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Physical Activity and Depressive Symptoms in Older Adults

*John Cairney, Brent E. Faight, John Hay,
Terrance J. Wade, and Laurie M. Corna*

Background: Although physical activity (PA) has been demonstrated to reduce symptoms of depression and anxiety, research on the mental health benefits of PA in older adults is limited. Moreover, the psychosocial factors that might mediate or moderate the relationship between PA and depression in this population are largely unexplored. *Methods:* Using a sample of adults age 65 and older ($N = 2736$), we examined whether the major components of the stress process model (stress, social support, mastery, self-esteem) and physical health mediate or moderate the relationship between PA and depressive symptoms. *Results:* Physical health has the single largest effect, accounting for 45% of the effect of PA on depression. The stress process model, with physical health included, accounts for 70% of the relationship between PA and depression. *Conclusions:* Among older adults with above average levels of perceived mastery, greater physical activity is associated with higher levels of depression. Limitations and directions for further research are discussed.

Key Words: physical activity, psychological distress, older adults, physical health status, stress process

Although the positive benefits of physical activity (PA) for physical health are well accepted, an active lifestyle also appears beneficial for psychological well-being.^{1,2} Several clinical trials have demonstrated significant decreases in depressive symptomatology with increased PA.³⁻⁶ Population-based research has also established a relationship between PA and psychological well-being (variously defined), in both cross-sectional¹ and longitudinal studies.⁷⁻¹⁰ The robustness of these findings suggest that engagement in regular PA leads to reduced symptoms of depression and anxiety.^{1,3,8}

The relationship between PA and depression in old age is less clear.^{2,3} Some research finds PA to be beneficial to mental well-being in older adults,¹¹⁻¹⁶ other studies do not.¹⁷⁻¹⁹ Much of this research is based on randomized, clinical-control trials with subjects already identified as clinically depressed. Research with

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population-based samples of older adults is much less common. One longitudinal study by Lampinen et al.,⁷ however, examined changes in the intensity of PA as a predictor of depressive symptoms using a sample of 663 Finnish adults age 65 and older. They found that individuals whose exercise intensity was reduced had a higher average number of depressive symptoms than individuals who remained as active or who increased the intensity of their PA. Given the small amount of population-based research on the relationship between PA and depression among adults age 65 and older, it is clear that more investigation is required.

The literature also lacks any clear, underlying conceptual framework to explain the complex processes that link PA to depression in old age.^{4,6} For example, in a recent review, Paluska and Schwenk³ outlined several psychological and physiological mechanisms thought to account for the positive impact of PA on mental health. Consistent with the criticisms of Biddle⁶ and Scully et al.,⁴ however, these mechanisms were presented as separate rather than interconnected processes linking PA to psychological well-being. Following the work of Martin and Wade,¹ we argue that the stress process model^{20,21} might be a useful theoretical model for examining the relationship between PA and symptoms of depression in old age. Indeed, many of the components of the stress process model have already been discussed in the extant literature as either important mediators or moderators in the PA–depression relationship.^{4,6,10} For example, reduced stress,^{14,22–24} positive self-conceptions and increased feelings of personal control,^{1,24} greater contact with friends and family and access to emotional support^{25–28} have all been found to be associated with PA. These same factors are also determinants of mental well-being.²⁰

As noted above, while individual pathways (e.g., PA → stress → depression) have been researched, we know of no work that has simultaneously examined multiple pathways connecting PA to depression in older adults. Figure 1 illustrates a modified version of the stress process model.²⁰ Most of the pathways connecting these constructs are unidirectional (with the exception of the reciprocal pathways connecting PA to physical health status and social support). The impact of PA on depression can be explained by the mediating effect of physical health, stress, social support, and psychosocial resources. In the case of physical health and social support, we have indicated reciprocal pathways because the literature is less clear about the directionality of these relationships. For example, while it is plausible that PA leads to better physical health which, in turn, could reduce depressive symptoms, it is equally conceivable, particularly in this population, that poor physical health hinders participation in PA. In epidemiological terms, physical health might confound the relationship between activity and depression. Similarly, the literature on social support and PA has generally found that greater social support leads to increased activity. Yet, it is equally probable that engagement in regular PA exposes individuals to others with whom they can develop supportive relationships. It is important to note that most of the PA and social support literature has focused on receipt of support to engage in physical activities only. It is our contention, however, that the PA is apt to influence and be influenced by more than just this domain-specific aspect of support. In this study, we include measures of general perceived support, contact with others, and social involvement.

The stress process literature also posits that psychosocial resources such as mastery and self-esteem, and social resources such as social support could buffer

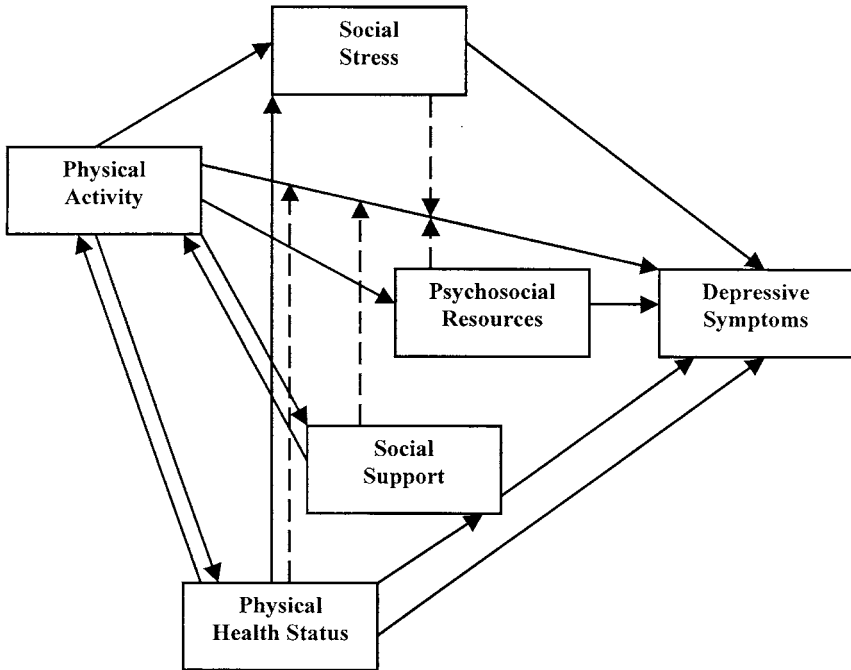


Figure 1 — Conceptual model linking physical activity to psychological distress in older adults

Note. The solid dark lines represent mediating pathways connecting constructs together (direct and indirect effects). Dashed lines represent the moderating or buffering effect of social support, psychosocial resources, social stress, and physical health status on the physical activity-depression relationship.

the impact of negative stressors on psychological well-being.²⁰ Therefore, we also tested the possibility that stress, self-esteem, mastery, social support, and physical health could moderate the impact of PA on depression (see Figure 1, dashed lines). For example, social support might enhance the positive effect of PA on distress. Those who are both active and part of a supportive network of friends and family report lower levels of distress than those who are active but not part of such a support network.

We know of only one study that uses the stress process model to examine the relationship between PA and depressive symptoms. Using a sample of adults age 20 to 64, Martin and Wade¹ found that the positive effect of PA on depression was maintained after controlling for chronic strain, self-esteem, and social support. Mastery was found to both mediate and moderate the relationship between activity and depression. In the latter case, mastery was more important for reducing depressive symptoms among individuals who are inactive than among those considered active.

The aim of this study was to test the applicability of the stress process model as a theoretical framework for understanding the relationship between PA and depression in old age. We hypothesized that a substantial amount of the effect of PA on depression will be explained by stress, mastery, self-esteem, physical health status, and social support. We further hypothesized that mastery, self-esteem, and support will all moderate the relationship between PA and depressive symptoms in a similar manner. Specifically, consistent with Martin and Wade,¹ we hypothesized that high levels of mastery, self-esteem, and social support will be more important for reducing depression among older adults who are relatively inactive. For those who are active (above average), these factors will be less important for reducing depression. We know of no published work that has examined the relationship between PA and depression using such a wide array of psychosocial and health variables.

Method

Sample

The sample was taken from the National Population Health Survey (hereinafter NPHS) conducted by Statistics Canada.³³ The NPHS was a 1994 telephone survey of a national probability sample of Canadian residents across all 10 provinces. One person from each household was selected to provide detailed personal information. Of the 18,342 possible respondents age 12 and older, 17,626 participated (a response rate of 96.1%). Because the primary focus of this study is on elderly adults, only those age 65 and older were selected, reducing the sample to $N = 2736$.

Measure of Depressive Symptoms

The six item depression symptom measure was assessed by asking respondents: "During the past month, how often did you feel: (1) ... so sad that nothing could cheer you up (2) ... nervous (3) restless or fidgety (4) ... hopeless (5) ... worthless (6) ... that everything was an effort?" Respondents answered each query by selecting one of the following five responses: "all of the time," "most of the time," "some of the time," "a little of the time," or "none of the time." The measure is scored such that higher scores reflect a greater number of depressive symptoms ($\alpha = 0.79$).

Measure of Physical Activity

Physical activity was estimated using a measure of energy expenditure. Respondents were asked whether they had participated in a broad range of 20 different physical activities in the past 3 months. These included leisure activities (e.g., gardening, social dance, golfing, bowling, fishing etc.), group activities or sports (e.g., ice hockey, baseball/softball, volleyball) and other activities that could be performed alone (e.g., walking, swimming, bicycling, jogging/running, cross-country skiing etc.). Respondents were also asked about the usual time (in minutes) spent participating in each activity and frequency of participation in the last three months. The intensity of each activity was expressed as the low-end metabolic equivalent (MET)

value (the energy cost of the activity expressed as kcal/kg body weight per hour of activity) of the activity. Using this information, a measure of energy expenditure was derived. Energy expenditure is expressed in kilocalories expended per day; higher scores indicate greater energy expenditure (i.e., higher physical activity).

Measures of Physical Health

The first measure of health status was an index of chronic conditions. Respondents were asked a series of questions about the presence of chronic conditions, for example, “Do you have diabetes diagnosed by a health professional—‘yes’ or ‘no’?” A list of 15 chronic conditions was selected from a larger list generated by Statistics Canada. Certain conditions such as acne and epilepsy were excluded from the final index because of too few positive responses. An index was created by summing “yes” responses to each health condition (0 to 15). Higher scores thus indicate higher levels of chronic conditions.

A measure for limitations in daily activities was also included. Respondents were prompted to answer “yes” or “no” to six questions: “Do you need the help of another person with: (1) grocery shopping, (2) normal housework, (3) heavy housework, (4) personal care, (5) moving about in your home, and (6) meal preparation?” Positive responses were summed to create an index. Higher scores indicate more limitations in daily activities.

Measures of Stress

Three measures of stress are available in the NPHS. The first measure is based on Wheaton’s measure of chronic stress.²⁹ The index measures the total number of stressors that individuals experience on a regular, on-going basis. In total, there were 16 questions containing elements that the respondent was asked to rate as stressful or not; higher scores reflect greater exposure to chronic stresses and strains (0 to 16). Because not all respondents would have answered every question (e.g., stressors associated with marriage or raising children), Statistics Canada adjusted the original index by multiplying the score from the index by the total number of items, and then dividing that product by the total number of questions that were relevant to each individual participant.

The second measure is a count of negative life events experienced by the respondent in the last 12 months. All “yes” responses were given a value of “1” and added together to form the index (range 0 to 10). Higher scores indicate greater exposure to negative life events. Again, because not all respondents would have answered every question, Statistics Canada adjusted the original index as described above.

Finally, the childhood adversities index measures the number of adverse events to which the respondents had been exposed during childhood, adolescence, or early adulthood (while living in their primary caregiver’s home). While we do not expect this measure to be influenced by PA, early traumas are important predictors of both subsequent stress and depression.²⁰ Therefore, we have included this measure in multivariate analyses. All “yes” responses were given a value of “1” and added together to form the index (range 0 to 7). Higher scores indicate greater exposure to negative, remote, or distal life events.

Psychosocial Resources Variables

Mastery measures the extent to which individuals feel that they have control over their lives. This construct is measured using Pearlin and Schooler's seven-item scale.³⁰ Respondents answered each statement by selecting one of the following responses: "strongly agree," "agree," "neither agree nor disagree," "disagree," or "strongly disagree." For example, one of the items asks respondents to indicate the degree to which they agree or disagree with the following statement: "You have little control over the things that happen to you." The measure is scored such that higher scores indicate a greater sense of mastery (0 to 28, $\alpha = 0.76$).

Self-esteem is measured using a subset of 6 items from Rosenberg's original 10-item scale that measures one's perception of self and self-worth.^{31,32} Respondents answered each statement by selecting one of the following responses: "strongly agree," "agree," "neither agree nor disagree," "disagree," or "strongly disagree." For example, one of the items asks respondents to indicate the degree to which they agree or disagree with the following statement: "You feel that you're a person of worth at least equal to others." The measure is scored such that higher scores indicate a greater sense of self-esteem (0 to 24, $\alpha = 0.85$).

Social Support

Three measures of social support are available: perceived social support, social involvement, and frequency of contact. Perceived social support is measured using four items: whether respondents feel that they have someone (1) they can confide in, (2) someone they can always count on, (3) someone who can give them advice, and (4) someone who makes them feel loved. Respondents answered "yes" or "no" to each item. Higher scores indicate greater perceived social support.

Social involvement is measured using two items, both of which reflect the frequency of participation and attendance at community association meetings and religious services respectively during the previous year. Higher scores indicate a greater level of social involvement (0 to 8).

Average frequency of contact is a derived variable that measures the average number of contacts the respondent had in the previous 12 months with family members and friends (who do not live with the respondent), and with neighbors. Average contact was then calculated by dividing contact (a value that indicates the total number of contacts for each of the eight categories listed above) by the size of the respondent's social network (a value that represents the total number of possible persons determined by positive responses to each category, such as "yes" to grandparents). Higher numbers indicate more contacts.

Measures of Socioeconomic Status

Socioeconomic status is measured by two different variables in these analyses—education and household income. Education is based on an item involving a combination of qualitative and ordinal categories. The original item was a 12-category variable reflecting different levels of educational attainment. While some categories appeared to be ordered, others did not. Thus, the original variable was recoded into eight categories: (1) no formal schooling, (2) elementary-level education, (3) some

secondary-level education, (4) high school diploma, (5) some education beyond high school, (6) college diploma or trade certificate, (7) undergraduate university degree, and (8) graduate degree (MA or PhD) or a degree in medicine. For multivariate analysis, the educational measure was treated as a continuous variable.

Household income was coded into the following 11 intervals in the 1994 NPHS, expressed in \$Can: (0) no income, (1) less than \$5000, (2) \$5000 to \$9999, (3) \$10,000 to \$14,999, (4) \$15,000 to \$19,999, (5) \$20,000 to \$29,999, (6) \$30,000 to \$39,999, (7) \$40,000 to \$49,999, (8) \$50,000 to \$59,999, (9) \$60,000 to \$79,999, and (10) \$80,000 or more. An 11-item scale was created by setting each scale value to the midpoint of the interval (e.g., 3 = \$12,499). For multivariate analysis, this variable was treated as continuous.

Controls

Age was coded into 5-y intervals from age 65 to age 80 and over. Gender was coded 1 for females, 0 for males. Marital status included three dummy variables for married (including common law), previously married (including widowed, divorced, and separated) and single (reference category).

Analysis

All analyses were computed using the standardized weighting scheme suggested by Statistics Canada.³³ Given the complexity of the sampling design, software packages such as STATA are typically used to calculate unbiased standard errors. Because of data release restrictions imposed by Statistics Canada, we did not have access to the design information necessary to use such software. Therefore, to address the design effect problem (underestimation of variances because of cluster sampling), the recalled-sampling weights are further adjusted by dividing by the overall design effect of the survey (1.61). This produces conservative variance estimates close to those produced by programs such as STATA or SUDAAN.³⁴

Results

Table 1 shows the sample characteristics and descriptive information for each variable included in the study. We next examined correlations between all continuous variables in the model. The strongest correlation is between PA and limitations in activity of daily living ($r = -0.232$, $P < 0.001$). Physical activity is also negatively correlated with depression ($r = -0.175$, $P < 0.001$) and chronic health problems ($r = -0.159$, $P < 0.001$). Interestingly, physical activity is only weakly correlated with one of the three stress measures—chronic stress ($r = -0.067$, $P < 0.01$). There is a positive correlation between PA and both mastery ($r = 0.161$, $P < 0.001$) and self-esteem ($r = 0.148$, $P < 0.001$).

Table 2 shows the results of an ordinary least squares regression analysis of depressive symptoms on PA controlling for physical health, stress, social support, mastery, and self-esteem. We used a technique of successive estimation whereby the mediating variables are entered separately into a base model containing physical activity. This allowed for an assessment of how much of the relationship between PA and distress can be explained by each of these variables separately

Table 1 Sample Characteristics (N = 2736)

Variables	N	%
Age		
65 to 69 y	841	31.2
70 to 74 y	739	29.1
75 to 79 y	547	20.3
80 y and over	609	19.3
Gender		
male	1040	38.3
female	1696	61.7
Marital status		
single	192	7.1
married	1204	44.4
previously married	1340	48.5
	Mean	SD
Psychological distress	2.71	3.41
Physical activity (kcal/d)	1.27	1.55
Household income (\$Can)	24,000	16,600
Education	3.70	1.60
Physical health status		
chronic conditions	1.77	1.55
limitations in activities of daily living	0.69	1.27
Social support		
perceived support	3.64	0.79
average frequency of contact	4.35	0.95
social involvement	3.56	2.76
chronic stress	1.67	1.99
Psychosocial resources		
mastery	18.83	4.23
self-esteem	19.81	2.86

Note. SD, standard deviation.

and simultaneously (full model). All models adjust for age, gender, marital status, and income (parameter estimates for these variables are not reported in the table but are available on request).

In Model 1, after adjusting for age, gender, marital status, income, and education, PA is associated with a decreased number of symptoms of depression in older adults ($b = -0.29$, $P < 0.001$). In Model 2, chronic conditions and limitations in activities of daily living are entered into the equation. The coefficient (unstandardized slope) for PA is reduced by 45% from Model 1. Both measures of physical health are related to depression net of PA and the statistical controls. Next, all three

Table 2 Ordinary Least Squares Regression of Psychological Distress on Physical Activity, Sociodemographics, Physical Health Status, Social Stress, and Psychosocial Resources ($N = 2736$)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Physical activity	-0.290 ^a (0.050)	-0.162 ^b (0.056)	-0.141 ^b (0.053)	-0.134 ^b (0.053)	-0.097 ^b (0.052)	-0.104 ^c (0.053)	-0.088 (0.052)
Chronic conditions		0.409 ^a (0.062)	0.290 ^a (0.060)	0.293 ^a (0.060)	0.235 ^a (0.058)	0.256 ^a (0.059)	0.226 ^a (0.058)
Limitations in activities of daily living		0.566 ^a (0.084)	0.542 ^a (0.080)	0.542 ^a (0.080)	0.445 ^a (0.078)	0.502 ^a (0.079)	0.440 ^a (0.078)
Chronic stress			0.436 ^a (0.043)	0.421 ^a (0.034)	0.299 ^a (0.044)	0.404 ^a (0.043)	0.308 ^a (0.044)
Life events			0.570 ^b (0.183)	0.533 ^b (0.183)	0.463 ^b (0.178)	0.497 ^a (0.181)	0.455 ^b (0.177)
Childhood adversities			0.089 (0.112)	0.076 (0.112)	0.053 (0.109)	0.085 (0.111)	0.070 (0.085)
Perceived social support				-0.208 (0.113)	-0.133 (0.109)	-0.174 (0.111)	-0.127 (0.11)
Social involvement				-0.02 (0.031)	-0.018 (0.030)	-0.008 (0.031)	-0.01 (0.030)
Average frequency of contact				-0.152 (0.091)	-0.124 (0.088)	-0.136 (0.090)	-0.120 (0.088)
Mastery					-0.194 ^a (0.021)		-0.167 ^a (0.023)
Self-esteem						-0.187 ^a (0.030)	-0.088 ^b (0.032)
Constant	4.13	3.45	3.47	4.91	4.17	4.49	4.08
R-squared	0.07	0.16	0.25	0.25	0.30	0.27	0.31

Note. All models adjust for age, gender, marital status, education, and income; unstandardized coefficients are reported (standard errors in parentheses).

^a $P < 0.001$, ^b $P < 0.01$, ^c $P < 0.05$ (2-tailed test).

measures of stress are entered simultaneously into Model 3. The coefficient for PA is reduced by 13% from Model 2. Only chronic stress and recent life events are positively associated with depression.

In Model 4, all three measures of social support are entered into the equation. While none of the measures are statistically significant, the inclusion of these variables reduced the coefficient for PA by an additional 5% from Model 3. Models 5 and 6 adjust for mastery and self-esteem, respectively. In Model 5, after mastery is entered into Model 4, the coefficient for PA is reduced by 28% (from Model 4). Mastery is associated with lower levels of depression in the model net of the other variables in the model ($b = -0.199$, $P < 0.001$). The introduction of self-esteem in

Model 6 reduces the coefficient for PA by 22% from Model 4. Similar to mastery, higher levels of self-esteem are associated with lower levels of depression ($b = -0.187, P < 0.001$). Finally, in Model 7, all variables are entered. The coefficient for PA is reduced by 70% from Model 1 and is no longer statistically significant ($b = -0.088, P < 0.10$). Chronic health problems, limitations in activities of daily living, chronic stress, life events, mastery, and self-esteem are all independently and significantly related to depression in the final model.

Test for Moderating Effects

Next, we tested to see whether the relationship between PA and depression was influenced by physical health, stress, psychosocial resources, and social support. A total of eight interaction terms were calculated (e.g., physical activity by chronic health problems) and entered, individually, into the full equation (Model 7). Given the large number of tests (eight in total, one for each interaction term) conducted, we performed a Bonferroni correction which the set P -value for statistical significance at $P < 0.001$. Only one interaction was statistically significant—physical activity by mastery. To interpret the interaction, we graphed the relationship (see Figure 2). Low and high values for mastery and PA (energy expenditure) correspond to -1 standard deviation and $+1$ standard deviation units, respectively.

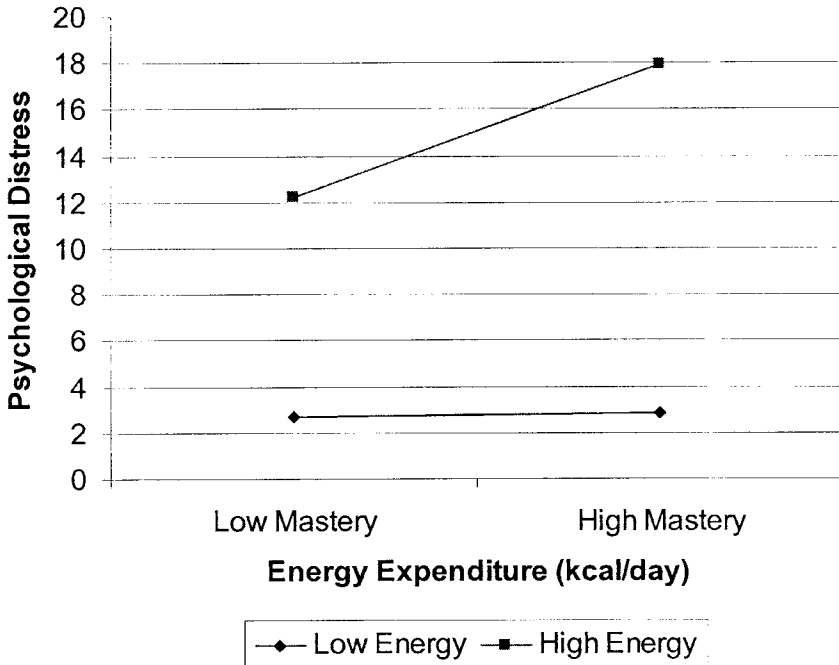


Figure 2 — Moderating effect of mastery on the physical activity-distress relationship

The graph shows that among older individuals with below-average levels of energy expenditure, there is no effect of mastery on depression. Moreover, these individuals have lower average levels of depression than individuals with above-average levels of energy expenditure. For individuals with above-average levels of PA, higher perceived mastery is actually associated with higher levels of depression.

Discussion

Our analysis shows that 30% of the variation in depressive symptoms is explained by the stress process model (Figure 1) with PA included. Approximately 46% of the relationship between PA and depression can be explained by the mediating effects of social stress, psychosocial resources, and social support—the core components of the stress process model. Physical health, however, had the single largest effect, accounting for 45% of the effect of PA on distress. The revised stress process model with physical health included accounts for 70% of the relationship between PA and distress. Physical health status has been used before as a predictor of mental well-being in adults.³⁵ Moreover, physical health has been used before in stress process research as a form of chronic stress.³⁶ These results confirm the first part of our hypothesis. Consistent with previous work,¹ our research suggests that the stress process model, including physical health status, is a useful framework to use to better understand the link between PA and psychological distress.

Not all of the pathways identified in our analytic model appear of equal importance. Our results suggest two of these pathways, physical health status, measured by chronic conditions and limitations in daily activities, and psychosocial resources (mastery and self-esteem) appear to account for the largest proportion of the effect of PA on depression in older adults. As stated at the beginning of this article, the relationship between PA, physical health, and psychological well-being is complex. For example, individuals who are suffering from chronic conditions or decreased functional independence might be less likely to engage in PA because of their poor health status. Moreover, they might also be more likely to report higher levels of depressive symptoms as a result of their poor physical well-being. Under this conceptualization, we might think of physical health status as a confounder in the relationship between PA and depression. It is also possible, however, that physical inactivity over time could have contributed to the onset of physical health problems in some adults that, in turn, resulted in depression. (i.e., physical health status is a mediating variable in the relationship between PA and psychological well-being). Although we cannot determine the causal ordering of these variables with cross-sectional data, given the importance of physical health status to PA and depression, more research into this question is warranted.

Our findings also suggest the importance of self-esteem in explaining the relationship between PA and depression. Through PA, older adults might gain a greater sense of accomplishment and self-worth, which in turn protects them from depression. As with all of the pathways in this analysis, however, the opposite effect could be occurring—those with a higher sense of self-esteem are more likely to engage in PA and have fewer symptoms of depression. Establishing the causal ordering of these variables also requires longitudinal data. Nevertheless, the importance of self-esteem in the PA–depression relationship is clearly established with these data.

Although the explanation identified above might explain the mediating effect of self-esteem on PA and depression, the interrelationships between PA, mastery, and depression are more complex. For example, it was interesting to note that for individuals with above-average levels of mastery, greater PA was associated with higher depression—a finding which is counterintuitive to our general understanding of the relationship between both mastery and depression and PA and depression. One explanation for this could be that these individuals believe that they can stay young or healthy through vigorous activity. Indeed, the high levels of mastery in this group suggest a strong belief in their own capacities for personal control. While exercise can forestall the onset of physical disease and limitations with age it cannot prevent these things from happening. Individuals who possess both a strong sense of personal control and who report high levels of PA might be more depressed than others because they are more in tune with the increasing disparity between their desire to remain vital and active and the increasing decrements to their physical health and overall functioning that accompany advanced age.

Closely related to this, it could also be the case that these same individuals (high physical activity/high sense of mastery) were very active throughout their lives. Therefore, the possibility of losing some of their physical capacities as they age might be more dispiriting than to individuals who were less active throughout their lives. In addition, their regular engagement in PA has helped to establish and maintain strong feelings of personal control. As they face the prospect of physical decline with advanced age, they experience greater depression in spite of both their continued attempts to maintain an active lifestyle, and their higher sense of personal control. In either case, more research is required to better understand the provocative relationship between PA, mastery, and depression demonstrated in these data.

Our analyses revealed that while social stress appears to mediate some of the relationship between PA and depression, the effect is small. This is surprising given that one might expect PA to affect perceived stress levels directly. Yet, it should be noted that this result could be because older adults tend to report less stress compared to younger adults.³⁷ In relation to younger adults, this pathway might not be as significant a factor among older adults simply because social stress is less prevalent in this age group. It has been noted, however, that previous findings showing a negative relationship between stress and age could be because most life events and chronic stress measures do not include stress domains that are salient to older adults.³⁸ Moreover, while the measures of stress included in this analysis have been shown to be important determinants of depression,²⁰ they are not necessarily significantly related to PA (e.g., childhood adversities). Stress measures that are sensitive to the life experiences of older adults, and those that are apt to more strongly correlate with PA, might produce different results when used as mediating/moderating variables in analyses such as these.

Surprisingly, our analysis revealed that social support had very little effect on the PA–depression relationship. While the inclusion of our three measures of social support did reduce, slightly, the coefficient for PA from Model 3 (by 5%), none of the three measures were significantly related to psychological distress. Moreover, the hypothesis that social support could influence the relationship between PA and depression was not supported. This might be due, in part, to the rather limited measures of social support available for analyses in these data. For example, social contact and social involvement do not assess a person's perception of the

willingness of others to assist them—they simply capture the potential availability of support. For example, regular contact with a child who is unwilling to assist their older parent when they are needed is not likely to reduce, but might be a source of, depression. Perceived support, while it does capture the degree to which a person feels loved, does not capture instrumental support (e.g., Is there a person who helps you when you are sick or with your grocery shopping?) These forms of support could be more salient to older adults and might be stronger links in the physical activity–distress relationship. For example, low participation in PA and having someone to help out around the home might not produce distress whereas low PA and no such support could be quite depressing. Finally, our data do not include measures of social support or social engagement specifically tied to participation in groups organized around physical activities (e.g., walking group or a lawn bowling club). The inclusion of such measures might better aid in understanding the role that PA plays in depression. The camaraderie experienced through group-based PA could provide an inoculant against feelings of depression. Clearly, much more work is required before we can conclude definitively that social support is of little consequence in the PA–distress relationship.

Up to this point, our discussion has focused on the psychosocial mechanisms that link PA to depression. Indeed, our analyses reveal that a substantial amount of the effect of PA on symptoms of depression can be explained by the inclusion of physical health and stress process measures. There are, however, likely complementary and parallel biologic mechanisms operating that also account for the distress-reducing impact of PA on psychological well-being.

While antidepressant responses are not completely understood at the cellular level,³⁹ the biochemical mechanism responsible for the therapeutic effects of PA in the endogenously depressed appears associated with the up-regulation of brain-derived neurotrophic factor (BDNF) mRNA in the central nervous system.^{24,40} An imbalanced concentration of neurotransmitters is responsible for mood elevations. Moreover, a chronic decrease in neurochemicals such as norepinephrine gives rise to outward expressions of depression.⁴¹ Acute stress stimulates the brain-norepinephrine system in animal models and temporarily depletes norepinephrine concentrations. Conversely, synthesis of norepinephrine is increased proportionally during chronic stress to maintain homeostasis in the brain.⁴⁰ Endurance activities such as swimming⁴² and running⁴³ have maintained or enhanced brain norepinephrine levels. The function of BDNF is to serve as a neurotransmitter regulator in stabilizing mood. Recent evidence in animal models has demonstrated that PA alone and in conjunction with antidepressant medication enhances and accelerates the BDNF mRNA expression in rats exposed to acute stress following forced swimming without a support platform.³⁹ Blumenthal and colleagues¹¹ identified similar antidepressant treatment effects following group PA and medication in a 16-wk randomized clinical trial of older adults with identifiable mild to moderate-major depressive disorder. Future work that collects both psychometric and biometric data among humans could greatly enhance our understanding of how psychosocial and biologic mechanisms work independently and synergistically to influence depression in older adults.

Notwithstanding potential biologic mechanisms, one of the principal links between PA and lessened distress appears to be through psychosocial resources. Perhaps there are sociocultural factors that intervene here to reinforce the signifi-

cance of these pathways. For example, one might ask, why is it that PA is linked to a positive self-concept? Are physically active older adults more psychologically adjusted because they are able to fit into a youthful, active culture? This could be especially relevant for an aging population whose cultural norms of activity, beauty, and self-worth are partly formed by dominant stereotypes in various popular media. Such popular representations tend to be youth-focused and are therefore generally devoid of generational peers of adults age 65 and over. Cultural conditions reinforce a context in which the ability to maintain a positive self-concept with age is related to the ability to “feel” and “look” young. That self-esteem partially mediates the relationship between PA and depression in this older population might be related as much to social and cultural forces that relate to self-image as it is related directly to an effect of PA.

Clearly, more work should be done to examine the interrelations of these factors, to determine, on the one hand, the degree to which the psychosocial benefits of PA that decrease depressive symptoms in older adults result directly from the inherent challenges and accomplishments of PA and, on the other hand, the degree to which this relationship between PA and psychosocial resources is itself mediated by cultural norms.

There are limitations in this study. It is not possible to assess the causal ordering of the variables in this analysis with these data. Moreover, the complexity of the interrelationships between the constructs in this model necessitates an examination of not just simple cause and effect relationships, but complex feedback loops. We were able to examine several interrelations and correlations among these pathways, but not to examine in detail the actual chains of events that connect these constructs. Multi-wave panel data over a sufficient period of time (e.g., 6 to 10 y) would allow us to examine such stability and change in these variables.

Another limitation concerns our outcome measure. While this measure has been used before as a measure of depressive symptoms with older adults (see Wade and Cairney^{44,45}), it has not been properly validated with this population. Unfortunately, this was the only measure of depressive symptoms available in these data. The two most commonly used measures of depression in the physical activity and mental health literature have been the Center for Epidemiologic Studies in Depression (CES-D) scale, and the Zung Self-rating Depression Scale.² The items in our scale were derived from other measures of depression including the CES-D; see Wade and Cairney⁴⁴ for a discussion. Moreover, the content of the items are clearly tapping into symptoms of depressed affect, and the scale therefore avoids the common problem of including items that are associated with physical health conditions (somatic items such as sleep disturbances) as well as symptoms of depression. Some have argued that the inclusion of somatic items could inflate estimates of depression in elderly populations.^{2,46} Nevertheless, our findings must be replicated with validated measures of depression if the results presented in this article are to be confirmed.

In addition, the measurement of physical activity among an elderly population also poses unique challenges as commonly used measures such as recall surveys have not been validated with older adults and might not accurately assess moderate intensity activities commonly performed by older adults.² Our measure of physical activity—energy expenditure—was derived, however, by questioning respondents about a broad range of physical activities that included leisure activities, group

activities, or sports and activities that could be performed alone, many of which are common among older adults such as gardening, fishing, bowling, and golfing. Moreover, the calculation of energy expenditure also included an assessment of frequency and duration of each of the activities in which they participated to more accurately assess actual energy expenditure.

Finally, it should be noted that all the measures in this study are based on self-reports and therefore subject to certain biases. In addition to social desirability, variation resulting from recall, especially significant in an older population, might also be a source of error.

Notwithstanding these limitations, we could find no other study in the published literature that has attempted to use a comprehensive set of mediating/moderating variables derived from the stress process model to examine the psychosocial pathways that connect PA to depressive symptoms in older adults. Our results, while preliminary, provide support not only for using this model, but also provide many intriguing avenues for further inquiry.

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