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Physical activity and stress resilience: Considering those at-risk for developing mental health problems

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ABSTRACT

Introduction: Physical activity (PA) has been shown to benefit mental health. While research on non-human animal species indicates that PA may confer protective effects on mental health by increasing resilience to stress via regulation of the stress response, the human literature offers inconsistent evidence regarding this idea. To help reconcile these inconsistencies, the present study of human adults tested the hypothesis that PA's protective effects, as indexed by self-perceived resilience, vary according to individual differences in trait anxiety, which has been linked to a dysregulated stress response and risk for developing mental health problems. Specifically, we predicted that individuals reporting high trait anxiety (and thus presumably more stress response dysregulation) would show a stronger association between PA and self-perceived resilience, than would peers with lower reported trait anxiety.
Methods: Undergraduate students ($n = 222$) completed online self-report measures regarding their PA level, trait anxiety, and self-perceived resilience.
Results: Hierarchical linear regression analyses yielded evidence of a significant interaction between trait anxiety level and PA, such that PA and self-perceived resilience were significantly and positively associated among individuals with high trait anxiety, but not among individuals with low and moderate trait anxiety.
Discussion: In conclusion, individuals with high trait anxiety, which may be a risk factor for developing clinically significant mental health problems, may preferentially show psychological, as well as physiological, benefits from PA.

1. Introduction

According to the Centers for Disease Control and Prevention (CDC), over 50% of adults in the United States fail to engage in recommended levels of physical activity (PA; CDC, 2012). This statistic is striking, given ample evidence that PA yields physical and mental health benefits, as well as potential protective effects. For instance, physically active individuals report reduced incidence of mental health problems and a dose-response relationship appears to exist between PA and mental health (Goodwin, 2003; Ströhle et al., 2007).

Substantial evidence links PA and psychological well-being; however, the path from PA to its notable psychological benefits is complex (Crone, Smith, & Gough, 2006). As the prevalence of stress-related mental health problems continues to surge (i.e., anxiety and depression; Kessler et al., 2005), much attention has focused on whether PA influences the stress response, or one's resilience to stress [see A to C in Fig. 1, which depicts associations among PA, mental health, and study specific variables referred to throughout the introduction], as a means of promoting mental health [Fig. 1, D] (Tsatsoulis & Fountoulakis, 2006). That is, does PA improve an individual's stress resilience, in turn, providing protection against stress-related mental health problems? Of note, we define resilience as the ability to respond and adapt successfully to acute or chronic adversity as a function of adaptive physiological/psychological stress responses (Feder, Nestler, & Charney, 2009). This definition is important to keep in mind, because researchers operationalize resilience in diverse ways.

Research using animal models lends ample support to the hypothesis that stress resilience at least partially accounts for the commonly observed negative association between PA and stress-related mental health problems. For example, the introduction of habitual PA prior to stress exposure (e.g., footshock, social defeat) attenuates the activation of, as well as changes in, physiological stress response systems that are typically observed in stressed

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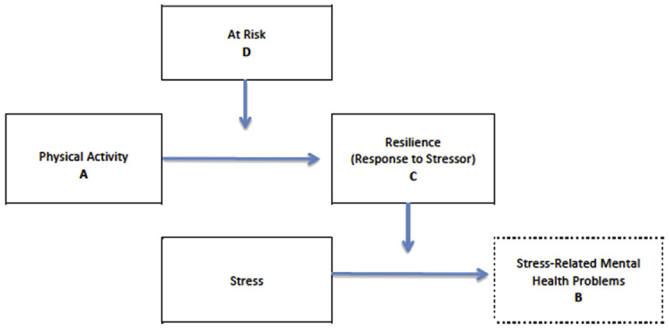

Fig. 1. Model showing the relationship among variables considered in the study. Stress-induced mental health problems are not assessed. Future research is needed that incorporates variables that measure these important outcomes.

sedentary rodents (Dishman et al., 2006; Greenwood & Fleshner, 2011; Stranahan, Lee, & Mattson, 2008). Similarly, habitual PA appears to protect rodents against negative behavioral consequences of stress that resemble human anxiety or depression symptoms (e.g., social avoidance, exaggerated conditioned fear, and interference with instrumental learning) (Greenwood & Fleshner, 2011, 2013). In essence, the non-human literature suggests that habitual PA increases physiological and behavioral resilience to stressors, which may help prevent stress-related mental health problems.

Generally, the human literature indicates that people who exercise regularly have lower risk for developing stress-related mental health disorders than do sedentary peers (Gerber & Pühse, 2009). Human studies have investigated whether PA confers such resilience by examining varied effects of PA on the stress response. For example, studies of physiological responses to laboratory stressors (e.g., mental arithmetic, public speaking, and cognitive interference tasks) have found that fitness and/or exercise training predict regulated cardiovascular activity, which is commonly identified as a marker of physiological resilience (e.g., Forcier et al., 2006). The literature also indicates that PA reduces self-reported psychological (i.e., anxious) responses to stressors. Rimmele et al. (2009) found that, compared to untrained males, elite male athletes not only showed significantly lower cortisol levels and heart rates, but also reported less state anxiety in response to psychosocial stress (i.e., public speaking). Additionally, Smith (2013) reported that PA attenuates the anxious response (i.e., state anxiety) to emotional stimuli (arousing pleasant/unpleasant/neutral images), which further suggests that PA may help people to better endure or manage daily anxieties and stressors.

Despite relatively coherent evidence of a positive association between PA and stress resilience, some human studies have yielded less consistent findings. For example, one literature review found the evidence for PA-induced augmentation of neuroendocrine stress reactivity in response to laboratory-based stressors to be inconclusive (Sothmann, 2006). Further, at least one study has shown that PA-induced changes in the physiological stress response do not extend to psychological responses to stress, defined as state anxiety (Klaperski, von Dawans, Heinrichs, & Fuchs, 2013).

Notably, much of the extant literature has focused on main effects, measuring associations between PA and stress resilience [see Fig. 1, A to C]. Limited research, in contrast, has examined moderators of such main effects. Therefore, there could be value in investigating individual differences that may serve as moderators, influencing the degree to which PA offers protective effects for different individuals. Findings from such research would help inform efforts to personalize prevention/intervention for mental health problems.

One potential moderator is the predisposition to respond with anxiety, a characteristic that places individuals at risk for developing stress-related psychological disorders [See Fig. 1, D]. Although some conceptualizations define risk and resilience as opposite sides of the same coin, the absence of risk factors does not necessarily confer resilience (Manyena, 2006). Further, research suggests that mechanisms of risk, like the predisposition to experience anxiety, are not always the opposite of those mediating resilience to stress (Poirier, Cordero, & Sandi, 2013).

Smits, Tart, Rosenfield, and Zvolensky (2011) conducted the only published study to date that examines individual differences in risk factors for the development of mental health problems or predisposed anxious responding, as a potential moderator of the impact of PA on resilience. For this study, predisposed anxious responding was defined as high levels of anxiety sensitivity, or the fear of somatic arousal. This characteristic is an established risk factor for anxiety and its disorders (Schmidt, Zvolensky, & Manor, 2006). Resilience was operationally defined as an individual's subjective distress rating following recurrent inhalation of 20% carbon dioxide (CO_2) enriched air (psychological response to physiological stressor). The researchers found that anxiety sensitivity moderated the association between PA and resilience, such that PA protected against elevated distress only in those who reported both high anxiety sensitivity and high levels of PA.

Smits and colleagues' findings suggest that PA's protective effects may be specific to those at elevated risk for psychological disorders. However, the conclusions that can be drawn on the basis of this study are of limited generalizability for two key reasons. First, anxiety sensitivity is a strong predictor of panic disorder (McNally, 2002), but less reliably predicts fear-based anxiety disorders (Naragon-Gainey, 2010). Second, the laboratory-based stressor used to elicit a measured stress response can only provide a proxy for individuals' responses to routine stressors (Kamarck & Lovallo, 2003; van Doomen & Turner, 1992). Accordingly, there is value in extending Smits and colleagues' research by examining whether and how different risk factors for stress-related mental health problems interact with PA to predict responses to daily life stress.

To this end, the present study examined trait anxiety as a potential moderator of the association between PA and stress resilience, defined as self-perceived ability to cope with daily stress. Trait anxiety is a broad risk factor for mental health problems that marks a tendency to pervasively experience anxiety and worry

Table 1
Descriptive statistics, Cronbach's alpha, and correlations in and between covariates and study variables ($N = 222$).

Variable	M (N)	SD (%)	α	1	2	3	4	5	6
1. Age	21.24	5.38		–	.06	–.05	–.17*	–.12	.14*
2. Gender[a]	171	77%			–	.04	.15*	–.12	–.03
3. Race						–	.12	–.003	–.19**
Caucasian	66	30%				–			
African American	105	47%				–			
Asian	34	14%				–			
Other	17	8%				–			
4. STAI-T Score	43.96	10.95	.91				–	–.05	–.63**
5. GPAQ	2159.01	2806.80						–	.08
6. CD-RISC 10	26.40	7.93	.92						–

Note: GPAQ = Global Physical Activity Questionnaire–Recreational Activity; STAI-T = State Trait Anxiety Inventory-Trait Form X; CD-RISC 10 = Connor Davidson Resilience Scale 10. The GPAQ α is not reported because the score comprises two items that are designed to measure different constructs.
*$p < .05$; **$p < .01$.
[a] Descriptive statistics are for the women in the sample.

(Spielberger & Sydeman, 1994). We selected trait anxiety as a putative moderator because individuals with high scores on measures of this construct commonly exhibit a dysregulated stress response (Duncko, Makatsori, Fickova, Selko, & Jezova, 2006; Jezova, Makatsori, Duncko, Moncek, & Jakubek, 2004), show enhanced vulnerability to stress, and are at risk for anxiety disorders (Elwood, Wolitzky-Taylor, & Olatunji, 2011; Sehlmeye et al., 2011). We predicted that, consistent with Smits and colleagues' (2011) findings regarding anxiety sensitivity, PA, and responses to stressors, individuals who self-reported high trait anxiety would exhibit a positive, significant association between PA and self-perceived ability to cope with daily stress; we expected this association to be weaker in peers who self-reported lower levels of trait anxiety.

2. Method

2.1. Participants and procedures

Participants were 222 undergraduates enrolled at a Southern, urban university (see Table 1 for descriptive statistics). The sample's racial distribution was roughly consistent with that of the university student body and the local population, according to census data (U.S. Census Bureau, 2012). Participation was restricted to those who self-identified as proficient in the English language. Participants were recruited through an online research management system for students enrolled in psychology courses. They received detailed information about this IRB-approved study and about the voluntary nature of their participation. All data were collected using the Survey Monkey online questionnaire tool (SurveyMonkey.com, LLC, Palo Alto, CA).

2.2. Measures

2.2.1. Demographics

Participants were asked to report their age, sex, and racial identity.

2.2.2. Physical activity level

The Global Physical Activity Questionnaire Version 2 (GPAQ-2; World Health Organization [WHO], 2001) was used to assess physical activity in a typical week across three contexts (i.e., activity at work, travel to and from places, recreational activities). The GPAQ-2 includes 16 self-report items that measure time spent engaged in 1) vigorous- and moderate-intensity activity at work and during recreation, 2) walking and/or biking for transportation for at least 10 min continuously, and 3) sedentary behavior. The GPAQ-2 has been shown to be valid and reliable, as well as appropriate for use in varied cultural contexts (WHO, 2012). Recent research shows acceptable evidence of test-retest reliability, concurrent validity, criterion validity consistent with other measures of PA, and suggest that the GPAQ version 2 is suitable as a measure for monitoring PA (Bull, Maslin, & Armstrong, 2009; Herrmann, Heumann, Der Ananian, & Ainsworth, 2013).

Recreational Metabolic Equivalents (METs) per week served as the measure of PA in an effort to closely approximate the PA-level variables used elsewhere in the exercise literature, especially the study we sought to replicate and extend (i.e., Smits et al., 2011). Recreational-based PA (or leisure), as opposed to occupational and/or transportation-based PA, has been shown to relate significantly to mental well-being, which is the overarching outcome variable of interest in the current study (Cerin, 2010). Recreational PA levels were calculated based on self-reported time spent engaged in vigorous- and moderate-intensity recreational PA. Using the procedures described in the Ainsworth et al. (2000) Compendium for PA, total time spent at each level was converted to METs, which reflect intensity of physical activity and energy expenditure.

2.2.3. Self-perceived resilience

The Connor Davidson Resilience Scale 10 (CD-RISC 10; Campbell-Sills & Stein, 2007) was used to assess self-perceived resilience in day-to-day life. The CD-RISC 10 is a unidimensional 10-item self-report measure designed to quantify resilience, conceptualized as successful stress-coping ability. This abbreviated measure was developed on the basis of a factor analysis of the original 25-item CD-RISC (Burns & Anstey, 2010; Campbell-Sills & Stein, 2007). The measure yields an overall resilience score (0–40), with higher scores reflecting greater perceived resilience. The CD-RISC 10 has been shown to have sound psychometric properties including reliability and validity across demographically diverse samples (Campbell-Sills & Stein, 2007; Coates, Phares, & Dedrick, 2013).

2.2.4. Trait anxiety

The State-Trait Anxiety Inventory- Form X (STAI-T; Spielberger, Gorsuch, & Lushene, 1970) was used to assess trait anxiety. The STAI-T is a 20-item self-report measure used to assess stable individual differences in anxiety proneness and scores reflect a general tendency to respond to the environment with anxiety (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). Previous studies have used the measure to operationally define vulnerability to anxious states (Indovina, Robbins, Nunez-Elizalde, Dunn, & Bishop, 2011). Item responses are summed to yield a total score ranging from 20 to 80, with higher scores indicating greater trait anxiety. The measure's author reported good test-retest reliability and inter-item consistency (Spielberger et al., 1970), which has since been replicated (Rule & Traver, 1983). The STAI-T has demonstrated good convergent and concurrent validity (Tilton, 2008), as well as convergent validity and strong psychometric properties across ethnic groups and gender (Novy, Nelson, Goodwin, & Rowzee, 1993).

2.3. Data analysis and statistics

2.3.1. Preliminary analyses

Prior to conducting analyses, data were inspected for errors, excessive missing cases, outliers, and normality of distribution in accordance with published approaches (Bulmer, 1979; Hoaglin & Iglewicz, 1987; Tabachnick & Fidell, 2007; WHO, 2001). Where needed, data were transformed to better approximate normality. The distribution of GPAQ PA was positively skewed ($Skewness_{GPAQ} = 1.63$, $SE = .21$); therefore, these data were square root transformed ($Skewness_{GPAQ\_transformed} = .44$, $SE = .21$). All other variables met assumptions of regression analysis.

Missing data resulted primarily from skipped responses on online questionnaires. Participants with complete data were older ($M = 21.95$, $SD = 6.32$ vs. $M = 20.2$, $SD = 3.35$), $t\ (231) = -2.52$, $p = .013$, less anxious ($M = 41.92$, $SD = 10.78$ vs. $M = 47.73$, $SD = 10.75$), $t\ (201) = 3.68$, $p < .001$, and perceived themselves as more resilient ($M = 68.10$, $SD = 14.61$ vs. $M = 62.68$, $SD = 18.54$), $t\ (214) = -2.76$, $p = .006$) than those who skipped items. We used the SPSS 18.0 multiple imputation procedure with fully conditional specification to estimate missing data on the STAI-T and CDRISC 10, creating 5 imputed datasets, each with 222 cases.

2.3.2. Hypothesis testing

To test whether trait anxiety moderated the association between PA and self-perceived resilience, we conducted a multiple hierarchical linear regression analysis. First, all predictors were either dummy coded (gender, race) or converted to z-scores, and then centered to facilitate interpretation of the findings and to

reduce collinearity. At Step 1 of the regression model, covariates–Gender, Age, Race–were regressed onto the outcome variable (total CD-RISC score, which indexed self-perceived resilience). Demographic variables were included as covariates based on results of preliminary analyses indicating significant associations with study variables. At Step two, mean-centered trait anxiety and square root transformed and centered PA METs were added to the model. Lastly, at Step three, the trait anxiety × PA interaction term was added to the model. To obtain this variable, the centered trait anxiety total was multiplied by the transformed and centered METs of physical activity.

We probed the interaction using procedures described in Aiken and West (1991) to elucidate how the relation between PA and self-perceived resilience differed among individuals with varying levels of trait anxiety. We first calculated new moderator variables to represent high and low trait anxiety scores by re-centering at 1 SD (10.95) below and above the mean, respectively. The mean-centered trait anxiety variable from the initial regression was used to represent moderate trait anxiety. The high and low trait anxiety variables were multiplied by the transformed and centered PA variable to create new interaction terms. Then, we conducted additional simple regression analyses for each level of the moderator (high and low anxiety) to determine the slope and significance of associations between PA and self-perceived resilience at each level.

3. Results

Table 1 describes sample characteristics in counts and percentages for categorical variables and means and standard deviations (SD) for continuous variables. Correlations among study variables are also presented in Table 1. While participants endorsed resilience levels comparable to those observed in other non-clinical adult samples (e.g., Campbell-Sills & Stein, 2007); reported trait anxiety levels were above what has been reported as an estimated clinical cut-off (Knight, Waal, Manning, & Spears, 1983). Of participants, 29.7% (n = 66) self-reported not engaging in any recreational PA; among the 70.3% of participants who reported engaging in recreational PA, 83.3% reported levels that exceeded the U.S. Department of Health and Human Services (USDHHS) recommended minimum (600 METs/week; USDHHS, 2008).

As shown in Table 2, hierarchical linear regression analysis results revealed that after controlling for age, gender, and race, trait anxiety significantly moderated the association between PA and self-perceived resilience. In the regression model all steps yielded statistically significant omnibus effects. There was a main effect of trait anxiety on self-perceived resilience (B = −.455, SE_B = .038, t [215] = −11.837, p < .001). There was also a nonsignificant trend towards a main effect of recreational PA (B = .024, SE_B = .013, t [215] = 1.781, p = .075). Consistent with the core hypothesis, the addition of the interaction term at the third step predicted significantly more variance in self-perceived resilience than did the second step (R^2 *change* = .02, p = .003), yielding a final model that accounted for 43% of the variance in the outcome variable. Notably, the interaction between PA and trait anxiety, while significant, accounted for only a small portion of the variance in resilience (B = .004, SE_B = .001, t [215] = 2.94, p = .003).

Probing the interaction yielded evidence that association between PA and self-perceived resilience varied among individuals who reported different levels of trait anxiety (See Fig. 2). As hypothesized, among individuals with high trait anxiety, PA related significantly and positively to self-perceived resilience (B_{High} = .063, t [215] = 3.304, p = .001). There was also a non-significant trend for the association between PA and self-resilience among participants with moderate trait anxiety (B_{mod} = .024, t [215] = 1.781, p = .075). We did not detect a significant association between PA and self-perceived resilience among participants with low trait anxiety (B_{Low} = −.015, t [215] = −.796, p = .426).

Table 2
Summary of hierarchical regression analyses predicting self-perceived resilience scores.

Predictor	CD-RISC					
	Model 1		Model 2		Model 3	
	β	SE_B	β	SE_B	β	SE_B
Step 1						
Gender	−.03	1.25	.08	1.01	.08	.99
Age	.13*	.10	.04	.08	.03	.08
Race	−.19**	.64	−.11*	.51	−.12*	.50
Step 2						
GPAQ			.09	.01	.09	.01
STAI-T			−.62**	.04	.63**	.04
Step 3						
STAI-T × GPAQ					.15**	.001
Adjusted R^2	.04**		.41**		.43**	

Note: Standardized regression weights (β) and standard error of B (SE_B) were averaged over 5 imputation datasets. CD-RISC = Connor Davidson Resilience Scale; STAIT = State Trait Anxiety Inventory- Trait Form X; GPAQ = Global Physical Activity Questionnaire- Recreational Activity.
*p < .05; **p = <.01.

4. Discussion

The present study was designed to evaluate whether individual differences in trait anxiety moderate the association between recreational PA and self-perceived resilience. Our results were consistent with this hypothesis. Specifically, a positive, statistically significant association between PA and self-perceived resilience was present among individuals who reported high trait anxiety, but not among those who reported low or moderate trait anxiety levels. It is unclear whether our findings are consistent with a dose-response relationship, in which the association between PA and self-perceived resilience is progressively stronger as trait anxiety increases, given that the association was non-significant in both the

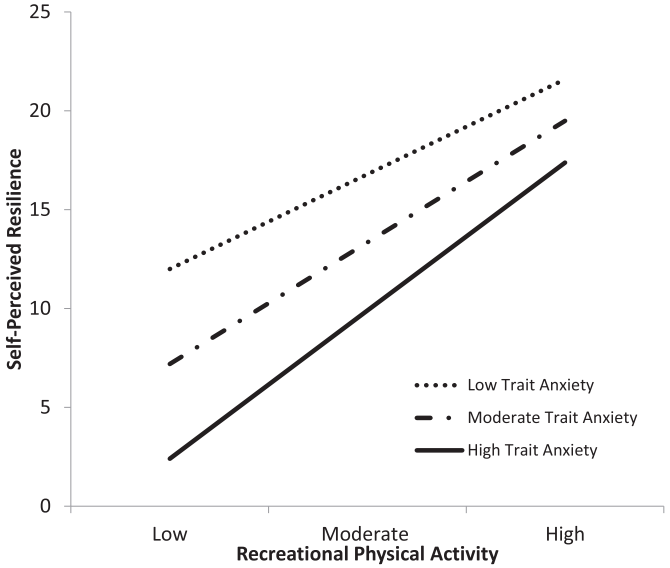

Fig. 2. Associations between recreational physical activity and self-perceived resilience at varying levels of trait anxiety.

low and moderate anxiety groups. It remains possible, however, that PA's protective effects, conveyed through stress resilience, may be better conferred, or more readily detected, as risk for mental health problems increases due to higher trait anxiety. This question warrants further research.

Of note, although the interaction term accounted for a significant portion of the variance in self-perceived resilience, this portion was very small. Individual differences that may influence the association between PA and resilience are diverse and heterogenous (e.g., neurobiological and psychological factors). Therefore, it is to be expected that the interaction between individual differences in trait anxiety and PA, which is only one of these many viable contributing factors, would make at most a modest contribution to variance in resilience.

Results indicating that PA may protect mental health by enhancing one's response to stress are generally consistent with existing empirical findings. Previous research on non-human species suggests strongly that PA leads to a better-regulated stress response, as indexed by both physiology and behavior, which in turn may mediate protective and positive effects of PA on mental health (Dishman, 1997; Greenwood & Fleshner, 2011). Likewise, human studies show that PA is associated with a better-regulated physiological response to psychological laboratory stressors (e.g., Klaperski et al., 2013; Spalding, Lyon, Steel, & Hatfield, 2004). The present data are also in line with the Cross Stressor Adaptation (CSA) Hypothesis, which provides a theoretical framework for understanding the protective effects of PA (Salmon, 2001; Sothmann, 2006). The theory posits that the stress of regular PA induces biological changes that augment the body's response to PA and other physiological stressors. This adaptation then generalizes to other physiological and psychological stress, improving resilience to a wide range of stressors.

What is less clear, given mixed findings in the literature, is *how* PA's purported regulation of the physiological stress response impacts an individual's psychological response to stress. As Campbell and Ehlert (2012) note, although physiological and psychological stress responses may be related; they could also be dissociated, such that perception is discordant with physiology. The current findings contribute to this literature by suggesting that PA relates not only to physiological and possibly psychological stress resilience in response to laboratory stressors, but that it also relates to less tangible mental health outcomes, such as individuals' perceptions of how they handle stress in daily life.

The finding that trait anxiety moderates the association between PA and self-perceived resilience converges with earlier findings of Smits and colleagues and carries them a step further. The same protective effect of PA appears to be evident when the risk for developing mental health problems is operationally defined as trait anxiety rather than as anxiety sensitivity. Given that trait anxiety is related to, but distinct from, anxiety sensitivity (Reiss, 1997), the present findings suggest that PA's protective effects may manifest in a greater number of at-risk individuals than Smits et al.'s results indicated. Current findings further build on Smits and colleagues' work by showing that the pattern holds, regardless of whether PA's protective effect is defined in terms of self-reported anxiety in response to a physiological stressor (CO_2 challenge), or in terms of self-perceived resilience to daily stress.

Although the present study was designed to replicate Smits and colleagues' (2011) work and yielded some results consistent with theirs, there were inconsistencies between the two. For instance, in the current study, associations between PA and resilience emerged across all participants, including those who reported high, low, or no PA. Smits et al., in contrast, only detected such associations among those who reported high levels of PA. One possible factor contributing to this discrepancy stems from the different approaches that the two studies took to defining and measuring resilience. The measures may be differentially sensitive to PA quantity, such that resilience defined as anxious perceptions of a physiological response in the moment relates only to higher levels of PA, but resilience defined according to general retrospective self-reports about behavior across multiple contexts is positively associated with even minimal PA.

This appears plausible in light of the effects that PA level may have on the physiological stress response and its correlates. For example, vigorous PA has been shown to reduce anxiety sensitivity more quickly and effectively than less vigorous PA (Broman-Fulks, Berman, Rabian, & Webster, 2004). The authors suggest that because vigorous PA is associated with a greater increase in heart rate and breathing, it provides a context in which individuals with higher anxiety sensitivity can become less afraid of these physiological sensations and can alter their anxious responses accordingly. Thus, in Smits et al.'s study, only the most active individuals may have experienced enough exposure to anxiety-related physiological sensations to respond to them in a resilient way. Further, intense and regular PA is associated with cardiac sympathetic changes (e.g., Cox, 1991); therefore, the more active individuals in Smits et al.'s study may have evaluated their physiological responses to stress in a more resilient way because their physiological responses were qualitatively different from those of individuals who exercised less.

In contrast, the association between PA and self-perceived resilience across all levels of PA observed in the current study may be partly driven by psychological mechanisms, such as cognitive and emotional experiences during PA, that are not as dependent on PA frequency, duration, and intensity. Such psychological mechanisms could include social engagement, self-esteem, and self-efficacy, the belief in one's capabilities, all of which have been shown to mediate associations between PA and mental health (see review: Gaudlitz, von Lindenberger, Zschucke, & Strohle, 2013). These mechanisms are less reliant on level of PA because they either simply coincide with PA, or are dependent on perceived effort or accomplishment, rather than on engagement in a specific level of PA. Further, a factor analysis of the CD-RISC yielded a factor that appears to reflect persistence and self-efficacy (Connor & Davidson, 2003). Thus, it is possible that the link between PA and self-perceived resilience may reflect PA-associated increases in feelings of self-efficacy. Overall, the inconsistency in findings may reflect the complex relationships between PA and mental health, where many mechanisms likely interact to lead to differential effects on stress responses and mental health.

The present results along with prior research, raise the possibility that individuals with elevated risk for developing mental health problems as a function of trait anxiety could preferentially benefit from the protective effects of PA. There are a couple of potential explanations for the findings. First, according to the law of initial values (Wilder, 1962), individuals who report high trait anxiety have more room for improvement in broad psychological functioning and resilience in response to PA than do low trait anxiety peers simply due to their initially elevated starting point. Second, PA-induced changes in the stress response, documented empirically and theoretically, may be more readily evident among individuals with high trait anxiety, at least in part because they may not be predisposed towards an adaptive response to stress (Charney, 2003; Duncko et al., 2006; McEwen & Lasley, 2002) and, thus, may preferentially benefit from PA-associated stress-response changes.

While the current findings suggest that protective effects of PA may be specific to individuals at risk for developing mental health problems, findings do not necessarily preclude the possibility that PA provides mental health benefits for those who are not at risk.

Those with moderate and low trait anxiety may experience other PA-evoked mental health benefits. There is evidence, for example, that PA improves aspects of mental health that are not typically captured with measures of self-perceived resilience, such as emotional well-being and mood (e.g., Galper, Trivedi, Barlow, Dunn, & Kampert, 2006). Thus, improvements in these alternative aspects of mental health may be mediated by mechanisms that are not directly associated with a resilient response to stress, but have been linked to positive mental health outcomes.

The current findings must be interpreted in light of several limitations. First, the current study assessed all variables concurrently; thus, we cannot identify causal links between PA and resilience. Second, it is unclear if our results generalize to individuals with demographic features distinct from our sample's; the undergraduates in this study represented a convenience sample and replication in large randomly selected samples is needed. Further, although the association between PA and resilience was specific to participants with high trait anxiety, and average trait anxiety in this undergraduate sample as a whole exceeded standard clinical thresholds (Knight, Waal-Manning, & Spears, 1983), it is not clear whether the findings translate to individuals with anxiety disorders. Third, we gathered data via web-based self-report questionnaires, where data accuracy cannot be verified (Albrecht & Jones, 2009), and responses can be influenced by factors that may undermine the validity of measures across participants, such as social desirability (Tanaka-Matsumi & Kameoka; 1986). Self-report concerns are particularly salient when measuring PA, given that retrospective PA questionnaires, like the GPAQ, may less accurately assess absolute time spent at varied exercise intensity levels than do objective measures (e.g., Adams et al., 2005; Sitthipornvorakul, Janwantanakul, & van der Beek, 2014; Slootmaker, Schuit, Chinapaw, Seidell, & Van Mechelen, 2009).

Despite these limitations, the present findings contribute support to arguments that those at risk for developing stress-related mental health problems as a function of factors such as trait anxiety may benefit from PA. These findings are of particular importance, given evidence that individuals with mental illnesses are less likely than healthy peers to engage in PA (Daumit et al., 2005). There thus may be value in implementing prevention approaches that promote regular engagement in PA before mental illness emerges, especially in those at risk. While prevention programs focused on cognitive-behavioral and skill-based education have been shown to be effective (e.g., Rose, Miller, & Martinez, 2009; Seligman, Schulman, DeRubeis, & Hollon, 1999), they can also be costly and inaccessible to some populations. In contrast, PA is universally available, and is increasingly recognized as a practice that reduces risk for stress-related disorders (Gerber & Pühse, 2009; Martinsen, 2008). Ultimately, the findings can be interpreted as lending support to efforts to incorporate PA into mental illness prevention recommendations and programs for such individuals, perhaps as a component of broad, community-targeted efforts to improve multiple aspects of functioning via PA (e.g., CDC, 2011; WHO, 2004).

Given these implications, the present study provides data that may inform a variety of lines of future work. Little is known about what a PA program aimed at improving mental health, especially psychological resilience, should look like (frequency, intensity, duration, timing, etc.) and who would benefit the most from such a program. Further, little is known regarding ways in which individual demographic and psychological differences may increase or decrease the likelihood that PA will yield mental health benefits. To address these questions, longitudinal and/or randomly controlled trial (RCT) studies that investigate whether regular PA enhances resilience and reduces risk for mental health problems in varied demographic and clinical groups are needed. In addition, continued research to clarify paths via which PA confers stress resilience and improves mental health is warranted (Cerin, 2010). Although the current findings support arguments that one mechanism linking PA and resilience comprises adaptations and constraint of the stress response, they are insufficient to establish causality. Additionally, given the complexity of associations between PA and mental health, which stem from multiple psychological and biological mechanisms, investigating alternative paths to improved mental health is a valuable area for future research.

Current findings indicate that PA is positively associated with self-perceived dispositional resilience among those with high trait anxiety. As such, for those at risk for mental health problems, PA may facilitate resilience and reduce the likelihood of developing stress-related symptoms or disorders. Future work clarifying mechanisms of PA's influence on stress resilience in high-risk populations will advance efforts to promote mental health.

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