Research paper

Physical activity partially mediates associations between "Big" personality traits and incident generalized anxiety disorder: Findings from the irish longitudinal study on ageing

Cillian P. McDowell[a,*], Kathryn E. Wilson[b], Derek C. Monroe[c], Cathal McCrory[a], Rose Anne Kenny[a,d], Matthew P. Herring[e,f]

[a] *The Irish Longitudinal Study on Ageing, Trinity College Dublin, D02 R590 Ireland*
[b] *Department of Kinesiology and Health, Georgia State University, Atlanta, GA, United States*
[c] *Department of Neurology, University of California, Irvine, CA, United States*
[d] *Mercer's Institute for Successful Ageing, St James's Hospital, Dublin, Ireland*
[e] *Department of Physical Education and Sport Sciences, University of Limerick, Ireland*
[f] *Physical Activity for Health Research Cluster, Health Research Institute, University of Limerick, Ireland*

ARTICLE INFO

ABSTRACT

Background: This study aimed to examine associations of personality with generalized anxiety disorder (GAD) and physical activity (PA), PA with GAD, and PA mediates associations between personality and incident GAD.

Methods: Participants aged ≥50 years completed the 60-item NEO-Five Factor Inventory questionnaire to assess personality and short-form International Physical Activity Questionnaire at baseline, and the Composite International Diagnostic Interview – Short Form to clinically assess GAD at baseline and 2, 4, and 6 years later. Participants who had GAD at baseline or reported having ever been told by a doctor that they had anxiety were excluded from analyses. Binary logistic regression quantified associations of the 'Big Five' personality traits with PA and incident GAD, and associations of PA with incident GAD (i.e., GAD at any point during follow-up). The 'counterfactual approach' identified potential mediating effects of PA in the associations between personality traits and incident GAD.

Results: Participants (n = 4582; 53.7% female) were aged 64.38 ± 8.88 years. Incidence of GAD was 2.95% (n = 135). Extraversion (OR=1.160, 95%CI=1.087–1.237), openness (1.113, 1.043–1.188), and conscientiousness (1.083, 1.015–1.155) were positively associated with physical activity. Neuroticism was positively (2.335, 1.945–2.803), and extraversion (0.700, 0.563–0.797), conscientiousness (0.826, 0.693–0.985), and PA (0.655, 0.451–0.952) were inversely, associated with the incident GAD. Approximately 8.7% of the effect of extraversion and 8.8% of the effect of conscientiousness on GAD was due to mediation by PA only.

Limitations: PA was self-reported

Conclusions: Personality screening may help to identify older adults at-risk of anxiety who would benefit from participation in physical activity interventions.

1. Introduction

People who express certain personality factors, like high neuroticism or low conscientiousness and extraversion, may be more prone to experiencing affective disorders and poor mental health (Beard et al., 2007; Kotov et al., 2010). Generalized anxiety disorder (GAD), a prevalent and debilitating anxiety disorder primarily characterized by chronic worry (American Psychiatric Association, 2013), has been viewed as an extreme form of neuroticism (Watson, 2005). Evidence

also demonstrates cross-sectional associations of low extraversion and conscientiousness with GAD, even after adjusting for neuroticism (Kotov et al., 2010) and at low levels of neuroticism (Naragon-Gainey and Simms, 2017). However, integrative models of personality and health indicate that these fundamental traits impact health outcomes indirectly through cognitive and/or behavioral mechanisms (Allen et al., 2019; Ferguson, 2013; Wilson, 2019). One possible but understudied pathway by which personality traits influence the development of GAD is through their relationships with physical activity.

Improved understanding of the relationships between personality, physical activity, and the development of GAD could lead to improved early detection of at-risk individuals and the development of behavioral interventions designed to mitigate symptoms.

Meta-analytic evidence supports positive associations between physical activity and the Big Five personality traits of extraversion, conscientiousness, and openness, and negative associations between physical activity and neuroticism (Wilson and Dishman, 2015; Sutin et al., 2016). However, few studies identified in these reviews examined older adult populations. In a large (>10,000) cohort of Australian adults, higher levels of conscientiousness and openness were observed to predict increased physical activity across eight years (Allen et al., 2017). Temporal stability in the personality exercise behavior relationship is supported in a large (>19,000) sample of adolescent and adult twin pairs and their families, such that exercisers are more extraverted and less neurotic than non-exercisers across the lifespan (de Moor et al., 2006). Evidence of a bidirectional relationship between personality and physical activity is mixed (Stephan et al., 2014; Allen et al., 2017); however, due to the substantial heritability of personality and its stability over the life course, it appears likely that personality has a greater effect on physical activity (Power and Pluess, 2015; Vukasović and Bratko, 2015). Moreover, as personality stability plateaus at approximately 30 years old (Terracciano et al., 2010), it is plausible that its association with physical activity across the lifespan may influence onset of GAD, which also has a median age of first onset of 30 years old (Kessler et al., 2012), among older populations

Prospective cohort studies have demonstrated that increased sedentary behavior and decreased physical activity are associated with the development of several mental health problems, including anxiety (McDowell et al., 2019a; Sanchez-Villegas et al., 2008; Schuch et al., 2019). Previous evidence from The Irish Longitudinal Study on Ageing (TILDA) showed that adults with GAD engaged in fewer days and weekly minutes of moderate and vigorous physical activity, while meeting World Health Organization (WHO) physical activity guidelines was associated with 57% lower odds of developing GAD (McDowell et al., 2018). Subsequent analyses showed that sociodemographic, physical, and psychological variables were associated with physical activity among those with GAD; physical health and performance variables (i.e., polypharmacy, waist circumference, timed-up-and-go, grip strength, and number of physical limitations) explained a significant but small degree of variation in physical activity beyond sociodemographic and psychological variables (McDowell et al., 2019b).

Although still developing, there has been an increased focus on understanding the complex relationships between personality, physical activity, and mental health (Wilson et al., 2016; de Moor and de Geus, 2018). Much of the available evidence focuses on mental distress generally, rather than examining specific disorders such as GAD. Given established associations of personality factors with both GAD and physical activity, it is plausible that some of the risk conveyed by personality on GAD is mediated by physical activity. Moreover, although dose-response relationships are generally valuable for quantifying associations between health outcomes and exposure to preventative behaviors, understanding these associations in the context of current public health recommendations for physical activity is crucial to the continued development of effective and scalable physical activity promotion programs. Therefore, we hypothesized that: (1) each of the Big Five personality traits would be associated with incident GAD at follow-up, (2) extraversion, conscientiousness, openness, and neuroticism would be cross-sectionally associated with physical activity, (3) physical activity would be associated with incident GAD at follow-up, and (4) physical activity would mediate associations between personality and incident GAD.

2. Methods

This study used STROBE recommendations to guide reporting (Von Elm et al., 2007).

2.1. Study design

This study examined cross-sectional associations of personality with physical activity, prospective associations of physical activity and personality with GAD, and the potential mediating role of physical activity in the association between personality and GAD. This study is embedded within TILDA, a large population-based study of a nationally representative sample of over 8000 community dwelling older adults aged ≥50 years. Data were analyzed from TILDA Waves 2–5. Details of TILDA methodology are fully described elsewhere (Kenny et al., 2010; Kearney et al., 2011; Whelan and Savva, 2013; Donoghue et al., 2018). Briefly, at baseline and follow-up participants were visited in their own homes by trained professional social interviewers who used computer assisted personal interviewing to capture information on health, social, and economic domains. Participants were then given a self-completion questionnaire to be returned after the visit, which was completed by 84% of participants. Participants were included if they were aged ≥50 years, reported that they had never been told by a doctor that they had dementia or anxiety, did not have anxiety at baseline, and had data on personality (Wave 2), physical activity (Wave 2), and GAD (Wave 2 and Waves 3, 4, or 5; *n* = 4808). Participants with missing covariate data were excluded (*n* = 226, 4.7%; *n* = 221 of these were missing data on alcohol intake), leaving a final sample of 4582 for analyses.

2.2. Personality

At Wave 2, the 60-item NEO-Five Factor Inventory questionnaire assessed neuroticism (the degree to which a person experiences the world as threatening and beyond his/her control), extraversion (reflects positive mood, optimism, and the degree to which a person needs attention and social interaction), openness (the degree to which a person needs intellectual stimulation, change, and variety), agreeableness (the degree to which a person needs pleasant and harmonious relationships with others), and conscientiousness (reflects planning behavior and future orientation, and the degree to which a person is willing to comply with conventional rules, norms, and standards) (McCrae and Costa, 2004). Responses to each item were scored on a five-point Likert scale ('strongly disagree' to 'strongly agree'), resulting in a 0–48 score for each trait. The five-factor structure of the NEOFFI has been affirmed in a number of studies and across different cultures (McCrae, 2002). In TILDA, internal consistency (α) for the five factors is 0.84 (Neuroticism), 0.73 (Extraversion), 0.72 (Openness), 0.70 (Agreeableness), and 0.78 (Conscientiousness; Nolan et al., 2019). To aid interpretation of regression results, scores for each trait are expressed as z-scores, meaning each trait has a mean of 0 and a standard deviation of 1.

2.3. Generalized anxiety disorder

The Composite International Diagnostic Interview Short-Form (CIDI-SF) was administered by trained professional social interviewers at Waves 2–5 to determine fulfillment of criteria for GAD (Kessler et al., 1998). Participants were classified as having GAD if they reported 1) a period of worry lasting at least five months, 2) severe worry, 3) difficult to control worry, and 4) at least three of seven additional physiological symptoms. Compared to the full CIDI in the US National Comorbidity Survey, the CIDI-SF demonstrated sensitivity of 96.6%, specificity of 99.8%, positive predictive value of 96.8%, negative predictive value of 99.8%, and total classification accuracy of 99.6% for GAD (Kessler et al., 1998). At Waves 1 and 2 participants were also asked if

Table 1

Explanation of the decomposition of potential effects.

Total effect	The overall effect of personality on GAD
Controlled direct effect	The direct effect of personality on GAD that was not explained by physical activity
Reference interaction	The effect of personality on GAD due to the interaction with physical activity
Mediated interaction	The effect of personality on GAD due to both mediation and interaction with physical activity
Pure indirect effect	The effect of personality on GAD that due to mediation by physical activity only

GAD = generalized anxiety disorder.

they had ever been told by a doctor that they had anxiety. Participants were classified as having prevalent anxiety if they answered yes, or if they screened positive for GAD in the Wave 2 CIDI-SF assessment. These participants were excluded from analyses. Incidence of GAD was defined as screening positive for GAD in any of the Waves 3, 4, or 5 CIDI-SF assessments.

2.4. Physical activity

The short form International Physical Activity Questionnaire (IPAQ-SF) assessed physical activity (Craig et al., 2003; Lee et al., 2011). Respondents reported the number of days and duration of vigorous intensity, moderate intensity, and walking activities undertaken during the previous seven days. Total number of minutes engaged in walking and moderate and vigorous intensity physical activity per week were summed, and respondents who reported engaging in activity for ≥16 h/day were excluded. Using standard scoring procedures, moderate intensity physical activity was considered to be four metabolic equivalents (METs) and vigorous intensity was considered to be eight METs, where one MET is the estimated energy expenditure at rest, two METS is twice this, etc. The remaining respondents were then grouped according to whether they met WHO physical activity guidelines (i.e., ≥150 minutes weekly of moderate physical activity or ≥75 minutes weekly of vigorous physical activity, or ≥600 MET.minutes of weekly moderate or vigorous intensity physical activity) (World Health Organization, 2010). Walking was not included in assessing adherence to the WHO physical activity guidelines as the IPAQ-SF does not assess walking intensity.

2.5. Covariates

Covariates were selected based on logical, theoretical, and/or prior empirical associations between personality, physical activity, and/or anxiety, and were measured at baseline. These included socio-demographic information: age (years), sex (male, female), education level (none/primary, secondary level, third level or higher), and marital status (married/living together as if married, not married, separated/divorced, widowed). Participants were categorized as non-problem drinkers (≤1) or problem drinkers (≥2) based on established cut-offs on the Cut Down, Annoyed, Guilty, Eye Opener alcohol scale (Mayfield et al., 1974; Buchsbaum et al., 1992). Smoking status was categorized as never, former, or current smoker. Participants were asked if they had ever been diagnosed with any chronic or cardiovascular conditions. Chronic conditions included lung disease, asthma, arthritis, osteoporosis, cancer, Parkinson disease, stomach ulcer, varicose ulcer, liver disease, or thyroid disease. Cardiovascular conditions included hypertension, stroke, angina, heart attack, heart murmur, or atrial fibrillation. Participants were classified based on number of chronic conditions (1, 2, ≥3), and cardiovascular conditions (1, 2, ≥3). Number of physical limitations was determined by asking about, and subsequently summing the number of, difficulties with walking, running, sitting, sit-to-stand, stair climbing, reaching overhead, stooping, kneeling, crouching, lifting heavy weights, pushing or pulling large objects and picking small coins from table.

2.6. Statistical analyses

Data were analyzed in Stata version 15.1 (StataCorp for Windows). Differences in personality and physical activity between participants included in the current study (i.e., the analytic sample) and participants excluded for incomplete covariate data were tested by one-way analysis of variance and chi-square tests, respectively. Participants with missing covariate data were excluded from analyses ($n = 226$). In the analytic sample means, standard deviations, and frequencies were calculated for each variable. Binary logistic regression quantified associations (i.e., adjusted odds ratios (ORs) and associated 95% confidence intervals (95%CIs)) of personality with physical activity and incident GAD, and of physical activity with incident GAD, adjusting for all covariates.

For Big Five personality traits that were significantly associated with both physical activity and GAD, causal mediation analyses were performed using the Stata command *med4way* to estimate the effect of change in the personality traits (from the mean to 1-SD above the mean) on odds of developing GAD when physical activity was optimal (i.e., when meeting the physical activity guidelines) and covariates were adjusted in the model (VanderWeele, 2015; Discacciati et al., 2018). Results from these analyses are presented in Tables 4 and 5, and statistically significant results are presented in the text of the Results. This mediation method has been applied in epidemiological studies where the exposure and mediator are measured at the same time (Hallgren et al., 2019). The overall effect of an exposure on an outcome, in the presence of a mediator with which the exposure may interact, can be decomposed into four components: how much is due to (1) neither mediation nor interaction (controlled direct effect), (2) the interaction only (reference interaction), (3) both mediation and interaction (mediated interaction), and (4) mediation only (pure indirect effect; see Table 1). When statistically significant, the final component indicates a potential mediating effect of the pathway variable.

3. Results

3.1. Participant characteristics

Compared to the analytic sample, participants excluded for missing covariate data had higher levels of neuroticism (19.2 ± 7.2 vs 17.6 ± 7.0; $p < 0.001$), lower levels of openness (26.7 ± 5.1 vs 27.8 ± 5.8; $p = 0.005$) and were less likely to meet the physical activity guidelines (38.05% vs 51.77%; $p < 0.001$). There were no differences in extraversion ($p = 0.119$), agreeableness ($p = 0.607$), or conscientiousness ($p = 0.104$). Characteristics of the analytic sample are presented in Table 2. Briefly, participants ($n = 4582$; 53.7% female) were aged 64.38 ± 8.88 years. Mean ± standard deviation scores for personality factors were 17.6 ± 7.0 (neuroticism), 28.5 ± 5.6 (extraversion), 27.8 ± 5.8 (openness), 33.8 ± 5.0 (agreeableness), and 33.4 ± 5.3 (conscientiousness). Around half (51.8%) of the sample met physical activity guidelines at baseline and incidence of GAD at follow-up was 2.95%.

3.2. Associations between personality, physical activity, and incident GAD

Results from binary logistic regressions are shown in Figs. 1 and 2 and Table 3. Briefly, a 1-SD increase in neuroticism was associated with

Table 2
Participant characteristics.

| Variable	N (%) or mean ± SD
Neuroticism	17.6 ± 7.0
Extraversion	28.5 ± 5.6
Openness	27.8 ± 5.8
Agreeableness	33.8 ± 5.0
Conscientiousness	33.4 ± 5.3
Meeting physical activity guidelines	2372 (51.77)
Incident generalized anxiety disorder	135 (2.95)
Age	64.38 ± 8.88
Female	2461 (53.71)
Education	
Primary	1028 (22.44)
Secondary	1869 (40.79)
Tertiary	1685 (36.77)
Marital status	
Married	3378 (73.72)
Separated/divorced	303 (6.61)
Widowed	549 (11.98)
Never married	352 (7.68)
Problem drinker	587 (12.81)
Smoking	
Never	2115 (46.16)
Former	1880 (41.03)
Current	587 (12.81)
Chronic conditions	
0	2317 (50.57)
1–2	2083 (45.46)
3+	182 (3.97)
Cardiovascular conditions	
0	3971 (86.67)
1–2	586 (12.79)
3+	25 (0.55)
Number of physical limitations	1.89 ± 2.01

SD = standard deviation.
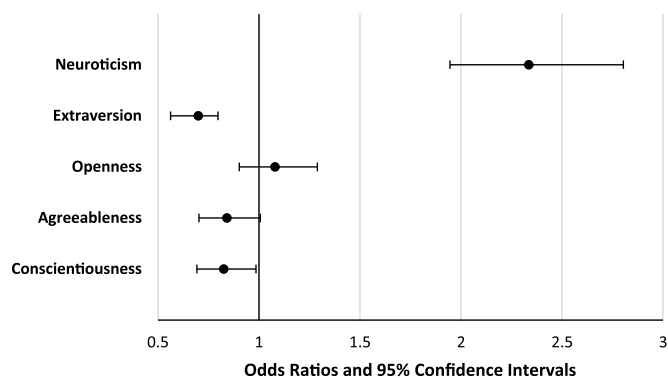
Fig. 1. Odds ratios and 95% confidence intervals from data presented in Table 3 as indicators of associations between personality traits and generalized anxiety disorder.

133.5% (OR = 2.335 [95%CI = 1.945 to 2.803]; $p < 0.001$) higher odds of developing GAD at follow-up. A 1-SD increase in extraversion and conscientiousness were associated with 30.0% (0.700 [0.563 to 0.797]; $p < 0.001$) and 17.4% (0.826 [0.693 to 0.985]; $p = 0.033$) lower odds of developing GAD, respectively. A 1-SD increase in extraversion, openness, and conscientiousness were associated with 16.0% (1.160 [1.087 to 1.237]; $p < 0.001$), 11.3% (1.113 [1.043 to 1.188]; $p = 0.001$), and 8.3% (1.083 [1.015 to 1.155]; $p = 0.016$) higher odds of meeting physical activity guidelines at follow-up, respectively. Participants who met the physical activity guidelines had 34.5% (OR = 0.655 [0.451 to 0.952]; $p = 0.026$) lower odds of developing GAD.
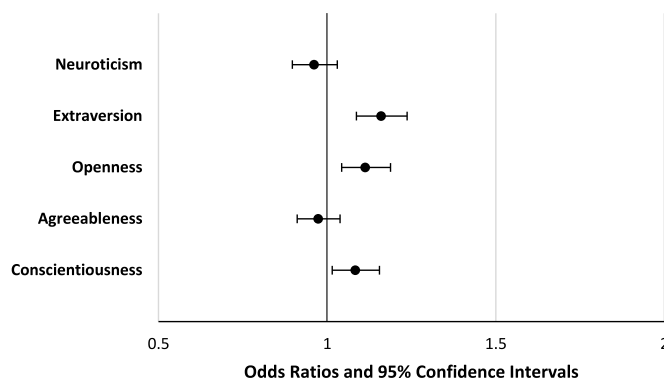

Fig. 2. Odds ratios and 95% confidence intervals from data presented in Table 3 as indicators of associations between personality traits and physical activity.

3.3. Physical activity as a mediator of the personality-GAD relationship

Results of mediation analyses for extraversion are presented in Table 4. The total effect was negative and statistically significant (β = −0.597; $p < 0.001$), again indicating that extraversion was inversely associated with GAD. This was significantly, partially explained by the controlled direct effect (83.1%; i.e., controlled direct effect divided by the total effect; β = −0.496; $p < 0.001$) and pure indirect effect (8.7%; i.e., pure indirect effect divided by the total effect; β = −0.052; $p = 0.007$). The effect of extraversion on GAD was not significantly explained by the reference interaction ($p = 0.466$) or the mediated interaction ($p = 0.469$).

Results were similar for conscientiousness (Table 5). The total effect was negative and statistically significant (β = −0.388; $p < 0.001$). This was significantly, partially explained by the controlled direct effect (85.1%; β = −0.330; $p = 0.003$) and pure indirect effect (8.8%; β = −0.034; $p = 0.015$). The effect of conscientiousness on GAD was not significantly explained by the reference interaction ($p = 0.803$) or the mediated interaction ($p = 0.803$).

4. Discussion

To the authors' knowledge, this is the first investigation of prospective interrelations of personality, physical activity, and GAD. As hypothesized, it found that (1) extraversion, openness, and conscientiousness were positively associated with physical activity, (2) neuroticism was positively, and extraversion, conscientiousness, and physical activity were inversely, associated with the incident GAD, and (3) approximately 8.7% of the effect of extraversion and 8.8% of the effect of conscientiousness on GAD was due to mediation by physical activity only. These findings build on previous cross-sectional reports of associations between personality factors and GAD and provide initial evidence of these associations among older adults, expand the limited body of evidence of associations between personality factors and physical activity among older adults, expand previous reports of lower odds of incident GAD among older adults meeting recommended physical activity levels with more rigorous methods, and provide, to our knowledge, the first evidence that physical activity partially mediates associations of extraversion and conscientiousness with incident GAD. This provides important evidence for the potential benefits of utilizing personality traits in personalized medicine, such as through the use of patient-level information to better understand how to approach and interact with patients or helping to identify and target which patients may be less likely to adhere to treatment regimens (Chapman et al., 2011). Personality screening prior to physical activity interventions may be beneficial so as to target older adults with high-risk personality profiles (i.e., low extraversion, low conscientiousness) who do not meet minimum recommended levels of physical activity.

Table 3

Odds ratios (ORs) and 95% confidence intervals (CIs) derived from binary logistic regression as indicators of associations between personality traits and generalized anxiety disorder (prospective) and physical activity (cross-sectional).

Personality trait (per 1-SD increase)	Generalized anxiety disorder OR (95%CI)	P-value	Physical activity OR (95%CI)	P-value
Neuroticism	**2.335 (1.945 to 2.803)**	**<0.001**	0.961 (0.897 to 1.030)	0.257
Extraversion	**0.700 (0.563 to 0.797)**	**<0.001**	**1.160 (1.087 to 1.237)**	**<0.001**
Openness	1.079 (0.903 to 1.289)	0.405	**1.113 (1.043 to 1.188)**	**0.001**
Agreeableness	0.842 (0.703 to 1.007)	0.060	0.973 (0.911 to 1.038)	0.406
Conscientiousness	**0.826 (0.693 to 0.985)**	**0.033**	**1.083 (1.015 to 1.155)**	**0.016**

SD = standard deviation; adjusted for age, sex, education, marital status, alcohol use, smoking, cardiovascular conditions, other chronic conditions, and physical limitations.

Table 4

Decomposition of the overall effect of extraversion on incident generalized anxiety disorder.

	β	95% CI	P-value
Total effect	−0.597	−0.736 to −0.458	**<0.001**
Controlled direct effect	−0.496	−0.649 to −0.343	**<0.001**
Reference interaction	−0.060	−0.222 to 0.101	0.466
Mediated interaction	0.012	−0.020 to 0.044	0.469
Pure indirect effect	−0.052	−0.091 to −0.014	**0.007**

Adjusted for age, sex, education, marital status, alcohol use, smoking, cardiovascular conditions, other chronic conditions, and physical limitations.

Table 5

Decomposition of the overall effect of conscientiousness on incident generalized anxiety disorder.

	β	95% CI	P-value
Total effect	−0.388	−0.602 to −0.175	**<0.001**
Controlled direct effect	−0.330	−0.550 to −0.110	**0.003**
Reference interaction	−0.028	−0.248 to 0.192	0.803
Mediated interaction	0.004	−0.025 to 0.032	0.803
Pure indirect effect	−0.034	−0.061 to −0.007	**0.015**

Adjusted for age, sex, education, marital status, alcohol use, smoking, cardiovascular conditions, other chronic conditions, and physical limitations.

Consistent with previous evidence, higher neuroticism, lower extraversion, and lower conscientiousness were associated with the development of GAD. Previously, Bienvenu et al. (2004) found only neuroticism to be associated with lifetime GAD, though the relatively small sample (*n* = 326) may not have been sufficient to detect differences in other personality factors. Subsequently, studies by Kotov et al. (2010) and Naragon-Gainey and Simms (2017) found that higher neuroticism, lower extraversion, and lower conscientiousness were strongly associated with GAD, while associations with conscientiousness and extraversion were independent of neuroticism. However, to date, most research has been cross-sectional and the current study is among the first to report prospective associations between personality and incident GAD.

Results support significant positive associations of physical activity with extraversion, openness and conscientiousness, consistent with existing evidence (Wilson and Dishman, 2015; Sutin et al., 2016; Allen et al., 2017; Artese et al., 2017). However, counter to previous findings (De Moor et al., 2006; Wilson and Dishman, 2015; Sutin et al., 2016) neuroticism was not significantly associated with physical activity. This unexpected observation may simply reflect a null relationship among older adults in Ireland. Previous evidence demonstrated that the association between neuroticism and physical activity is significantly heterogeneous among adults aged ≥45 years, while effects for European samples were also significantly heterogeneous and smaller than half those observed in North American samples (Wilson and Dishman, 2015). Alternatively, this observation may reflect confounding due to the physical activity measure used, as previous

evidence among a sample of female university freshman demonstrated that relationships of extraversion and neuroticism with physical activity may differ between self-reported and accelerometer measured physical activity (Wilson et al., 2015).

Personality theorists generally agree that behavioral action is unlikely to arise directly from personality; rather, personality is thought to influence behavior through its influence on, or interaction with cognitive, affective, and/or behavioral factors relevant to the behavior of interest. For example, extraversion and conscientiousness influence attitudes and a sense of control over engaging in physical activity which, in turn, may influence intention to engage in physical activity (Rhodes and Smith, 2006; Rhodes and Dickau, 2013). Conscientiousness and neuroticism have been observed to interact with exercise goal setting and self-efficacy to overcome barriers, respectively, to influence objectively measured physical activity (Smith et al., 2016). This growing body of evidence supports theoretical postulates of integrative, meta-theoretical models of the personality system. However, more comprehensive investigations are needed to test the myriad intrapersonal processes that explain how traits interact with each other, and with cognitive-affective, behavioral and environmental factors to influence physical activity and other health behaviors (Ferguson, 2013; Wilson 2019). Elucidating how individual differences impact physical activity behavior, and whether they can be leveraged to enhance efforts in physical activity promotion, may be beneficial (Wilson, 2019; Rhodes and Wilson 2020). To do so, large-scale longitudinal observations and randomized controlled trials involving multivariate analyses which integrate models of personality, social cognitions, and affective, behavioral, and environmental influences on behavior change are needed.

In the current study, physical activity was strongly associated with lower odds of incident GAD. These findings confirm previous findings from TILDA that showed lower odds of incident GAD at two-year follow-up among older adults meeting physical activity guidelines (McDowell et al., 2018). However, the current findings rigorously expand upon these by excluding participants with a lifetime history of anxiety, using solely the CIDI-SF to diagnose GAD, examining prospective associations across six years of follow-up, and adjusting for additional relevant covariates (e.g., alcohol use, cardiovascular conditions, other chronic conditions, and physical limitations). Despite these more rigorous methods, the magnitude of the association did not meaningfully differ between the former and current studies while the precision of the point estimate improved.

Physical activity partially mediated the associations of extraversion and conscientiousness with incident GAD, though the magnitude of the pure indirect effect was small (~9%). As low extraversion and conscientiousness increase risk for GAD even at low levels of neuroticism (Naragon-Gainey and Simms, 2017), the current findings could provide a basis for personality screening prior to interventions to increase physical activity so as to target individuals with high-risk personality profiles (low extraversion, low conscientiousness) who do not meet physical activity recommendations. Additionally, based on previous evidence (Wilson and Dishman, 2015) and the significant associations

of extraversion and conscientiousness with physical activity in the current study, higher levels of extraversion and conscientiousness that may be expected among more physically active individuals may confer some protection against the influence of high neuroticism (Naragon-Gainey and Simms, 2017) in the development of GAD.

4.1. Strengths and limitations

Observations in the current study are supported by a number of strengths. For example, this study uses a prospective design controlling for baseline and lifetime presence of anxiety. Personality is comprehensively measured using the full 60-item NEO-FFI. To our knowledge, TILDA is the only longitudinal study of aging to include the full 60-item instrument. Finally, the CIDI-SF is a strong measure of GAD, with a total classification accuracy of 99.6% compared to the full CIDI. This study also has several limitations. Firstly, this study is observational and causality cannot be determined. Secondly, although the IPAQ-SF is a widely used measure of physical activity, the validity of self-reported physical activity can be low, especially among low socioeconomic populations (Winckers et al., 2015; Dowd et al., 2018), which may predispose the results to over-reporting (Shook et al., 2016). Additionally, it is possible that interrelations between individual personality traits and physical activity or GAD are influenced by one or more other traits within individuals; however, examination of these potential complex interactions was beyond the scope of the current study. Finally, exclusion of participants may have introduced bias into the sample; however, the number of exclusions was relatively low (i.e., 4.7% of the sample).

4.2. Future research

Future research would benefit from using validated devices that capture physical activity frequency, duration, and intensity. Secondly, future research should examine interrelations of personality, physical activity, and onset of GAD in younger cohorts as median age of first onset of GAD is 30 years old (Kessler et al., 2012) and personality stability does not plateau until approximately 30 years old (Terracciano et al., 2010). Thirdly, valuable information may be gleaned from examining interactions between traits within individuals, as well as relationships between facet traits, secondary to the primary Big Five personality traits, and physical activity in the prediction of incident GAD. For example, the conscientiousness facet most frequently associated with anxiety and depressive disorders, particularly GAD, is self-discipline (Bienvenu et al., 2004), which may be a key overlapping factor that influences GAD, physical activity, and their interrelations over time that warrants further investigation. Fourthly, it is plausible that the associations observed in the current study are modified by participant characteristics such as age, sex, or health status; however, studies with larger samples and higher incidence rates of anxiety would be required to precisely examine these putative modifiers. Finally, future research should seek to understand how and why different personality traits impact on physical activity. Such information may be invaluable in developing and implementing effective interventions aimed at increasing physical activity behaviors.

4.3. Conclusions

In a large sample of older Irish adults, this study examined interrelations of personality, physical activity, and GAD. Extraversion, openness, and conscientiousness were positively associated with physical activity. Neuroticism was positively, and extraversion, conscientiousness, and physical activity were inversely, associated with the incident GAD. Approximately 8.7% of the effect of extraversion and 8.8% of the effect of conscientiousness on GAD was due to mediation by physical activity only. Personality screening may help to identify older adults at-risk of anxiety who would benefit from participation in physical activity interventions.

Ethics

CRediT authorship contribution statement

Cillian P. McDowell: Formal analysis, Methodology, Writing - original draft. **Kathryn E. Wilson:** Writing - original draft. **Derek C. Monroe:** Writing - original draft. **Cathal McCrory:** Methodology, Writing - review & editing. **Rose Anne Kenny:** Writing - review & editing, Supervision. **Matthew P. Herring:** Methodology, Writing - review & editing, Supervision.

Declaration of Competing Interest

The authors declare no conflicts of interest.

Funding

Acknowledgements

References

Allen, M.S., Magee, C.A., Vella, S.A., Laborde, S, 2017. Bidirectional associations between personality and physical activity in adulthood. Health Psychol. 36 (4), 332.

Allen, M.S., Laborde, S., Walter, E.E., 2019. Health-related behavior mediates the association between personality and memory performance in older adults. J. Appl. Gerontol. 38 (2), 232–252.

American Psychiatric Association, 2013. Diagnostic and Statistical Manual of Mental Disorders (DSM-5®). American Psychiatric Pub, Arlington.

Artese, A., Ehley, D., Sutin, A.R., Terracciano, A, 2017. Personality and actigraphy-measured physical activity in older adults. Psychol. Aging 32 (2), 131.

Beard, J.R., Heathcote, K., Brooks, R., Earnest, A., Kelly, B, 2007. Predictors of mental disorders and their outcome in a community based cohort. Soc. Psychiatry Psychiatr. Epidemiol. 42 (8), 623–630.

Bienvenu, O.J., Samuels, J.F., Costa, P.T., Reti, I.M., Eaton, W.W., Nestadt, G, 2004. Anxiety and depressive disorders and the five-factor model of personality: a higher- and lower-order personality trait investigation in a community sample. Depress. Anxiety 20 (2), 92–97.

Buchsbaum, D.G., Buchanan, R.G., Welsh, J., Centor, R.M., Schnoll, S.H, 1992. Screening for drinking disorders in the elderly using the CAGE questionnaire. J. Am. Geriatr. Soc. 40 (7), 662–665.

Chapman, B.P., Roberts, B., Duberstein, P, 2011. Personality and longevity: knowns, unknowns, and implications for public health and personalized medicine. J. Aging Res 2011.

Craig, C.L., Marshall, A.L., Sjöström, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., et al., 2003. International physical activity questionnaire: 12-country reliability and validity. Med. Sci. Sports Exercise 35 (8), 1381–1395.

De Moor, M., Beem, A., Stubbe, J., Boomsma, D., De Geus, E, 2006. Regular exercise, anxiety, depression and personality: a population-based study. Prev. Med. 42 (4), 273–279.

de Moor, M.H.M., de Geus, E.J.C, 2018. Causality in the associations between exercise, personality, and mental health. In: Budde, H., Wegner, M. (Eds.), The Exercise Effect On Mental Health. Routledge, New York, NY, pp. 67–99.

Discacciati, A., Bellavia, A., Lee, J.J., Mazumdar, M., Valeri, L, 2018. Med4way: a Stata command to investigate mediating and interactive mechanisms using the four-way effect decomposition. Int. J. Epidemiol.

Donoghue, O.A., McGarrigle, C.A., Foley, M., Fagan, A., Meaney, J., Kenny, R.A, 2018. Cohort profile update: the irish longitudinal study on ageing (TILDA). Int. J.

Epidemiol. 47 (5), 1398.

Dowd, K.P., Szeklicki, R., Minetto, M.A., Murphy, M.H., Polito, A., Ghigo, E., et al., 2018. A systematic literature review of reviews on techniques for physical activity measurement in adults: a DEDIPAC study. Int. J. Behav. Nutr. Phys. Act. 15 (1), 15.

Ferguson, E., 2013. Personality is of central concern to understand health: towards a theoretical model for health psychology. Health Psychol. Rev. 7, S32–S70.

Hallgren, M., Vancampfort, D., Owen, N., Rossell, S., Dunstan, D.W., Bellocco, R., Lagerros, Y.T, 2019. Prospective relationships of mentally passive sedentary behaviors with depression: mediation by sleep problems. J. Affect. Disord.

Kearney, P.M., Cronin, H., O'Regan, C., Kamiya, Y., Savva, G.M., Whelan, B., et al., 2011. Cohort profile: the Irish longitudinal study on ageing. Int. J. Epidemiol. 40 (4), 877–884.

Kenny R.A., Whelan B.J., Cronin H., Kamiya Y., Kearney P., O'Regan C. et al., The design of the Irish longitudinal study on ageing. 2010.

Kessler, R.C., Andrews, G., Mroczek, D., Ustun, B., Wittchen, H.U, 1998. The World Health Organization composite international diagnostic interview short-form (CIDI-SF). Int. J. Methods Psychiatr. Res. 7 (4), 171–185.

Kessler, R.C., Petukhova, M., Sampson, N.A., Zaslavsky, A.M., Wittchen, H.U, 2012. Twelve-month and lifetime prevalence and lifetime morbid risk of anxiety and mood disorders in the United States. Int. J. Methods Psychiatr. Res. 21 (3), 169–184.

Kotov, R., Gamez, W., Schmidt, F., Watson, D, 2010. Linking "big" personality traits to anxiety, depressive, and substance use disorders: a meta-analysis. Psychol. Bull. 136 (5), 768.

Lee, P.H., Macfarlane, D.J., Lam, T., Stewart, S.M, 2011. Validity of the international physical activity questionnaire short form (IPAQ-SF): a systematic review. Int. J. Behav. Nutr. Phys. Act. 8 (1), 115.

Mayfield, D., McLeod, G., Hall, P, 1974. The CAGE questionnaire: validation of a new alcoholism screening instrument. Am. J. Psychiatry 131 (10), 1121–1123.

McCrae, R.R., 2002. Cross-cultural research on the five-factor model of personality. Online Read. Psychol. Cult. 4 (4), 1–2.

McCrae, R.R., Costa, P.T., 2004. A contemplated revision of the NEO Five-Factor Inventory. Pers. Individ. Differ. 36 (3), 587–596.

McDowell, C.P., Dishman, R.K., Gordon, B.R., Herring, M.P, 2019a. Physical activity and anxiety: a systematic review and meta-analysis of prospective cohort studies. Am. J. Prev. Med. 57 (4), 545–556.

McDowell, C., Gordon, B., MacDonncha, C., Herring, M, 2019b. Physical activity correlates among older adults with probable generalized anxiety disorder: results from The Irish Longitudinal Study on Ageing. Gen. Hosp. Psychiatry 59, 30–36.

McDowell, C.P., Dishman, R.K., Vancampfort, D., Hallgren, M., Stubbs, B., MacDonncha, C., et al., 2018. Physical activity and generalized anxiety disorder: results from The Irish Longitudinal Study on Ageing (TILDA). Int. J. Epidemiol. 47 (5), 1443–1453.

Naragon-Gainey, K., Simms, L.J., 2017. Three-way interaction of neuroticism, extraversion, and conscientiousness in the internalizing disorders: evidence of disorder specificity in a psychiatric sample. J. Res. Pers. 70, 16–26.

Nolan, A., McCrory, C., Moore, P, 2019. Personality and preventive healthcare utilisation: evidence from the Irish Longitudinal Study on Ageing. Prev. Med. 120, 107–112.

Power, R.A., Pluess, M., 2015. Heritability estimates of the Big Five personality traits based on common genetic variants. Transl. Psychiatry 5 (7), e604.

Rhodes, R., Smith, N., 2006. Personality correlates of physical activity: a review and meta-analysis. Br. J. Sports Med. 40 (12), 958–965.

Rhodes, R.E., Dickau, L., 2013. Moderators of the intention-behaviour relationship in the physical activity domain: a systematic review. Br. J. Sports Med. 47 (4), 215–225.

Rhodes, R., Wilson, K., 2020. Personality and Exercise. In: Schinke, R.J., Hackfort, D. (Eds.), Encyclopaedia of Sport Psychology. International Society of Sport Psychology.

Sanchez-Villegas, A., Ara, I., Guillen-Grima, F., Bes-Rastrollo, M., Varo-Cenarruzabeitia, J.J., Martinez-Gonzalez, M.A, 2008. Physical activity, sedentary index, and mental disorders in the SUN cohort study. Med. Sci. Sports Exercise 40 (5), 827–834 May 1.

Schuch, F.B., Stubbs, B., Meyer, J., Heissel, A., Zech, P., Vancampfort, D., Rosenbaum, S., Deenik, J., Firth, J., Ward, P.B., Carvalho, A.F, 2019. Physical activity protects from incident anxiety: a meta-analysis of prospective cohort studies. Depress. Anxiety 36 (9), 846–858.

Shook, R.P., Gribben, N.C., Hand, G.A., Paluch, A.E., Welk, G.J., Jakicic, J.M., et al., 2016. Subjective estimation of physical activity using the international physical activity questionnaire varies by fitness level. J. Phys. Act. Health 13 (1), 79–86.

Stephan, Y., Sutin, A.R., Terracciano, A, 2014. Physical activity and personality development across adulthood and old age: evidence from two longitudinal studies. J. Res. Pers. 49, 1–7.

Sutin, A.R., Stephan, Y., Luchetti, M., Artese, A., Oshio, A., Terracciano, A, 2016. The five-factor model of personality and physical inactivity: a meta-analysis of 16 samples. J. Res. Pers. 63, 22–28.

Terracciano, A., McCrae, R.R., Costa Jr, P.T, 2010. Intra-individual change in personality stability and age. J. Res. Pers. 44 (1), 31–37.

VanderWeele, T., 2015. Explanation in Causal inference: Methods For Mediation and Interaction. Oxford University Press.

Von Elm, E., Altman, D.G., Egger, M., Pocock, S.J., Gøtzsche, P.C., Vandenbroucke, J.P, 2007. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Ann. Intern. Med. 147 (8), 573–577.

Vukasović, T., Bratko, D., 2015. Heritability of personality: a meta-analysis of behavior genetic studies. Psychol. Bull. 141 (4), 769.

Watson, D., 2005. Rethinking the mood and anxiety disorders: a quantitative hierarchical model for DSM-V. J. Abnorm. Psychol. 114 (4), 522.

Whelan, B.J., Savva, G.M., 2013. Design and methodology of the Irish Longitudinal Study on Ageing. J. Am. Geriatr. Soc. 61, S265–S268.

Wilson, K.E., Das, B.M., Evans, E.M., Dishman, R.K, 2015. Personality correlates of physical activity in college women. Med. Sci. Sports Exercise 47 (8), 1691–1697.

Wilson, K.E., Das, B.M., Evans, E.M., Dishman, R.K, 2016. Structural equation modeling supports a moderating role of personality in the relationship between physical activity and mental health in college women. J. Phys. Act. Health 13 (1), 67–78.

Wilson, K.E., Dishman, R.K, 2015. Personality and physical activity: a systematic review and meta-analysis. Pers. Individ. Dif. 72, 230–242.

Wilson, K.E., 2019. Personality and Physical Activity. In: Anshel, M.H., Petruzzello, S.J. (Eds.), APA Handbook of Sport and Exercise Psychology: Vol. 2. Exercise Psychology. APA, pp. 219–239. http://dx.doi.org/10.1037/0000124-012.

Winckers, A.N., Mackenbach, J.D., Compernolle, S., Nicolaou, M., van der Ploeg, H.P., De Bourdeaudhuij, I., et al., 2015. Educational differences in the validity of self-reported physical activity. BMC Public Health 15 (1), 1299.

World Health Organization, 2010. Global Recommendations on Physical Activity For Health. World Health Organization, Geneva Available at. http://www.who.int/dietphysicalactivity/factsheet_recommendations/en/ Accessed date: 13 January 2020.