most reliable predictors of

maintenance. The difference is likely due to the much larger number of papers in our review than in that prior paper.

Theorists and practitioners are often interested in whether there are different predictors of adoption (vs. inactivity) behavior compared with maintenance (vs. relapse) [117–120]. Our review represents the largest and most robust examination of this premise. Given the high prevalence of inactive adults, an understanding of PA adoption is clearly the most important outcome variable for intervention. Overall, affective judgments (i.e., enjoyment and pleasure from PA) and the behavioral processes of change were the only reliable correlates of PA adoption, but sustained research is advisable because of the small number of studies with these constructs at present. Both of these constructs have theoretical support in the PA domain. For example, the processes of change results support the tenets behind models such as the health action process approach [120], the multi-process action control model [118], and obviously the transtheoretical model [21] where regulatory behaviors are considered essential to move from a decision to act to actual behavioral adoption. The relationship between affective judgments and adoption supports self-determination theory [121], the multi-process action control model [118], and other hedonic models of PA [122] where feeling states and pleasure are considered central to behavioral enactment. When taken into consideration with the positive predictive effects on PA for those with greater affective responses during exercise, this review clearly suggests that making exercise enjoyable/pleasurable is an important target for intervention. Behavioral theories that favor cognitive over affective determinants of behavior, such as social cognitive theory [123], theory of planned behavior [98], and protection motivation theory [112], or pure social or environmental models, may have limited utility in PA adoption [122].

No variables predicted maintenance reliably from relapse. The failure of variables to identify maintenance is interesting and may stem from three reasons. First, the definition of maintenance may contribute to this problem as a duration of time (e.g., active for x months) is likely to be too vague to define a process of maintenance [17, 117, 124]. Second, the variables under study thus far may not determine the maintenance process. For example, habit and identity have both been shown to have high prevalence among PA patterns [118, 125], but they were absent in the longitudinal change studies at present. Finally, it is possible that maintenance is a theoretically desired but unvalidated construct that ultimately does not represent PA (i.e., one is always in a pattern of behavioral acquisition). Many of our theories such as social cognitive theory [123] and theory of planned behavior [98] take this general position. Future

research is needed to disentangle which of these possibilities explains the findings of this review.

While the findings of this review provided interesting insights into key targets for intervention and the limits/advantages of contemporary PA theories, they also serve as a valuable platform for future research. The contemporary literature is clearly limited by self-reported PA, which may bias the findings [126]. Indeed, only one study [45] employed accelerometry in the longitudinal change design. Future research needs to use more objective assessment of MVPA in order to validate the findings in this review. Another glaring limitation of the current PA change literature is a very low number of studies that examine time-varying covariation among predictors and change in PA. Analysis of change in predictor and its correspondence with change in PA is likely important to understand PA changes as a consequence of the predictor [127]. Furthermore, baseline assessment of the predictor followed by analysis of change in PA may set up the results for null findings when predictor variables are largely static across time. For example, among the built environmental research, it would seem imperative to examine actual changes in environment and their relationship to PA changes [128]; it seems unlikely that static environments would have any impact on fostering PA change and this may account for the null findings in this review. This “change–change” examination in longitudinal designs is likely present for many of the existing datasets so researchers are encouraged to (re)examine their datasets and provide this level of detail in future papers.

In addition to the limits of the literature present in this review, the findings contained herein are limited by the methods in this review. For example, studies outside of our search terms, the English language, or published work could modify the overall interpretation of our results. In addition, a different follow-up cut-point may also yield different findings.

5 Conclusion

In summary, this review of 67 independent datasets evaluating PA change included 26 variables organized by demographic, behavioral, intra-personal, inter-personal, and environmental categorizations. Only intention and the onset of motherhood could reliably predict overall PA change. Affective response to exercise and social isolation were also linked to PA, but more research is needed to examine the robustness of these findings. Among datasets configured to predict PA adoption, affective judgments and behavioral processes of change were the only reliable predictors, although these also had a limited number of samples. There were no reliable predictors of maintenance

when compared with PA relapse. The results underscore the importance of individual-level motivation, particularly affect, and behavioral regulations in PA changes, but also denote critical social/life-course variables. These results, however, are limited by PA measurement bias and the few studies that employed time-varying covariation between predictor variables and PA.

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