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Personality and physical activity: A systematic review and meta-analysis

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ABSTRACT

Whether personality determines physical activity or its outcomes is relevant for theory and public health but has been understudied. We estimated the population correlations between Big-Five personality factors and physical activity and examined whether they varied according to sample characteristics and study features. Database searches were conducted according to PRISMA guidelines, for articles published in the English language prior to November 1st, 2013. Sixty-four studies including a total of 88,400 participants yielded effects (k) for Extraversion (88), Neuroticism (82), Conscientiousness (69), Openness (51) and Agreeableness (52). Significant mean r was found for Extraversion ($r = .1076$), Neuroticism ($r = -.0710$), Conscientiousness ($r = .1037$) and Openness ($r = .0344$), but not Agreeableness ($r = .0020$). Effects were moderately heterogeneous (I^2 range = 44–65%) and varied by sample characteristics (e.g., age, gender, or clinical status) and/or study features (e.g., measure quality or item format). This analysis expands results of previous reviews and provides new support for a relationship between physical activity and Openness. Future studies should use better measures of physical activity and prospective designs, adjust for statistical artifacts, and consider advances in the conceptualization of personality.

1. Introduction

Physical activity among adults and youths in the US is below levels recommended for health promotion (Centers for Disease Control & Prevention, 2007, 2013; Physical Activity Guidelines Advisory Committee, 2008; US Department of Health, 2010) and is a target of public health interventions, which often have modest success (Heath et al., 2012; Kriemler et al., 2011; Metcalf, Henley, & Wilkig, 2012). Factors that may modify the success of physical activity interventions, or their varying health outcomes (Bouchard, Blair, & Church, 2012) have received little study. However, theory (Eysenck & Eysenck, 1985; Gray, 1991; McCrae & Costa, 1999) and some evidence from observational studies (Rhodes & Smith, 2006) suggest that personality explains some of the natural variation in physical activity. Personality may also help explain or modify commonly reported (Asmundson et al., 2013; Cooney et al., 2013; Herring, Jacob, Suveg, Dishman, & O'Connor, 2012; Herring, O'Connor, & Dishman, 2010; Herring, Puetz, O'Connor, & Dishman, 2012; Physical Activity Guidelines Advisory Committee, 2008) associations between physical activity and several aspects of mental health (De Moor, Beem, Stubbe, Boomsma, & De Geus, 2006). Furthermore, such associations could serve as a platform from which to investigate genetic factors common to personality and physical activity (Bouchard & McGue, 2003; Bray, Hagberg, & Perusse, 2009; Dishman, 2008; Jang, Livesley, & Vernon, 1996; Riemann, Angleitner, & Strelau, 1997; Stubbe et al., 2006).

Personality consists of stable traits that are observable across ages, genders, and cultures. Generally, traits represent enduring and consistent between-person differences in predispositions for cognitions, emotions, and behaviors. The study of personality has overcome several obstacles in both the conceptualization of testable and observationally supported constructs, as well as their measurement (Eysenck, 1991; John & Srivastava, 1999). A wealth of evidence supports the existence of five primary factors of personality (Digman, 1989; Goldberg, 1993; McCrae & Costa, 1987; O'Connor, 2002), though reliance on self-report measures and factor analysis has led to some criticism of the five factor model by those in favor of theories postulating fewer primary dimensions and offering testable hypotheses about underlying physiology (e.g. Eysenck & Eysenck, 1985; Gray, 1991; Zuckerman, 2005), or by those claiming that five factors are not enough to account for important individual differences in behavior (Paunonen & Jackson, 2000). Nevertheless, most of the literature involving personality and physical activity has used either Eysenck's three factor model (Eysenck & Eysenck, 1985) or the Five Factor Model of personality (McCrae & Costa, 1999).

Physical activity is defined as bodily movement caused by skeletal muscles that results in increased energy expenditure

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(Caspersen, Powell, & Christenson, 1985), including incidental movement and purposeful exercise. Physical activity is complex. It encompasses several dimensions (frequency, intensity, duration, and mode), which presents a challenge for physical activity measurement (Tudor-Locke & Myers, 2001). The evidence on physical activity and personality is based on data collected with physical activity measures of varying quality, ranging from the use of validated recall interviews and questionnaires, single-item or author-adapted self-reports, dichotomies of active or inactive participants, to objective methods such as accelerometry.

A prior meta-analysis of 33 studies (Rhodes & Smith, 2006) reported heterogeneous correlations between physical activity and Extraversion ($r = 0.23$), Conscientiousness ($r = 0.20$) and Neuroticism ($r = -0.11$). However, heterogeneity was not quantified and there were not enough effects retrieved to permit strong tests of factors that might moderate the observed correlations. Analyses for moderation of significant associations between physical activity and personality should include tests of sample characteristics relevant to either construct as well as qualities of construct measurement that differ between studies. Furthermore, common traits, such as Extraversion and Neuroticism, measured in alignment with differing theories may reflect similar yet inequivalent psychological constructs, potentially biasing observed relationships; this possibility should be considered when aggregating effects. The aim of the systematic review and meta-analysis reported here is to estimate the population correlations between common personality factors and physical activity and to examine whether they vary according to selected sample characteristics and study features.

2. Methods

2.1. Data searches

In accordance with PRISMA guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009), we conducted an extensive database search of articles published prior to November 1st, 2013. Searches of PubMed, Web of Science, Medline, PsycInfo, GoogleScholar, and SportDiscus using the search terms *exercise* or *physical activity* plus one of the following: *personality*, *big five*, *five factor model*, *extraversion*, *extravert*, *neuroticism*, *neurotic*, *emotional stability*, *openness*, *agreeableness*, *conscientiousness*, *psychoticism*, *trait anxiety*, *trait impulsivity*, *sensitivity to punishment*, *sensitivity to reward*, *positive affectivity*, *negative affectivity*, *positive emotionality*, *negative emotionality*, *BIS*, *BAS*, *behavioral inhibition*, *behavioral activation*, or *behavioral approach*. Searches were restricted to titles and abstracts containing the specified key words, and written in English. Manual searches of the references listed in retained articles were also conducted.

2.2. Selection of studies

Inclusion extended to published articles that measured physical activity behavior and one or more major personality trait, and required the use of a personality instrument with acceptable internal consistency and test–retest reliability, which has also been validated through confirmatory factor analysis. Measures of fitness were excluded as they are correlated with, though not measures of, physical activity behavior (Caspersen et al., 1985). Likewise, we excluded studies comparing athletes and non-athletes as such a dichotomization is reflective of participation in organized, competitive activities, but does not estimate overall physical activity level. To control for attenuation of effects resulting from extreme range restriction (Hunter, Schmidt, & Le, 2006), we excluded studies that used physical activity as an inclusion or exclusion factor (i.e. only recruiting athletes or sedentary people). Variables of interest were measured as continuous or discrete, comparing groups scoring high or low on the respective variable. Attempts were made to contact the corresponding author for studies that reported measuring physical activity and personality but did not report enough information to calculate effect sizes.

A preliminary examination of the search results revealed that only the traits Extraversion, Neuroticism, Conscientiousness, Openness, and Agreeableness yielded 10 or more effects. Inclusion was therefore restricted to those studies reporting effects compatible with the Five Factor Model, commonly referred to as the "Big Five" (Goldberg, 1993; John & Srivastava, 1999). This included effects for which Extraversion and Neuroticism were measured as conceptualized in the five factor model, as well as by Eysenck (1970) and Cattell (1947). A preliminary moderator analysis found no difference in effect according to personality model used for the measurement of Extraversion and Neuroticism. Therefore, effects from differing personality models were retained. Based on theoretical expectations (Eysenck, 1967; Eysenck, Nias, & Cox, 1982; John & Srivastava, 1999; McCrae & Costa, 1999) and previous reports (Rhodes & Dickau, 2013; Rhodes & Smith, 2006), we expected to find positive associations between physical activity level and Extraversion and Conscientiousness, and a negative association with Neuroticism.

2.3. Effect size calculation

Included effects were recorded independently by the first author, and represent bivariate relationships between physical activity level and the respective trait. Among cases with more than two physical activity categories, groups were collapsed to form meaningful dichotomies for effect size calculation (e.g. high or low active; active or inactive). Studies that measured physical activity using stages of change from the Transtheoretical Model (Prochaska & Velicer, 1997) were included when effects could be derived for mean differences between those in the 'action' or 'maintenance' stages and those in the 'preparation' stage or earlier, resulting in an "active or inactive" dichotomy. Sample size was used to cross-reference and confirm that data provided by authors responding to a request for more information matched the sample reported on in the respective publication.

Point biserial r was derived from effect size d for effects reported as means and standard deviations or independent samples t tests. Adjustments for false dichotomization and reports of point biserial or phi coefficients were made according to Hunter and Schmidt (1990), to derive estimates of r and its sampling error adjusted for false dichotomization of the independent and dependent variables. Insufficient reporting of reliability statistics prohibited the correction for range restriction (Hunter et al., 2006), as well as measurement error (Hunter & Schmidt, 2004). In accordance with standards for meta-analysis of r, all correlations were standardized using Fisher's z prior to aggregation and regression moderator analysis, and then were back-transformed to reflect the population correlation (Rosenthal, 1991b).

2.4. Selection and coding of moderators

Sufficient reporting allowed examination of several potential effect modifiers. See Supplemental Table 1. At least 5 effects per moderator level were required for inclusion in the moderator analyses. When necessary, groups were collapsed to accommodate the group size requirement so as to maximize the number of included effects, while preserving a meaningful comparison. In the most extreme case, the analysis for age as a moderator of the association between physical activity and both Agreeableness and Openness was collapsed to create a dichotomy (i.e. those <35, or $\geqslant 45$ years of age) to compensate for the small number of effects, or complete absence of effects, for more restrictive age groups. Specifically, no effects were found for adults aged 35–44 for Openness or Agreeableness. For both traits there were 27 effects for people <25 years old, only 2 effects for adults between 55–64 years, 10 or more effects for ages 45–54, and less than 7 effects for 25–34 year olds.

2.4.1. Sample-characteristics

Sufficiently reported sample characteristics relevant to the study of physical activity and/or personality included (1) age, (2) gender, (3) clinical status (clinical vs. nonclinical), and (4) geographic region (North America vs. Europe). Age is an obvious candidate for effect moderation, since both physical activity (Caspersen, Pereira, & Curran, 2000) and personality (Roberts, Walton, & Viechtbauer, 2006) are observed to change with age. Though there is evidence to suggest that gender does not moderate the relationship between personality and physical activity (Lochbaum et al., 2010), the sample used in that investigation was age range restricted. It is plausible that an examination of gender as it interacts with other potential moderators will reveal a more complex relationship between gender, physical activity, and primary personality. Moderation by clinical status may be of special interest to clinicians utilizing physical activity as a treatment. For example, if clinical status interacts with one or more personality trait to influence physical activity level, clinicians may have the advantage of identifying those at a heightened risk for poor treatment adherence. Lastly, an examination of moderation by country or culture is of specific relevance to postulates of personality theory, and is also supported by regional geographic variation between nations in physical activity level (Stubbe et al., 2006). Attempts to collapse effects into meaningful comparisons resulted in a dichotomy of effects derived in North America and Europe.

2.4.2. Study features

We also examined moderation by several relevant study features including study design, physical activity measurement quality and definition, personality scale item format, and presence or absence of experimental demand. The relevance of study design is highlighted by the previous meta-analysis (Rhodes & Smith, 2006), which reported that effects derived from prospective designs were larger than those from cross-sectional designs. To assess the risk of bias resulting from the use of poor quality physical activity measures, we examined moderation by physical activity measurement quality. The number of retrieved effects allowed for a dichotomous comparison: (1) self-report and objective measures with evidence of validity, hereafter referred to as 'valid' measures, and (2) self-report measures with uncertain validity, referred to here as 'unvalidated' measures. Effects were also coded for the operational definition of physical activity in each study, consistent with conventional standards for quantifying physical activity exposure (Physical Activity Guidelines Advisory Committee, 2008). Levels included (1) volume, representative of overall energy expenditure, commonly reported as METs/time, (2) general quantity, a measure of frequency of physical activity meeting a minimum time requirement without reference to intensity, (3) quantity of moderate-to-vigorous and (4) quantity of mild-to-moderate physical activity, reflecting frequency of continuous physical activity at a specified intensity meeting a minimum duration (e.g. bouts per week of moderate-to-vigorous activity lasting at least 20 min), (5) frequency, and (6) active/inactive dichotomy. The specification of levels as quantity of mild-to-moderate, or moderate-to-vigorous, is a result of mixed physical activity definitions within the literature, where oftentimes, effects were reported for physical activity measured as "mild-to-moderate" or "moderate-to-vigorous" physical activity. Effects were coded to reflect personality scale item format as personality measurement has evolved from (1) adjective checklists to (2) surveys using full statement or question item format. Finally, effects were coded to indicate the imposition of experimental demand, here defined as the measurement of intention to participate in physical activity prior to the period during which physical activity was measured.

2.5. Statistical analysis

A random-effects model was used to aggregate the mean correlation between physical activity and each of the Big Five personality traits (Hedges & Olkin, 1985; Lipsey & Wilson, 2001) using Macro MeanES in SPSS version 21.0 (IBM, 2012; Wilson, 2006). Heterogeneity of effects was tested using Q and I^2 (Higgins, Simon, Deeks, & Altman, 2003). A significant Q reflects heterogeneity between effects, whereas I^2 indicates the percentage of between effect variance that is not sampling error. Conventionally, I^2 values approximating 25%, 50%, or 75% and greater indicate low, moderate, or high heterogeneity. Effects were nested within studies, which might systematically differ from each other. Therefore, to adjust for between-study variance and correlated effects within studies, a multi-level mixed linear regression model with robust maximum likelihood estimation was also applied according to standard procedures (Cheung, 2008; Hox, 2010) in Mplus 7.11 (Muthén & Muthén, 1998–2013). Parameters and their errors were estimated with clustering on study using the Huber–White sandwich estimator to calculate standard errors that are robust to hetero-scedasticity and correlated effects (Froot, 1989, White, 1980; Williams, 2000). The number of unpublished or un-retrieved effects averaging zero from samples of mean size that would diminish the significance of observed effects to $p > .05$ was estimated as fail-safe N+ (Rosenberg, 2005). Funnel plots were graphed and evaluated (Egger, Smith, Schneider, & Minder, 1997) to estimate possible publication bias (Sterne et al., 2011).

All moderator analyses were pre-specified and were conducted using random effects maximum likelihood estimation according to planned contrasts (Rosenthal, 1991a, 1991b) using regression analysis by Macro MetaReg in SPSS version 21.0 (IBM, 2012; Wilson, 2006). Multiple regression models were used to test the independence of significant univariate effects. In subsequent multi-level models, the effect of each independent moderator was first tested separately by comparing each conditional model (which included the intercept and the moderator) with the unconditional intercept-only model using a likelihood ratio test and the adjusted Bayesian Information Criterion (BIC) (Muthén & Muthén, 1998–2013). Significant 2-way interactions were decomposed using simple contrasts (Rosenthal, 1991a, 1991b). Limited cell numbers prohibited the examination of 3-way interactions. Because moderator levels for features of the physical activity construct were not ordinal, a random effects analog to a one way ANOVA (SPSS Macro MetaF; SPSS 21.0, IBM, 2012; Wilson, 2006) was used to examine possible moderation by features of the physical activity construct followed by contrasts with Bonferroni-adjustment to protect alpha at $p < .05$.

3. Results

Figure 1 describes the screening process for included studies. A total 7370 records were screened, 521 were assessed for eligibility, and 64 studies including a total of 88,400 participants were included, 49 of which reported enough information for effect size calculation and 15 for which values were obtained from the corresponding author. Mean age of the samples ranged from 14.8 to 92.9 years old. Among the studies using validated physical activity tools, 10 used the Godin Leisure Time Exercise Questionnaire (GLTEQ; Shephard, 1997), 6 used self-report items borrowed from

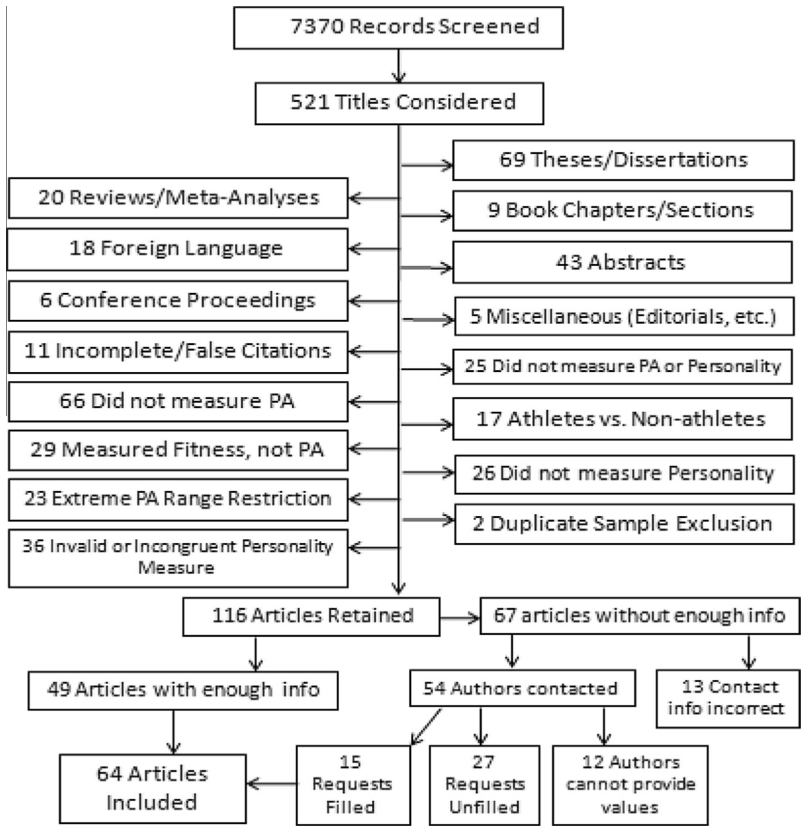

Fig. 1. Flow chart of study inclusion. PA, physical activity; Info, information.

epidemiological cohort studies, 2 used frequency of facility use, 2 used program adherence, and each of the following were used once: accelerometers, the Dutch International Physical Activity Questionnaire (IPAQ; Craig et al., 2003), a physical activity diary and the Global Physical Activity Questionnaire (GPAQ; Armstrong & Bull, 2006). Among the studies using an unvalidated physical activity measure, 21 studies reported using a nonspecific or author-adapted self-report, 12 used a single self-report item, 3 used a nonspecific or unvalidated interview, 2 measured physical activity using stages of the Transtheoretical Model (Prochaska & Velicer, 1997), and each of the following were used once: the Personal Lifestyle Questionnaire (Muhlenkamp & Brown, 1983), Physical Activity Scale 2 (Andersen, Groenvold, Jørgensen, & Aadahl, 2010), and Kirkcaldy's Recreational Interest Inventory (Kirkcaldy & Furnam, 1991). Descriptive details for each included study are listed in Supplemental Table 1. Forest plots for each trait (Supplemental Figs. 1–5) display weighted effect sizes and their variance according to study for each included effect.

3.1. Mean effects

The total number of effects, the mean effect sizes (95%CI), and the heterogeneity statistics Q and I^2 for the association of each of the Big Five traits with physical activity, as well as values for each moderator level and the contrast weights used in regression moderator analyses, are displayed in Tables 1–5. The number of studies and derived effects, respectively, for each personality trait were: 56 and 88 for Extraversion, 54 and 82 for Neuroticism, 38 and 69 for Conscientiousness, 30 and 51 for Openness, and 29 and 52 for Agreeableness. Studies contributing more than one effect for a trait reported an average of 3 effects per trait. Mean effect size r for physical activity and Extraversion ($r = .108$, 95%CI = .0914, .1238), Neuroticism ($r = -.071$, 95%CI = −.0867, −.0554), Conscientiousness ($r = .104$, 95%CI = .0837, .124), and Openness ($r = .034$, 95%CI = .0128, .0560) were all statistically significant ($p < .01$). The mean effect size r for Agreeableness and physical activity was not statistically significant ($r = .002$, 95%CI = −.0169, .0208, $p = .8392$). In multi-level models, mean effect r was: Extraversion ($r = .112$, 95%CI = .0844, .1385), Neuroticism ($r = -.072$, 95%CI = −.0934, −.0504), Conscientiousness ($r = .10$, 95%CI = .0755, .1375), Openness ($r = .037$, 95%CI = .0017, .0722), and Agreeableness ($r = .001$, 95%CI = −.0245, .0265), with significant variance for all effects except Agreeableness ($z = 0.87$, $p = .386$). Mean effects for all of the Big Five were moderately heterogeneous (I^2 range 44–65%), which is apparent in the funnel plots generated for each of the dimensions (Supplemental Figs. 6–10). Egger's test for bias was significant for all personality dimensions (t-values 3.0–7.8, $p \leqslant .003$) except Agreeableness (t-value = −0.124, $p = .902$). However, the mean effects for these four traits remained significant ($p \leqslant .0017$) and heterogeneous (Q's 100.45–236.15, and I^2 51.31–64.01) in sensitivity analyses that excluded effects derived from sample sizes larger than the mean sample size plus 3 standard deviations (two total effects removed from Extraversion, and one each from Neuroticism, Conscientiousness, and Openness). Funnel plots were generally symmetrical, although several outlying effects were observed for each trait. However, after removal of four effects from the largest outlying sample sizes (>3SD), fail-safe N was 9694 for Extraversion, 4552 for Neuroticism, 3161 for Conscientiousness, and 164 for Openness.

3.2. Moderator analyses: Extraversion

Initial moderator analyses revealed that geographic region, experimental demand, and physical activity definition were independent moderators of the relationship between physical activity and Extraversion. In the multi-level model, only physical activity

Table 1
The relationship between physical activity and Extraversion: mean effects and heterogeneity coefficients.

	Contrast weight	N	Mean ES	95%CI	Q	I^2
Overall mean ES		88	.1076[d]	[.0914, .1238]	247.1632[d]	65.20
Gender						
Females only	−1	23	.1131[d]	[.0694, .1564]	84.6093[d]	75.18
Males only	.5	13	.0874[c]	[.0404, .1341]	23.4549[a]	53.10
Both	.5	52	.1100[d]	[.0904, .1294]	138.5104[d]	63.90
Age						
<25 years	1	33	.1373[d]	[.0955, .1786]	154.9035[d]	79.99
25–34 years	2	15	.1014[d]	[.0685, .1341]	29.0504[a]	55.25
35–44 years	3	7	.0579	[−.0036, .1190]	4.8078	0
45–54 years	4	15	.0842[d]	[.0593, .1090]	24.5777[a]	47.11
⩾55 years	5	9	.1035[d]	[.0739, .1329]	11.8389	40.87
Sample type						
Clinical sample	1	10	.1345[b]	[.0508, .2163]	12.6928	36.97
Nonclinical sample	−1	78	.1062[d]	[.0896, .1227]	233.3032[d]	67.42
Geographic region[*]						
North America	1	49	.1356[d]	[.1079, .1630]	156.9391[d]	70.05
Europe	−1	28	.0696[d]	[.0420, .0972]	80.8501[d]	67.84
East Asia [Japan only]		6	.1135[d]	[.0959, .1310]	3.2637	0
Study design						
Cross-sectional	1	63	.1018[d]	[.0845, .1190]	120.9784[d]	49.58
Prospective/longitudinal	−1	25	.1198[d]	[.0819, .1575]	120.7949[d]	80.96
PA tool						
Unvalidated self-report	−1	52	.1080[d]	[.0909, .1249]	101.5452[d]	50.76
Validated self-report	.5	27	.1077[d]	[.0697, .1454]	131.0880[d]	80.93
Objective measure	.5	9	.0988[a]	[.0101, .1860]	9.9822	29.88
PA definition[*]						
Volume		18	.1097[d]	[.0699, .1492]	42.7075[c]	62.54
General quantity		12	.1005[d]	[.0581, .1426]	27.8181[b]	64.05
Quantity of moderate-to-vigorous		14	.1377[d]	[.0944, .1805]	78.5843[d]	84.73
Quantity of mild-to-moderate		11	.0423[b]	[.0134, .0712]	9.6688	6.92
Frequency		8	.0119	[−.0790, .1025]	18.2401[a]	67.11
Dichotomy		17	.0871[d]	[.0435, .1304]	26.6354[a]	43.68
Personality measure item format						
Adjective	−1	18	.0928[d]	[.0470, .1383]	72.8412[d]	78.03
Statement/question	1	70	.1116[d]	[.0945, .1287]	166.5678[d]	59.18
Experimental demand[*]						
Yes	−1	15	.1835[d]	[.1030, .2617]	75.9486[d]	82.88
No	1	73	.0948[d]	[.1094, .1094]	147.7734[d]	51.95

[a] Significant at $p < .05$.
[b] Significant at $p < .01$.
[c] Significant at $p < .001$.
[d] Significant at $p < .0001$.
[*] Significant univariate moderation.

definition remained significant ($\beta = -.079$, SE = .019, $z = -4.25$, $p < .0001$). Model fit ($\chi^2(5) = 290.2$, BIC = 296) was improved compared to the intercept-only model ($\Delta\chi^2(3) = 501.2$, $p < .0001$, BIC 296 vs 340). The correlation was smaller when physical activity was defined as quantity of mild-to-moderate physical activity compared to all other physical activity construct definitions.

Significant 2-way interactions were found for gender and geographic region ($z = 2.24$, $p = .0252$) and gender and experimental demand ($z = 2.79$, $p = .0052$). Modeled together, the gender-by-experimental demand remained significant ($z = 2.36$, $p = .0184$) but the gender-by-region was not ($z = 1.78$, $p = .075$). Females under experimental demand exhibited stronger effects than all subjects without experimental demand ($z = 4.45$, $p < .0001$) as well as all other groups combined ($z = 3.94$, $p = .0001$). Studies of females under experimental demand reported smaller effects than all studies employing such measure ($z = 3.00$, $p = .0027$). In the multi-level model, the gender-by-experimental demand remained significant ($z = 2.48$, $p = .013$). Model fit ($\chi^2(3) = 294.0$, BIC = 300) was improved compared to the intercept-only model ($\Delta\chi^2(2) = 446.8$, $p < .0001$, BIC 300 vs 340). The residual variance was .005 (SE = .003, $z = 1.72$, $p = .085$), indicating that 29% of the variance between effects was explained by the conditional model.

3.3. Moderator analyses: Neuroticism

Geographic region was the only significant univariate moderator of the relationship between physical activity and Neuroticism ($\beta = -.2888$, SE = .0092, $z = -2.6361$, $p = .0084$). In the multi-level model, the effect of geographic region was no longer significant ($z = 0.083$, $p = .406$). Significant 2-way interactions were observed for gender and geographic region ($z = 2.81$, $p = .0049$), as well as gender and physical activity measurement quality ($z = 2.20$, $p = .0280$). Modeled together, the gender-by-region effect was significant ($z = 2.44$, $p = .0146$) but the gender-by-measurement quality effect was no longer significant ($z = 1.63$, $p = .1025$). In the multi-level model, neither the gender-by-region effect ($p = .918$) nor the gender-by-measurement quality effect ($p = .395$) was significant.

3.4. Moderator analyses: Conscientiousness

Univariate moderation of the relationship between Conscientiousness and physical activity was observed by study design ($\beta = -.3055$, SE = .0116, $z = -2.6495$, $p = .0081$), physical activity definition, personality scale item format ($\beta = .3352$, SE = .0222,

Table 2
The relationship between physical activity and Neuroticism: mean effects and heterogeneity coefficients.

	Contrast weight	*N*	Mean ES	95%CI	*Q*	I^2
Overall mean ES		82	−.0710[d]	[−.0867, −.0554]	188.0551[d]	57.46
Gender						
Females only	−1	25	−.0720[c]	[−.1102, −.0335]	64.0027[d]	64.06
Males only	.5	13	−.0546[d]	[−.0772, −.0320]	12.0331	8.59
Both	.5	44	−.0762[d]	[−.0962, −.0561]	109.7146[d]	61.72
Age						
<25 years	1	35	−.0683[d]	[−.1109, −.0509]	81.3290[d]	59.42
25–34 years	2	10	−.0803[d]	[−.1121, −.0483]	13.6114	41.23
35–44 years	3	6	−.0920	[−.2204, .0395]	22.8163[c]	82.47
45–54 years	4	16	−.0471[d]	[−.0697, −.0245]	22.7203	38.38
⩾55 years	5	7	−.0714[a]	[−.1304, −.0118]	21.2217[b]	76.44
Sample type						
Clinical sample	1	11	−.0336	[−.1109, .0441]	14.2557	36.87
Nonclinical sample	−1	71	−.0729[d]	[−.0889, −.0569]	173.0697[d]	60.13
Geographic region[*]						
North America	1	49	−.0929[d]	[−.1148, −.0710]	95.8006[d]	50.94
Europe	−1	25	−.0434[c]	[−.0686, −.0182]	50.5683[b]	54.52
East Asia [Japan only]		6	−.0462[b]	[−.0776, −.0147]	7.3373	45.48
Study design						
Cross-sectional	1	60	−.0719[d]	[−.0905, −.0532]	120.8647[d]	52.01
Prospective/longitudinal	−1	22	−.0689[d]	[−.1019, −.0356]	66.8650[d]	70.90
PA tool						
Unvalidated self-report	−1	49	−.0744[d]	[−.0897, −.0590]	72.5221[a]	35.19
Validated self-report	.5	24	−.0627[b]	[−.1004, −.0248]	101.3410[d]	78.29
Objective measure	.5	9	−.0200	[−.1101, .0704]	10.2800	31.91
PA definition						
Volume		16	−.0425	[−.0910, .0062]	42.3820[c]	66.97
General quantity		12	−.0922[d]	[−.1372, −.0469]	31.7232[c]	68.48
Quantity of moderate-to-vigorous		15	−.0825[d]	[−.1178, −.0470]	36.4976[c]	64.38
Quantity of mild-to-moderate		9	−.0421[a]	[−.0818, −.0022]	11.7717	40.54
Frequency		14	−.0784[d]	[−.1098, −.0469]	19.0381	36.97
Dichotomy		16	−.0704[c]	[−.1092, −.0313]	20.9306	33.11
Personality measure item format						
Adjective	−1	11	−.0405[c]	[−.0624, −.0185]	8.9191	0
Statement/question	1	71	−.0776[d]	[−.0957, −.0595]	173.5681[d]	60.25
Experimental demand						
Yes	−1	12	−.0982[b]	[−.1567, −.0390]	21.2411[a]	52.92
No	1	70	−.0671[d]	[−.0832, −.0509]	162.3349[d]	58.11

[a] Significant at $p < .05$.
[b] Significant at $p < .01$.
[c] Significant at $p < .001$.
[d] Significant at $p < .0001$.
[*] Significant univariate moderation.

$z = 2.9799$, $p = .0029$), and experimental demand ($\beta = -.5854$, SE = .0108, $z = -5.9323$, $p < .0001$). Modeled together, personality scale item format ($z = 3.63$, $p < .0003$) and experimental demand ($z = 5.00$, $p < .0001$) remained significant, but study design ($z = 0.089$, $p = .929$) and physical activity definition ($z = 0.520$, $p = .603$) were not independently related to effect size. Results favored prospective studies, and studies that imposed experimental demand. In the multi-level model, the effect for experimental demand remained significant ($z = 2.23$, $p = .026$) and the effect for personality measure item format was nearly significant ($z = 1.82$, $p = .069$).

Two significant 2-way interactions were observed: (1) physical activity measurement quality and experimental demand ($p = .0035$), and (2) physical activity measurement quality and personality item format ($p = .0009$). Modeled together, the interaction of physical activity measure quality with experimental demand ($z = 2.29$, $p = .0222$) and with personality item format ($z = 2.08$, $p = .0379$) remained independently related to effect size. In the multi-level model, the interaction of physical activity measure quality with experimental demand was no longer significant ($z = 0.02$, $p = .985$), but the interaction of physical activity with personality item format remained significant ($z = 2.43$, $p = .015$). Model fit ($\chi^2(7) = 196.4$, BIC = 204) was improved compared to the intercept-only model ($\Delta\chi^2(5) = 24.8$, $p < .0001$, BIC 204 vs 229). The residual variance was .003 (SE = .001, $z = 1.88$, $p = .06$), indicating that 40% of the variance between effects was explained by the conditional model. Effects derived from unvalidated physical activity measures used in conjunction with statement or question personality items had stronger effects than those with adjective personality items ($z = 3.95$, $p = .0001$) or any study including adjective personality items ($z = 3.07$, $p = .0021$). Unvalidated physical activity measures used with personality items in adjective format yielded weaker effects than those from studies measuring personality in statement or question format ($z = 3.98$, $p = .0001$) and compared to all other groups combined ($z = 4.60$, $p < .0001$).

3.5. Moderator analyses: Openness

The relationship between openness and physical activity was moderated by experimental demand ($\beta = -.3662$, SE = .0144, $z = -2.82$, $p = .0047$), and a 2-way interaction between gender

Table 3
The relationship between physical activity and Conscientiousness: mean effects and heterogeneity coefficients.

	Contrast Weight	*N*	Mean ES	95%CI	Q	I^2
Overall mean ES		69	.1037[d]	[.0837, .1237]	170.3278[d]	60.66
Gender						
Females only	−1	17	.1351[d]	[.0983, .1716]	27.6941[a]	45.84
Males only	.5	7	.0897[d]	[.0492, .1298]	3.8008	0
Both	.5	45	.0954[d]	[.0702, .1206]	126.2417[d]	65.94
Age						
<25 years	1	28	.1221[d]	[.0846, .1592]	108.1114[d]	75.95
25–44 years	2	16	.1021[d]	[.0678, .1360]	26.5376[a]	46.88
⩾45 years	3	14	.0579[d]	[.0308, .0849]	17.1518	30.04
Sample type						
Clinical sample	1	9	.1332[c]	[.0633, .0633]	8.6114	18.71
Nonclinical sample	−1	60	.1017[d]	[.0809, .1224]	159.3303[d]	63.60
Geographic region						
North America	1	42	.1038[d]	[.0822, .1254]	69.6017[b]	42.53
Europe	−1	22	.1025[d]	[.0637, .1410]	85.4640[d]	76.60
Study design[*]						
Cross-sectional	1	47	.0843[d]	[.0638, .1047]	93.7585[d]	52.00
Prospective/longitudinal	−1	22	.1526[d]	[.1044, .2001]	68.2672[d]	70.70
PA tool						
Unvalidated self-report	−1	38	.1005[d]	[.0715, .1294]	123.2487[d]	70.79
Validated self-report	.5	25	.1118[d]	[.0861, .1374]	36.6493[a]	37.24
Objective measure	.5	6	.0846	[−.0015, .1695]	1.9260	0
PA definition[*]						
Volume		17	.0787[d]	[.0437, .1134]	24.2311	38.10
General quantity		5	.0672	[−.0014, .1352]	8.4111	64.33
Quantity of moderate-to-vigorous		18	.1168[d]	[.0763, .1568]	65.1076[d]	75.43
Quantity of mild-to-moderate		10	.0887[d]	[.0490, .1282]	14.7342	45.70
Frequency		11	.2136[d]	[.1342, .2901]	27.0216[b]	70.39
Dichotomy		8	.0552[c]	[.0232, .0870]	6.1695	2.75
Personality measure item format[*]						
Adjective	−1	15	.0537[b]	[.0195, .0878]	34.5423[b]	62.36
Statement/question	1	54	.1208[d]	[.0982, .1433]	113.0053[d]	53.98
Experimental demand[*]						
Yes	−1	18	.1994[d]	[.1591, .2391]	27.4761	41.77
No	1	51	.0719[d]	[.0544, .0894]	83.0082[b]	40.97

[a] Significant at $p < .05$.
[b] Significant at $p < .01$.
[c] Significant at $p < .001$.
[d] Significant at $p < .0001$.
[*] Significant univariate moderation.

and physical activity measurement quality ($z = 2.45$, $p = .0143$). In the multi-level model, the effect of experimental demand was not significant ($z = 0.541$, $p = .589$), but the interaction between gender and use of a validated measure of physical activity remained significant ($z = 2.24$, $p = .025$). Model fit ($\chi^2(5) = 175.8$, BIC = 180) was improved compared to the intercept-only model ($\Delta\chi^2(3) = 61.5$, $p < .0001$, BIC 180 vs 187). Effects from studies that sampled females and used a validated measure of physical activity were smaller than effects from all other studies ($z = -2.91$, $p = .0036$).

3.6. Moderator analyses: Agreeableness

Gender, age and clinical status were significant univariate moderators of the relationship between Agreeableness and physical activity. Modeled together in multiple regression analysis, age group remained significant ($\beta = -.3718$, $z = -2.64$, $p = .0082$), but gender ($\beta = -.1555$, $z = -1.15$, $p = .2499$) and clinical status ($\beta = -.2035$, $z = -1.51$, $p = .1304$) were no longer significant. Tests for 2-way interactions were not significant ($p > .05$). In the multi-level model, the effect of age group remained significant ($z = -4.06$, $p < .0001$). Model fit ($\chi^2(5) = 130.2$, BIC = 134) was improved compared to the intercept-only model ($\Delta\chi^2(3) = 44.7$, $p < .0001$, BIC was 134 vs 169). The residual variance was .001 (SE = .001, $z = 1.40$, $p = .161$), indicating that 50% of the variance between effects was explained by the conditional model. Among adults ages 35–65 years the effect was small and negative ($r = -.0407$, 95%CI = −.0620, −.0193, $p < .001$).

4. Discussion

The associations of physical activity with Extraversion, Neuroticism, and Conscientiousness reported here are consistent with, but smaller than, correlations reported in a prior review of a smaller number of studies (Rhodes & Smith, 2006). Reasons for the difference in effect sizes between studies are unclear, but likely include the larger number of included effects in our analysis, which should better approximate the population values, and differences in meta-analytic adjustments used between studies. Here we also provide new evidence for a small but significant relationship between physical activity and Openness. Judged by conventional statistical guides for interpreting the size of a Pearson correlation coefficient (Cohen, 1988), the mean effects reported here are small. However, the estimates may be a little low because of the unreported reliability of physical activity measures used in most of the studies retrieved. Effects were mostly heterogeneous, but moderator analysis accounted for small amounts of the variance

Table 4
The relationship between physical activity and Openness: mean effects and heterogeneity coefficients.

	Contrast Weight	N	Mean ES	95%CI	Q	I^2
Overall mean ES		51	.0344[b]	[.0128, .0560]	102.8891[d]	52.38
Gender						
Females only	−1	16	.0074	[−.0425, .0573]	41.5860[c]	66.33
Males only	.5	6	.0479[a]	[.0011, .0945]	4.4248	9.60
Both	.5	29	.0449[c]	[.0208, .0690]	48.7959[b]	44.67
Age						
14–35 years	1	30	.0295	[−.0025, .0615]	86.2884[d]	67.55
35–65 years	2	14	.0245[a]	[.0032, .0458]	9.5636	0
Sample type						
Clinical sample	1	10	.0591	[−.0071, .1248]	6.1216	0
Nonclinical sample	−1	41	.0327[b]	[.0095, .0558]	95.7300[d]	59.26
Geographic region						
North America	1	33	.0402[a]	[.0067, .0736]	83.6161[d]	62.93
Europe	−1	13	.0246[a]	[.0005, .0487]	17.0145	35.35
Study design						
Cross-sectional	1	36	.0227[a]	[.0001, .0453]	63.3825[b]	46.36
Prospective/longitudinal	−1	15	.0694[b]	[.0166, .1218]	33.6134[b]	61.32
PA tool						
Unvalidated self-report	−1	28	.0374[c]	[.0180, .0567]	32.5193	20.05
Validated self-report	.5	16	.0303	[−.0214, .0818]	62.9786[d]	77.77
Objective measure	.5	7	−.0128	[−.0960, .0705]	4.7709	0
PA definition						
Volume		11	.0000	[−.0352, .0353]	8.6666	0
General quantity		5	.0169	[−.0202, .0540]	2.4693	0
Quantity of moderate-to-vigorous		14	.0358	[−.0036, .0752]	41.1016[d]	70.80
Quantity of mild-to-moderate		7	.0723[a]	[.0043, .1397]	22.5325[c]	77.81
Frequency		9	.0664	[−.0171, .1490]	17.9174[a]	60.93
Dichotomy		5	.0170	[−.0430, .0770]	3.2763	8.43
Personality measure item format						
Adjective	−1	10	.0485[a]	[.0092, .0877]	25.2487[b]	68.32
Statement/question	1	41	.0287[a]	[.0028, .0545]	74.1580[c]	47.41
Experimental demand[*]						
Yes	−1	11	.1001[b]	[.0282, .1710]	25.6096[b]	82.89
No	1	40	.0203[a]	[.0004, .0402]	62.9733[b]	39.66

[a] Significant at $p < .05$.
[b] Significant at $p < .01$.
[c] Significant at $p < .001$.
[d] Significant at $p < .0001$.
[*] Significant univariate moderation.

between effects and studies. Thus, residual confounding by unreported variables likely attenuated the mean effects. Also, when correlations of these sizes are viewed in terms of population rates, the associations found here for Extraversion, Neuroticism, and Conscientiousness represent a binomial difference of about 7–10% in physical activity between low and high personality scores in a normal distribution (Rosenthal, 1991a), indicating that personality influences physical activity in as many as 1 out of 10 people in the population. This is of sufficient size to recommend further study to clarify the role of habitual physical activity in elaborations of personality theory, the public health importance of personality in helping explain the genetic basis of physical activity and for better understanding the effectiveness of interventions to increase physical activity behavior.

The observations are theoretically plausible. It has been suggested (Eysenck et al., 1982) that the link between Extraversion and physical activity results from a heightened tendency to seek out strong sensory stimulation (such as physical activities) among Extraverts, whereas Introverts tend to avoid it. Also, Extraverts are typically very social and outgoing, which may increase their likelihood of exposure to settings that offer opportunities to be physically active. Higher levels of physical activity among Extraverts may fulfill a drive for stimulation and socialization. In contrast, individuals scoring high on Neuroticism exhibit heightened anxiety, vulnerability and self-consciousness, which may inhibit their willingness to act on, or reduce their exposure to opportunities to be physically active. Neuroticism is also related to heightened autonomic responsiveness to intense stimuli, and a predisposition for negative affect (Eysenck, 1967; Gray, 1991), which could explain lower levels of physical activity if the physiological response of increased arousal during exercise is perceived negatively. Conscientious people are characterized as deliberate and disciplined, they have a strong sense of duty, and are more likely to adhere to a variety of health behaviors (Bogg & Roberts, 2004). Conscientious people may be better at self-regulating behavior, and physical activity may also satisfy their need for feelings of competence (Ingledew, Markland, & Sheppard, 2004). Those with high levels of Openness are usually receptive to ideas and opportunities for new experiences, and are often willing to try new things; such individuals may be more likely to engage in different types of physical activity and more frequently than people who score low on Openness.

Funnel plots for each trait (see Supplemental Figs. 6–10) corroborate heterogeneity statistics, and display outlying effects that were mainly explained by moderator analysis. Tests of funnel plot asymmetry indicated that effects for all traits, except for Agreeableness, were significantly biased, though a conservative sensitivity analysis confirmed that significant mean effects remained after

Table 5
The relationship between physical activity and Agreeableness: Mean Effects and heterogeneity coefficients.

	Contrast weight	*N*	Mean ES	95%CI	*Q*	I^2
Overall mean ES		52	.0020	[−.0169, .0208]	90.0739[c]	44.49
Gender[*]						
Females only	−1	17	.0308[a]	[.0045, .0571]	12.9243	0
Males only	.5	7	−.0228	[−.0916, .0461]	12.1347	58.80
Both	.5	28	−.0053	[−.0305, .0199]	55.9775[c]	53.55
Age[*]						
14–35 years	1	33	.0163	[−.0035, .0362]	44.1146	29.73
35–65 years	2	12	−.0407[c]	[−.0620, −.0193]	8.1603	0
Sample type[*]						
Clinical sample	1	9	−.0847[a]	[−.1517, −.0168]	5.5464	0
Nonclinical sample	−1	43	.0073	[−.0121, .0267]	78.8997[c]	48.04
Geographic region						
North America	1	34	.0075	[−.0154, .0303]	49.7927[a]	35.73
Europe	−1	13	−.0016	[−.0307, .0338]	34.1847[c]	67.82
Study design						
Cross-sectional	1	38	.0050	[−.0160, .0259]	66.1851[b]	45.61
Prospective/longitudinal	−1	14	−.0089	[−.0538, .0361]	22.9516[a]	47.72
PA tool						
Unvalidated self-report	−1	30	.0075	[−.0167, .0318]	57.9738[b]	51.70
Validated self-report	.5	16	−.0052	[−.0370, .0266]	23.8033	41.18
Objective measure	.5	6	−.0376	[−.1535, .0793]	8.2273	51.38
PA definition						
Volume		14	−.0050	[−.0404, .0304]	18.7878	36.13
General quantity		5	−.0101	[−.0755, .0554]	7.7320	61.20
Quantity of moderate-to-vigorous		14	−.0074	[−.0400, .0253]	27.8451[b]	56.90
Quantity of mild-to-moderate		7	.0403[a]	[.0074, .0730]	4.2852	0
Frequency		8	.0119	[−.0790, .1025]	18.2401[a]	67.11
Personality measure item format						
Adjective	−1	10	.0029	[−.0290, .0349]	16.6957	52.08
Statement/question	1	42	.0010	[−.0224, .0244]	73.3707[b]	45.48
Experimental demand						
Yes	−1	9	.0353	[−.0256, .0960]	14.4661	51.61
No	1	43	−.0027	[−.0223, .0168]	72.9879[b]	43.83

[a] Significant at $p < .05$.
[b] Significant at $p < .01$.
[c] Significant at $p < .001$.
[*] Significant univariate moderation.

excluding outlying effects. Though funnel plot asymmetry is commonly interpreted as an indication of publication bias (Sterne & Harbord, 2004), an alternative possibility is that the size of the relationships between personality traits and physical activity might truly differ according to other characteristics of people, environmental contexts, or features of the methods used in the studies we reviewed here. Our moderator analyses helped to clarify the heterogeneity of effects for physical activity and all five traits. A staged approach to moderator analyses was conducted to provide an in depth understanding of the effects reported in the literature. The progression from univariate, to multivariate and finally multilevel analyses of moderators permits a clearer interpretation of true moderators as opposed to apparent moderators confounded by other variables or by correlated effects. Though we were able to code for and test several pertinent moderator variables, an inquiry into differences according to physical activity mode or setting was precluded by the absence of such information in the accumulated evidence. Important differences may exist in the type of physical activity preferred and possible interactions with environmental prompts or barriers for people of differing personalities.

Sample characteristics and study features moderated the association between personality traits and physical activity behavior, but they were frequently not substantiated after multi-level analyses. Effects for Extraversion and Neuroticism both appeared to be significantly moderated by an interaction between gender and geographic region. In both cases, European females seemed responsible for the interaction. However, multi-level analyses revealed that these observations were due to correlated effects. Initial results suggested that the positive relationship between physical activity and Extraversion was weakened among European females, whereas the negative association with Neuroticism was strengthened. Of the 15 Extraversion effects reported for North American females, 13 were nested within 5 studies (Adams & Nettle, 2009; Courneya, Bobick, & Schinke, 1999; Courneya & Hellsten, 1998; Lochbaum et al., 2010; Rhodes, Courneya, & Bobick, 2001). Additionally, only four effects for European females were retrieved for Extraversion, and five were retrieved for Neuroticism (Harma, Ilmarinen, & Knauth, 1988; Hendry, 1975; Herrera & Gómez-Amor, 1995; Kull, Ainsaar, Kiive, & Raudsepp, 2012; Ševčíková, Ružanská, & Sabolová, 2000). Though gender differences in personality are replicable across cultures (Costa, Terracciano, & McCrae, 2001), physical activity and its difference between genders vary widely between countries (Bauman et al., 2009). Moderation by an interaction between gender and geographic region could be driven by international differences in physical activity level between genders. Though our final results support the absence of a gender by region interaction, there is currently too little evidence to confidently rule it out. Small effect sizes between personality and physical activity, coupled with the small number of independent effects retrieved and the relevance of gender and nation to physical activity level and personality call for more gender specific international research to strengthen this evidence, and confirm or refute this observation.

Correlations between physical activity and both Neuroticism and Openness were significantly moderated by an interaction between gender and physical activity measurement quality, though moderation remained only for Openness in the multi-level analysis. Planned contrasts demonstrated an inflation of the relationship between physical activity and Openness in studies of females measured with poor quality physical activity instruments, emphasizing the importance of using a validated measure of physical activity. The absence of effect moderation by physical activity measurement quality among males may indicate that males more reliably estimate their physical activity level than do females regardless of the quality of physical activity self-report. Perhaps a more detailed and structured self-report is required to properly estimate physical activity among females with sufficient sensitivity to accurately observe the small relationships between physical activity and personality.

In addition to sample characteristics, the relationship between physical activity and personality appears sensitive to methodological features. This is especially true for the association between physical activity and Conscientiousness which was moderated by experimental demand, and an interaction between physical activity measurement quality and personality item format. Effects were inflated by the inclusion of a measure of intention (i.e. experimental demand), and among studies using an unvalidated physical activity measure with a personality measure with statement or question item format. Conversely, use of unvalidated physical activity measures in conjunction with personality measures in adjective checklist format seemed to reduce the mean effect, suggesting a polarizing effect of poor physical activity measurement on the observed correlation according to personality item format. Though this is an appealing challenge to explain on theoretical grounds, this interaction is driven by a single effect retrieved for Conscientiousness that used an unvalidated physical activity measure and an adjective checklist (Bogg, Voss, Wood, & Roberts, 2008). Rather than call for more studies using a less desirable measurement format, perhaps future studies might utilize both kinds of measures for each construct to empirically test this possibility. This seems a better route than to encourage studies using poor quality measures independently to gradually build up the evidence. Additional work is therefore needed to clarify the possibility of this peculiar interaction, so as to inform researchers in their methodological choices and to minimize false inflation of effects resulting from study designs.

The notion of experimental demand herein is conceptually reflective of a bias l commonly termed the Rosenthal effect, or the Pygmalion effect (Pfungst, 1911; Rosenthal & Jacobson, 1968). Though most commonly discussed in reference to participant performance relative to some form of imposed expectation (such as academic performance and teacher expectation), this bias could also apply to physical activity behavior in studies which ask participants to report how active they intend to be prior to the period during which physical activity is measured. Our results suggest that this possibility is specifically relevant for individuals scoring high for Conscientiousness. Because conscientious people are predisposed to dutifully carry out plans (i.e. intentions), it could be expected that the act of stating their intention for physical activity functions as a prompt for subsequent physical activity behavior. Further support is found in a recent systematic review (Rhodes & Dickau, 2013) in which Conscientiousness is suggested to moderate the intention/behavior relationship as it relates to physical activity. This is essentially the same effect we describe, though from a different perspective and with less evidence. Taken together, these observations suggest that employing a record of intention among conscientious persons may enhance intervention efficacy by acting as a prompt. Evidence opposing this suggestion comes from a recent meta-analysis reporting a small non-significant effect for the technique "prompting intention formation," on efficacy of health behavior interventions (Michie, Abraham, Whittington, McAteer, & Gupta, 2009). However, this evidence is limited in several ways. Effects for different target behaviors were analyzed together likely confounding the results, the extent of variation in the application of this technique (e.g. self-report, interview, daily log, etc.) is unreported, and personality was not considered as a potential moderator, further validating additional research testing the interplay between Conscientiousness, measures of intention and physical activity level.

Effects for Extraversion were moderated by an interaction between gender and experimental demand. More research is needed to clarify this moderation as only 3 effects were retrieved for Extraversion among samples of females responding to measures of intention (Courneya et al., 1999; Rhodes, Courneya, & Jones, 2002). A plausible reason for gender differences in the impact of reporting intention on the relationship between Extraversion and physical activity is unclear. It is possible that, because women report higher levels of Conscientiousness than men (Costa et al., 2001) this interaction could be confounded with the influence of Conscientiousness. An interaction between Conscientiousness and Extraversion has been explored elsewhere (Witt, 2002), though not relative to physical activity level. A conceptual theory for the interaction of personality dimensions has been elaborated in the AB5C Big Five personality circumplex, which consists of ten two-dimensional circumplexes that consider all possible pairs of Big Five dimensions as coordinates in conceptual space (Hofstee, De Raad, & Goldberg, 1992), though it has received relatively little attention.

The moderation of effects for Extraversion and Neuroticism by study design suggested previously (Rhodes & Smith, 2006) to favor prospective studies was not observed the analysis we report here. It is possible that those earlier observations were confounded by experimental demand within the prospective designs among the smaller number of retrieved effects in the prior analysis (Rhodes & Smith, 2006). The presumed Rosenthal effect on physical activity behavior imposed by a measure of intention has yet to be empirically tested, making a conclusive statement as to the nature of this artifact premature. Experiments to test the effect of measuring intention prior to measuring physical activity should be conducted, and personality should be considered as a covariate, particularly Conscientiousness.

The relationship between Extraversion and physical activity was also moderated by differences in the operational definition of physical activity across studies. Results suggest that this effect is intensity dependent, which is logical in consideration of the lower order facets of Extraversion. It has been suggested that this relationship may be driven completely by the lower order facet Activity (Rhodes et al., 2002). The Activity facet is reflected in "rapid tempo and vigorous movement, in a sense of energy, and in a need to keep busy" (Costa & McCrae, 1992). It is easy to see how these qualities might influence the relationship between Extraversion and physical activity to be intensity-dependent. This may explain why effects are weaker among physical activity measures capturing mild-to-moderate physical activity than among measures for any other physical activity construct (e.g., Courneya & Hellsten, 1998; Courneya et al., 1999; Lochbaum et al., 2010; Wheeler, Wagaman, & McCord, 2012). It is also plausible that the lower order facet Excitement Seeking influences the relationship between Extraversion and physical activity mode, as excitement seekers may be more likely to engage in activities with higher risk (Freixanet, 1991). Such an effect could also be expected to influence physical activity intensity, frequency and/or duration indirectly through physical activity mode. Little work has been done to clarify the relationship between physical activity and the spectrum of lower order facets contributing to the Big Five (Rhodes & Pfaeffli, 2012), though such clarification may be key to identifying important sources of variation in the associations between physical activity and primary personality. Investigators studying such effects would do well to extend their reports to include measures of pertinent primary traits to facilitate coordinated science in the study of personality.

Though the population effect of physical activity and Agreeableness was not significant, moderator analysis suggests that this relationship is dependent on age such that significant effects are observed for those >35 years only. Of the 52 effects for Agreeableness, 27 were from samples <25 years old, 6 were from samples 25–34 years old, 10 came from samples between 45–54 years old, and 2 were from samples $\geqslant$55 years old. Out of a desire to retain as many effects as possible for moderator analyses, we collapsed groups into a dichotomy representing samples < or >35 years old. Agreeableness is very stable across the lifespan, only changing significantly with an increase after age 50 (Roberts et al., 2006), and physical activity after age 35 remains relatively stable through middle adulthood with a small increase around retirement age before a steady decline during the final stage of life (Caspersen et al., 2000). The negative association between these constructs among samples greater than 35 years old may be driven by the simultaneous increase in Agreeableness after age 50 and the steady decline of physical activity in the final stage of life. Of the 14 effects for samples greater than 35 years old, 8 came from samples with a mean age greater than 50 years. On the other hand, this moderation may also be the result of a confounding variable. Additional work is needed to clarify the impact of age on the relationship between physical activity and Agreeableness, and to test for possible confounding variables.

A particularly interesting finding was the absence of significant moderation of the relationship between physical activity and Neuroticism after controlling for correlations between nested effects. Neuroticism is one of the most extensively studied personality dimensions in reference to physical activity behavior, and predisposes individuals to the development of mental disorders (Beard, Heathcote, Brooks, Earnest, & Kelly, 2007) which are significantly improved with physical activity (Asmundson et al., 2013; Cooney et al., 2013; Herring, O'Connor, & Dishman, 2010). These clear relationships between personality, physical activity and mental health support the notion that personality could modify the relationship between physical activity and mental health, as suggested elsewhere (De Moor et al., 2006). Though it was the least heterogeneous of the significant effects found, it still exhibits moderate heterogeneity, suggesting the presence of confounding variables. Research is needed to assess the possibility that the observed heterogeneity in the effect between Neuroticism and physical activity could result from individual differences in other personality dimensions, or other features not considered here.

4.1. Limitations

Limited statistical power to detect interactions (Hedges & Pigott, 2004), particularly 3-way interactions, resulted from the relatively small number of studies that reported on common or similarly defined moderator factors for each trait. This is particularly relevant to the impact of study features on the relationship between Conscientiousness and physical activity. Multiple 2-way interactions and diversity in the measurement and conceptualization of physical activity and personality among these studies support the possibility of more complex interactions for which there is insufficient evidence to test. This study is also limited by our inability to correct for measurement error (Hunter & Schmidt, 2004), as test–retest reliability was reported for less than 1% of the physical activity measures, and for none of the personality measures used in studies included in the present analysis. Reference to a validation publication for the test–retest reliability of physical activity and personality measures was observed for 13% and 1%, respectively, of the included studies. Internal consistency was reported for only 11% of the physical activity measures and 58% of the personality measures among retrieved effects, and an additional 4% cited a validation publication for the personality measure used. Though the correction for measurement error was reported in the previous meta-analysis (Rhodes & Smith, 2006) the reliability estimates used were not, rendering our observations incomparable to that analysis. We were also unable to test moderator variables reflective of physical activity mode and setting due to insufficient reporting in the literature. It is likely that personality influences the type of physical activity in which one participates, as well as how one responds to environmental prompts or barriers for physical activity. Lastly, it is possible that the correlation between one trait and physical activity is influenced by one or more other traits within individuals. An examination of moderation by sample mean personality scores on the observed relationship between each trait and physical activity may further clarify the observed widespread heterogeneity of effects, but was beyond the scope of this analysis. The possibility of complex interactions between primary personality traits influencing physical activity level is consistent with personality theory, and deserves an independent examination.

4.2. Conclusions

In conclusion, the available evidence supports a significant relationship between physical activity and the traits Extraversion, Neuroticism, Conscientiousness, and Openness. Analyses also support an age dependent relationship between physical activity and Agreeableness. Effects were heterogeneous and, except for Neuroticism, were moderated by characteristics of the sample or study features. Interactions influencing these relationships suggest that more complex moderation may be present in some cases, though more evidence is needed to appropriately assess this possibility. Physical activity and personality are dynamic constructs, and traits should not be expected to contribute to physical activity uniformly. It is important to test relationships between physical activity and personality in terms of the dimension of physical activity expected to reflect individual differences in the trait of interest (e.g. Excitement Seeking is likely to influence mode, whereas Self-Discipline is likely to influence frequency). In addition to age and gender, psychological constructs (e.g. other traits) and environmental influences (e.g. physical activity exposure and culture) are expected to moderate or possibly mediate the relationship between physical activity and personality, and should be identified and described. Variation in the measurement and conceptualization of physical activity and personality limits our ability to more accurately describe their true relationships, and highlights the lack of a consistent research paradigm in these fields and the challenges presented for cross-study comparisons.

The use of objective physical activity measures to capture frequency, duration and intensity, preferably in conjunction with a self-report of physical activity mode among studies exploring physical activity and personality is recommended, as are prospective study designs, so that we may more precisely conceptualize how personality influences the development of habitual physical activity. Detailed descriptions of samples and more work examining associations of lower order traits and physical activity are encouraged to facilitate a better understanding of physical activity as a behavioral domain that manifests personality differences as well as the application of personality theory by interventionists and clinicians seeking to increase physical activity.

The relationship between personality and physical activity may modify the widely reported relationship between physical activity and mental health outcomes (De Moor et al., 2006). Because the observable effect between physical activity and personality is small, large samples will be required to test these possibilities. Also, advances in behavioral genetics will surely inform our understanding of the link between primary personality and habitual physical activity. Research examining potential pleiotropic mechanisms linking physical activity to primary personality is needed (Dishman, 2008). Further studies might also consider advancements in biologically driven conceptualizations of personality (Gray, 1982, 1991; Gray & McNaughton, 2000; Zuckerman, 1991, 2005) and their interactions with reinforcement history in physical activity settings.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.paid.2014.08.023.

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