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The Different Roles of Perceived Stress in the Association Between Older Adults' Physical Activity and Physical Health

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Objective: This 4-year longitudinal study examined the different roles of perceived stress in the association between older adults' physical activities and physical health. We hypothesized that physical activities would exert beneficial effects on physical health by preventing chronically high levels of perceived stress. ***Methods:*** We assessed baseline levels of physical activities and repeated measures of perceived stress and physical symptoms in 3 waves of data from a sample of 157 older adults. ***Results:*** Among participants with high (but not low) baseline levels of perceived stress, physical activity predicted a 2-year reduction of perceived stress and a 4-year prevention of physical health symptoms. Moreover, the interaction effect on 4-year changes in physical symptoms was mediated by 2-year changes in perceived stress. ***Conclusions:*** Physical health benefits of physical activity are particularly pronounced among older adults who perceive high levels of stress, and this effect is mediated by a prevention of chronically high perceptions of stress.

Keywords: physical health, perceived stress, physical activities, older adulthood

Research suggests that perceptions of stress play an important role in the link between physical activity and physical health. First, physical activity has been shown to reduce perceptions of stress (Salmon, 2001). Second, physical activity and low stress are generally associated with better physical health (Cohen, Janicki-Deverts, & Miller, 2007; Haskell et al., 2007). Third, the health benefits of activity are particularly evident among individuals who experience high, as compared with low, levels of stress (Brown & Siegel, 1988; Carmack, Boudreaux, Amaral-Melendez, Brantley, & Moor, 1999). These findings suggest that physical activity could benefit health by ameliorating chronically high levels of stress, but this mechanism has not yet been demonstrated in longitudinal research. Here, we tested this possibility in three waves of data from a 4-year longitudinal study of community-dwelling older adults. We expected that engaging in physical activity would ameliorate stress and thereby mediate good physical health in persons who perceive high levels of stress. By contrast, we did not expect these effects to be apparent among persons low in stress, as these individual are generally at a lower risk of developing health problems and health benefits of physical activity may be less likely to operate through a reduction of low stress levels.

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Physical Activities, Perceived Stress, and Physical Health

The maintenance of a physically active lifestyle is an important contributor to older adults' physical health (Centers for Disease Control and Prevention, 2010; Haskell et al., 2007; Pate et al., 1995). Some of the benefits of physical activity are attributable to modulation of biological processes involved in disease (e.g., increased cardiorespiratory fitness, decreased blood pressure, more musculoskeletal strength; Dunn et al., 1997; Faulkner, Green, & White, 1994), but there is also evidence that psychological mechanisms, such as the perception of stress, may explain beneficial health effects of physical activity. Perceived stress represents appraisals of person–environment interactions that can influence emotional and biological processes (Lazarus & Folkman, 1984). In addition, perceived stress is associated with a number of adverse physical health outcomes, likely in a causal fashion (Cohen, 1996; Cohen, Kamarck, & Mermelstein, 1983; Cohen, Tyrrell, & Smith, 1991).

In support of this process, research suggests that high levels of perceived stress contribute to negative affect (e.g., feelings of anxiety and depression) and biological and behavioral processes (e.g., dysregulated cortisol rhythms or nonadherence to medical regimes) that may heighten vulnerability to various physical health problems (Cohen et al., 2007; Cohen, Kessler, & Underwood, 1997; McEwen, 1998; Miller, Chen, & Cole, 2009; Miller, Chen, & Zhou, 2007). Moreover, physical activity is generally associated with decreased levels of perceived stress (King, Taylor, & Haskell, 1993; Norris, Carroll, & Cochrane, 1990; Salmon, 2001) and alters some of the behavioral and biological processes through which perceived stress can affect physical health outcomes (e.g., less smoking, better nutrition practice, less cortisol output or cardiovascular reactivity; Boutelle, Murray, Jeffery, Hennrikus, & Lando, 2000; Crews & Landers, 1987; Fleshner, Kennedy, Johnson, Day, & Greenwood, 2009; Rimmele et al., 2009; Wankel & Sefton, 1994).

These findings suggest that physical activity has physical health benefits, which may operate partially through amelioration of perceived stress. However, several longitudinal studies have shown that physical activity does not always explain large portions of variance in physical health outcomes (Guszkowska, 2005; Mead et al., 2007). Such a lack of stronger associations could be due to the possibility that physical activity is not equally adaptive among different groups of individuals. For example, physical activity may exert its adaptive effects on physical health, particularly among individuals who are vulnerable to developing a disease if it attenuates or counteracts some of the underlying risk factors or pathogenic mechanisms. By contrast, the health effects of physical activities may be less pronounced among individuals who are at a lower risk of developing physical disease. A corollary of this argument is that perceived stress itself could not only mediate, but also moderate, the link between physical activity and physical health (Brown, 1991; Brown & Siegel, 1988; Carmack et al., 1999). In this scenario, physical activity may be particularly beneficial for health among individuals who perceive high levels of stress because it can ameliorate their maladaptive stress levels and some of its emotional, behavioral, and biological consequences.

We note that this process would be consistent with research indicating that people can be stressed over different periods of time, and that the chronic rather than the temporary perception of stress is detrimental to a person's physical health. Such consequences of chronic stress may be due to its harmful long-term effects on emotional, physiological, and behavioral responses that influence susceptibility to, and course of, disease (Kiecolt-Glaser, Glaser, Gravenstein, Malarkey, & Sheridan, 1996; Kiecolt-Glaser et al., 2003; Miller et al., 2008, 2009; Miller, Cohen, & Ritchey, 2002; Schulz, Kirschbaum, Pruessner, & Hellhammer, 1998). Transient perceptions of stress, by contrast, should be less problematic for a person's physical health as they may not give rise to sustained patterns of biological dysregulation or maladaptive health behaviors.

Further support for the proposed process stems from research documenting that physical activity is associated with better physical health particularly among individuals who experience many stressful life events, and that this association can be explained by psychological distress (Brown, 1991; Brown & Siegel, 1988; Carmack et al., 1999). In addition, longitudinal research has shown that the deleterious effects of widowhood on functional health declines were more pronounced among community-dwelling older adults who engaged in low, as compared with high, levels of physical activities (Unger, Johnson, & Marks, 1997). Finally, experimental intervention research suggests that engaging obese women or cancer survivors in exercise programs can decrease their experience of stress (Cramer, Nieman, & Lee, 1991; Hughes, Leung, & Naus, 2008; for a review, see Salmon, 2001).

These studies demonstrate that health benefits of physical activity can occur particularly among individuals who perceive high levels of stress, and that physical activity can reduce stress levels in vulnerable populations that confront problematic life circumstances. Nonetheless, the present literature did not document the complete process that links physical activity, perceived stress, and physical health outcomes over time. In particular, it has not been shown that the beneficial effects of physical activity on the prevention of chronically high levels of stress can mediate subsequent levels of physical health. From our theoretical perspective, however, such associations are likely to occur, and demonstrating this process in longitudinal research may contribute to our understanding of the adaptive health effects of physical activity.

The Present Research

This research examined whether physical activity would have differential health benefits in higher versus lower stress individuals. We expected the health benefits to be most apparent in the former group, in whom physical activity would reduce high stress levels over time. By contrast, we did not expect these benefits of physical activity to be apparent in the low-stress individuals. To start examining this possibility, we analyzed three waves of data from a 4-year longitudinal study of older adults. Our analysis focused on predicting physical health symptoms (e.g., chest pain, joint pain, or difficulty breathing) because such symptoms can be signs of a variety of underlying or developing physical diseases and have been associated with distress and biological markers of stress in previous research (Wrosch, Miller, Lupien, & Pruessner, 2008; Wrosch, Schulz, & Heckhausen, 2002; Wrosch, Schulz, Miller, Lupien, & Dunne, 2007). More specifically, we examined whether the interaction between baseline levels of physical activity and perceived stress would predict changes in physical symptoms over time. In addition, we expected that changes in perceived stress would mediate this interaction effect.

Method

Participants

This study is based on a sample of community-dwelling older adults who took part in the longitudinal Montreal Aging and Health Study (MAHS; Wrosch et al., 2007). Participants were recruited through newspaper advertisement. The only inclusion criterion was that participants had to be older than 60 years because we were interested in examining a normative sample of older adults. In 2004, we conducted the first wave of the MAHS by assessing a heterogeneous sample of 215 older adults from the Montreal area. The 2-year follow-up included 184 participants, and 164 subjects participated in the 4-year follow-up. Reasons for nonparticipation were being deceased ($n = 13$), having problems that prevented participation ($n = 17$), refusing further participation ($n = 8$), and being unable to locate participants ($n = 13$). Seven additional participants were excluded from the analyses because they did not participate in the 2-year follow-up. The final sample included 157 participants who were on average 72 years old ($SD =$ 5.55) and 48% of the sample was male. Study attrition over 4 years was not significantly associated with baseline measures of the study variables, except for age. Older participants were more likely to discontinue their study participation, $t(213) = -2.30$, $p < .05$.

Materials

The main study variables included repeated measures of physical health symptoms and perceived stress, as well as baseline measures of physical activities. In addition, the study included a number of covariates associated with health-relevant sociodemographic characteristics (i.e., age, sex, education) and baseline levels of chronic health problems (see Tables 1 and 2 for zero-order correlations, means, standard deviations, and frequencies of main study variables).

Physical health symptoms were measured at baseline, 2-year follow-up, and 4-year follow-up by administering a symptom checklist that has been validated in previous research with older adults (Wrosch et al., 2002). Participants reported at bedtime on three typical days whether they had experienced each of 12 physical health symptoms during the day (e.g., chest pain, joint pain, or shortness of breath; PRIME MD: Spitzer et al., 1994). Daily measures of physical symptoms were significantly correlated with each other (rs_{T1} = .65 to .75, $ps_{T1} < .01$; rs_{T2} = .61 to .77, $ps_{T2} < .01$; rs_{T3} = .44 to .67, $ps_{T3} < .01$), and we obtained indicators of physical health symptoms for baseline, 2-year follow-up, and 4-year follow up by counting the total number of symptoms experienced across all 3 days (see Table 2). Levels of physical symptoms showed a linear increase across waves, $F(1, 156) = 7.71$, $p < .01$.

Perceived stress was measured at baseline, 2-year follow-up, and 4-year follow-up by administering the 10-item version of the Perceived Stress Scale (Cohen et al., 1983). Respondents were asked to rate how frequently they experienced 10 different situations over the past month (e.g., "How often have you been upset because of something that happened unexpectedly?" or "How often have you felt difficulties were piling up so high that you could not overcome them?") by using a 5-point Likert-type scale ranging from 1 (*never*) to 5 (*very often*). Indicators of perceived stress were obtained by averaging the ratings of the 10 items separately for baseline, 2-year follow-up, and 4-year follow-up ($\alpha s > .87$). Levels of perceived stress did not significantly change across waves, $F(1, 156) = 1.05$, $p > .05$.

Participants' engagement in physical activity was assessed at baseline by administering an open-response format questionnaire used in previous research (Miller, Cohen, & Herbert, 1999; Paffenbarger, Blair, Lee, & Hyde, 1993). Participants were asked whether they engage in any regular activity (e.g., walking, jogging, bicycling, etc.) long enough to work up a sweat. In addition, they reported how many days per week and for how long each time they engage in physical activities. This measure has been validated by previous research, showing that it predicts objective markers of fitness, such as oxygen uptake during pedal ergometry (Siconolfi, Lasater, Snow, & Carleton, 1985). To obtain a measure of participants' weekly physical activity, we multiplied the number of days participants were physically active by the hours participants usually engaged each time in physical activities. On average, participants engaged approximately 2 hr/week in physical activities (see Table 2). Note that based on the physical activity guidelines from

Table 2
Means, Standard Deviations, and Frequencies of Main Study Variables (N = 157)

Construct	
Mean (*SD*) physical health symptoms	
Baseline	2.59 (3.20)
2 years	2.87 (3.50)
4 years	3.42 (4.04)
Mean (*SD*) perceived stress	
Baseline	2.42 (0.65)
2 years	2.42 (0.65)
4 years	2.47 (0.73)
Mean (*SD*) hours of weekly physical activity (baseline)	2.10 (3.25)
Mean (*SD*) number of chronic health problems (baseline)	0.80 (0.81)
Arthritis (%)	29.90
Diabetes (%)	14.10
Cancer (%)	3.20
Lung or other respiratory disease (%)	10.80
Heart condition (%)	17.20
Difficulty bathing (%)	2.50
Difficulty managing finances (%)	2.50
Mean (*SD*) age (years)	71.72 (5.55)
Male (%)	48.40
Mean (*SD*) education (baseline)[a]	2.09 (1.07)
None (%)	4.00
High school (%)	31.30
Trade (%)	28.70
Bachelor's (%)	24.00
Master's or doctorate (%)	12.00

Note. Mean (*SD*) are presented for continuous variables.
[a] Education was measured by asking participants to report their highest educational degree completed (0 = none, 1 = high school, 2 = trade, 3 = undergraduate degree, 4 = graduate degree).

Table 1
Zero-Order Correlations Between Main Constructs

Variable	1	2	3	4	5	6	7	8	9	10
1. Physical health symptoms (baseline)										
2. Physical health symptoms (2-year follow up)	.58**									
3. Physical health symptoms (4-year follow up)	.48**	.57**								
4. Perceived stress (baseline)	.34**	.28**	.26**							
5. Perceived stress (2-year follow up)	.25**	.29**	.31**	.63**						
6. Perceived stress (4-year follow up)	.33**	.31**	.30**	.68**	.76**					
7. Physical activities (baseline)	−.08	−.09	−.17*	−.11	−.07	−.17*				
8. Age	−.08	−.07	−.10	−.11	.03	−.01	−.12			
9. Sex[a]	.09	.03	.10	.11	.12	.16*	−.09	.06		
10. Education	−.20*	−.16*	−.07	−.21**	−.14	−.21**	.09	−.20*	−.14	
11. Chronic health problems	.24**	.31**	.21**	.08	.08	.12	−.08	−.06	−.03	−.05

[a] Higher values represent female participants.
* $p < .05$. ** $p < .01$.

the Centers for Disease Control and Prevention (2010), 69.4% of our sample can be classified as insufficiently active (fewer than 150 min/week of total activity) and 30.6% as active (at least 150 min/week of total activity).

To reduce the possibility of spurious associations, this study incorporated a number of covariates that were associated in previous research with activity engagement, perceived stress, or physical health problems. These variables included participants' age, sex, education, and chronic health problems (Denton, Prus, & Walters, 2004; Lee, Lindquist, Segal, & Covinsky, 2006). Education was measured by asking participants to report their highest educational degree completed (0 = none, 1 = high school, 2 = trade, 3 = undergraduate degree, 4 = graduate degree). A measure of chronic health problems was derived based on research identifying conditions associated with premature mortality in older adults (Lee et al., 2006). It included six conditions: diabetes, cancer, lung or other respiratory disease, heart condition, difficulty bathing, and difficulty managing finances (Lee et al., 2006). In addition, we incorporated the presence of arthritis into our measure, given that this disease is associated with both perceived stress and daily symptoms (Wrosch & Schulz, 2008; Thomason, Brantley, Jones, Dyer, & Morris, 1992).

Results

Data Analyses

The hypotheses were tested by conducting two sets of analyses. In the first set, we examined whether baseline levels of perceived stress would moderate the effect of baseline levels of physical activities on changes in older adults' physical health symptoms over time. To this end, we conducted two separate regression analyses predicting 2-year and 4-year levels in physical health symptoms by baseline levels of physical symptoms, physical activities, and perceived stress (Step 1) and the interaction between physical activities and perceived stress (Step 2). All analyses controlled for a number of covariates (i.e., age, sex, education, and chronic health problems), and predictor variables were standardized prior to conducting the analyses.

In the second set, we investigated whether the interaction between baseline levels of physical activities and perceived stress in predicting changes in physical health symptoms would be mediated by a reduction of perceived stress. To test this hypothesis, we conducted bootstrap analyses (Preacher & Hayes, 2008), which examined whether 2-year changes in perceived stress exert an indirect effect on the interaction effect between physical activity and perceived stress in predicting changes in physical health symptoms. The analysis was based on 5,000 bootstraps, and the indirect effect was evaluated as significant if the bias-corrected 95% confidence interval did not cross zero (see Preacher & Hayes, 2008).

Perceived Stress as a Moderator

The results of the first set of analyses showed that baseline levels of physical symptoms were significantly associated with 2-year levels, $F(1, 149) = 48.32$, $B = .50$, $SE = .07$, $R^2 = .20$, $p < .01$, and 4-year levels of physical symptoms, $F(1, 149) = 29.16$, $B = .42$, $SE = .08$, $R^2 = .14$, $p < .01$. Moreover, the first step of the analyses indicated that of the covariates, only chronic health symptoms significantly predicted 2-year increases in physical symptoms, $F(1, 149) = 7.19$, $B = .18$, $SE = .07$, $R^2 = .03$, $p < .01$. The other covariates and the main effects of physical activity and perceived stress were unrelated to 2-year or 4-year changes in physical symptoms, $Fs(1, 149) < 3.00$, $ps > .05$. However, the second step of the analyses confirmed a significant interaction between physical activities and perceived stress in predicting 4-year changes in physical symptoms, $F(1, 148) = 4.20$, $B = -.16$, $SE = .08$, $R^2 = .02$, $p < .05$. We note that the interaction between physical activity and perceived stress remained significant if we controlled in additional analyses for 2-year or 4-year changes in physical activity, and that this interaction was not found in the analysis of 2-year changes in physical symptoms, $F(1, 148) = 0.94$, $p > .05$. Furthermore, neither the quadratic main effect for physical activity nor the quadratic interaction effect between physical activity and perceived stress predicted 4-year changes in physical symptoms.

Figure 1 illustrates the significant interaction effect. We plotted the association between hours of weekly physical activity (0–5 hours, where 5.35 hr represented 1 standard deviation above the sample mean) and 4-year changes in physical health symptoms for participants who perceived high (+1 *SD*) and low (−1 *SD*) baseline levels of stress (Aiken & West, 1991). The pattern of results indicated that, above and beyond baseline levels of physical health symptoms, the highest symptom levels after 4 years were found among participants who reported high baseline levels of perceived stress and did not engage in physical activities. A calculation of the simple slopes confirmed this interpretation by demonstrating that physical activity was significantly associated with fewer increases in physical symptoms over time among participants who perceived high baseline levels of stress, $B = -.34$, $SE = .16$, $p < .01$, but not among their counterparts who perceived low levels of stress, $B = -.04$, $SE = .10$, $p > .05$.

Perceived Stress as a Mediator

To examine whether 2-year changes in perceived stress would mediate the observed interaction effect on 4-year changes in phys-

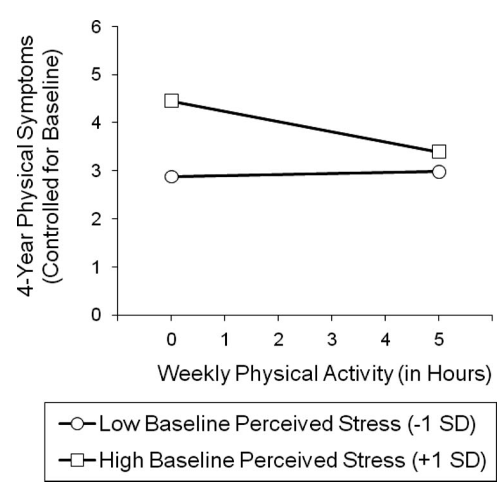

Figure 1. Associations between baseline levels of physical activity and 4-year changes in physical health symptoms, separately for participants who experienced high and low baseline levels of perceived stress.

ical symptoms, we conducted bootstrap analyses. To this end, we used the "indirect SPSS macro" (Preacher & Hayes, 2008) and repeated the above-reported analysis for predicting 4-year changes in physical health symptoms; in addition, we incorporated 2-year levels of perceived stress as a potential mediator. Note that this analysis controlled for baseline perceived stress, which implies that the mediating variable was independent of its baseline levels and represents 2-year changes in perceived stress.

Figure 2 illustrates the mediation model tested. The results of the analysis demonstrated that the interaction between baseline levels of physical activity and perceived stress significantly predicted changes in perceived stress over 2 years, $F(1, 148) = 10.10$, $B = -.22$, $SE = .07$, $R^2 = .04$, $p < .01$ (see Path A in Figure 2). The obtained pattern for this interaction effect closely resembled the results found for predicting 4-year changes in physical symptoms. Physical activity was significantly associated with a reduction of perceived stress over 2 years. This association was apparent among participants with high, but not low, baseline perceived stress ($+1$ *SD*: $B = -.29$, $SE = .02$, $p < .01$ vs. -1 *SD*: $B = .13$, $SE = .02$, $p > .05$).

The findings further showed that increased levels of perceived stress over 2 years were independently associated with increases in physical symptoms over 4 years, $F(1, 147) = 4.67$, $B = .20$, $SE = .09$, $R^2 = .02$, $p < .05$ (see Path B in Figure 2). Moreover, the analyses demonstrated that the interaction effect between baseline levels of physical activities and perceived stress in predicting 4-year changes in physical symptoms was rendered nonsignificant, $F(1, 147) = 2.13$, $B = -.12$, $SE = .08$, $R^2 = .01$, $p = .15$, if 2-year changes in perceived stress were included as a potential mediator into the model (see Path C in Figure 2). In fact, the bootstrap analyses confirmed that 2-year changes in perceived stress exerted a significant indirect effect on the interaction between physical activities and perceived stress in predicting 4-year changes in participants' health symptoms (95% BCI [–.196, −.002]). This pattern of results suggests that the reduction of perceived stress mediated the beneficial effect of physical activity on fewer physical symptoms among participants who perceived high baseline levels of stress.

Discussion

This longitudinal study examined the roles of perceived stress in the association between physical activities and older adults' physical health. We hypothesized that engaging in physical activities would have health benefits among individuals who perceived high (but not low) levels of stress. The study's results supported our hypotheses by demonstrating significant interaction effects between baseline levels of physical activity and perceived stress on 2-year changes in perceived stress and 4-year changes in physical symptoms. These results showed that among participants with high baseline levels of perceived stress, those who frequently engaged in physical activities experienced a reduction of perceived stress over 2 years and fewer increases in physical health symptoms over 4 years. No effects of physical activity on changes in perceived stress or physical symptoms were obtained among participants who perceived only low stress levels at baseline.

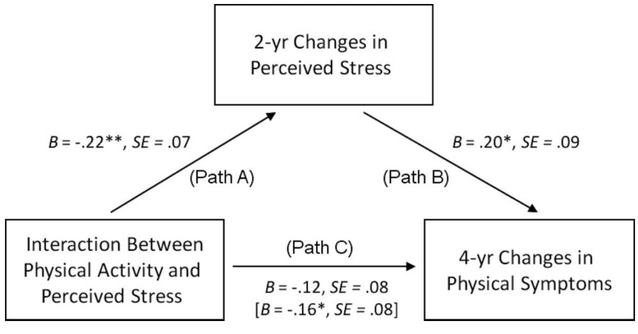

Figure 2. Mediation model examining the effect of 2-year changes in perceived stress on the association between baseline levels of physical activity and perceived stress on 4 year-changes in physical health symptoms. $^{*}p < .05$; $^{**}p < .01$.

In addition, 2-year reductions in perceived stress exerted a significant indirect effect on the interaction between baseline levels of physical activities and perceived stress in predicting 4-year changes in physical health problems. These findings demonstrate that physical activity has the potential to ameliorate chronically high perceptions of stress and thereby produce long-term benefits on physical health.

The study's findings are important for different reasons. First, they substantiate previous research suggesting that associations between physical activity and physical health can be more pronounced among individuals with high, as compared with low, levels of stress (Brown, 1991; Brown & Siegel, 1988; Carmack et al., 1999; Unger et al., 1997). The present study extends this line of work by demonstrating that such effects also appear among community-dwelling older adults. This implies that physical activity may be especially beneficial for physical health among vulnerable older adults who perceive stress. By contrast, older adults who are better adjusted psychologically may have more favorable health trajectories, and as such, the benefits of physical activity in them are less pronounced. However, it is important to note that the majority of our sample consisted of "young-old" individuals and many of the more severe health stressors occur in later phases of older adulthood (Smith & Baltes, 1997). Accordingly, it is possible that physical activity could become more adaptive among participants with low baseline levels of stress, when new age-related stressors emerge in their future. A corollary of this argument is that the observed interaction effect between physical activity and perceived stress may become smaller in later stages of the life course when individuals increase their likelihood of encountering more physical stressors based on age-normative biological declines (Baltes, 1997). In such circumstances, we would expect to observe strong health effects of physical activity—independent of participants' baseline stress levels—given that physical activity can ameliorate the psychological impact of emerging stressors and provide direct biological benefits (e.g., musculoskeletal strength; Faulkner et al., 1994) to counteract age-normative health declines (for research showing general effects of physical activity on physical health, see Simonsick et al., 1993).

Second, the findings document an important mechanism that can explain health-related variability in old age. This mechanism is associated with the prevention of chronically high levels of perceived stress. In particular, it shows that physical activity cannot only reduce elevated perceptions of stress over time, but such reductions in stress levels can further protect older adults' physical health. This pattern of findings provides an explanation for the above-discussed stronger health effects of physical activity among individuals who perceive high (as compared with low) levels of stress. Physical activity may prevent stressed individuals from entering into a downward spiral, characterized by chronically high perceptions of stress and subsequent increases in physical health problems.

Finally, we think that our findings have implications for models of psychosocial determinants of illness, as they point to complex and dynamic interactions between health-promoting behaviors (e.g., physical activity) and psychological risk factors (e.g., perceived stress). Our study suggests that the presence of a psychological risk factor can generally enhance a person's likelihood of developing physical symptoms and thus increases the importance and adaptive value of engaging in health-promoting behaviors. In turn, the engagement in health-promoting behaviors can contribute to long-term physical health outcomes if the behavior has the potential to attenuate the psychological risk factor. We therefore suggest that theory and research should extend the present analysis in long-term longitudinal studies and examine additional psychological risk factors (e.g., depression or anxiety) as well as other health-promoting behaviors (e.g., adaptive sleeping or eating patterns) to identify the health behaviors that are particularly well suited to prevent chronic levels of different psychological problems (for effects of physical activity and stressors on different psychological problems, see Carmack et al., 1999). Research along these lines may not only contribute to improved psychological theories of physical health, but may also provide important information that can be used to promote the physical health of individuals who experience psychologically problematic situations.

There are limitations to this research that need to be addressed in future studies. First, the predictor and outcome variables were assessed with self-report measures. In this regard, we note that our study did not assess participants' memory capacity, which could influence the validity of self-report measures. However, given that the reliability of our perceived stress measure remained high across time (αs $>$ .87), and that our sample of older adults was on average relatively healthy at baseline, we think that it is unlikely that our findings are due to memory impairments. In addition, self-reports could be influenced by other dispositional constructs, such as negative affectivity or neuroticism (Portella, Harmer, Flint, Cowen, & Goodwin, 2005; Watson & Pennebaker, 1989). Although such general biases are less likely to occur in longitudinal analyses because change scores should be less affected by disposition-based individual biases, we note that our study included measures of neuroticism and negative affectivity (Costa & McCrae, 1992; Watson, Clark, & Tellegen, 1988), and follow-up analyses revealed that these variables did not affect the reported interaction effects. Nonetheless, we suggest that future studies should use objective measures of memory capacity, physical health, and activities (e.g., Mora, DiBonaventura, Idler, Leventhal, & Leventhal, 2008; Nasreddine et al., 2005; Parker, Strath, & Swartz, 2008) to substantiate the conclusions drawn from our study.

Second, our findings suggest that perceived stress and physical activity can be relatively independent from each other, which allowed us to demonstrate significant interaction effects. However, future research is needed to identify the variables that determine individual differences in the association between perceived stress and activity engagement. In this regard, it would be interesting to identify psychological factors that help maintain high levels of physical activity among older adults who encounter stressful life circumstances. Such factors could be related to social support or perceptions of control and should be included in future studies.

Third, our analyses did not identify the mechanisms through which physical activities attenuated perceived stress and through which the latter predicted subsequent health problems. In this regard, the stress-reducing effects derived from physical activity may be associated with changes in attentional focus or improved coping patterns. Physical activity typically turns people's attention away from stressful circumstances (Bahrke & Morgan, 1978) and therefore could provide a temporary respite from life stress, or physical activity may serve a beneficial restorative function that allows people to deal with stressful circumstances more effectively. In addition, exercise could counteract some of the endocrine and immune dysregulation that is often associated with high stress levels (see Cohen et al., 2007).

Finally, although our measure of physical symptoms may represent a reliable nonspecific proxy for developing disease and mortality among the elderly (Sha et al., 2005), the analyses did not examine the development of more severe health problems (e.g., cancer, functional limitations, or mortality) or the health benefits deriving directly from physical activity (e.g., cardiorespiratory fitness or musculoskeletal strength; Dunn et al., 1997; Faulkner et al., 1994). We argue that our approach has some important advantages because it has the potential to detect physical health changes across different diseases. However, we note that supplemental analyses showed that our predictor variables were unrelated to changes in chronic health problems, functional limitations, or mortality. Nonetheless, future research should conduct long-term follow-ups of individuals' chronic health problems, given that our sample was just approaching a life phase during which the likelihood of experiencing chronic health problems rapidly increases (Smith & Baltes, 1997). In addition, such an approach should examine a wider range of psychosocial, cognitive, and health variables (e.g., cardiorespiratory fitness) to provide a more comprehensive picture of the pathways to healthy aging.

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