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Behavioral and Psychosocial Predictors of Physical Performance: MacArthur Studies of Successful Aging

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Background. Performance-based measures of physical performance are examined for an older cohort of relatively high-functioning men and women. The influences of baseline behavioral, social, and psychological characteristics on patterns of change in performance over 2.5 years are examined.

Methods. A cohort of relatively high-functioning men and women, aged 70–79, identified in 1988 by subsampling from three community-based studies on the basis of physical and cognitive function. Baseline assessments included physical performance, sociodemographic characteristics, health status, and behavioral, social, and psychological characteristics. A summary measure of physical performance was developed from tests of balance, gait, lower body strength and coordination, and manual dexterity. In-home assessments were repeated at follow-up in 1991.

Results. Linear regression models were used to identify significant behavioral, social, and psychological predictors of better performance at follow-up, controlling for known sociodemographic and health status predictors. Significant, independent associations with better performance were found for participation in moderate and/or strenuous exercise activity and greater frequency of emotional support from social networks, particularly among those reporting low frequency of instrumental support. These effects remained significant independent of incident health conditions during follow-up. None of the psychological characteristics was a significant predictor.

Conclusions. Maintenance of better physical performance within a high-functioning cohort is influenced by prior exercise behavior and social network emotional support. Observed patterns of both decline and improvement in performance suggest that older age is not uniformly associated with declines. Predictors of better performance identified here may offer potential for effective interventions to promote more successful aging.

IDENTIFICATION of the determinants of physical functioning and risks for declines in functioning at older ages continues to be a topic of considerable gerontologic research. Interest in the determinants of more successful aging has led researchers to investigate the heterogeneity in physical functioning or physical performance abilities within healthier, more high-functioning groups of older adults. A primary goal is to determine what factors predict higher levels of physical ability and activity as opposed to simply the absence of "disability."

Newly developed measurement protocols to assess physical performance include tests covering a more comprehensive range of difficulty, including higher levels of performance. This permits assessments of performance abilities along the full spectrum of functioning from lower through higher levels, revealing much greater heterogeneity in functioning than was apparent from earlier studies (1–4). Previously reported data from our own cohort study of relatively high-functioning older men and women (aged 70–79) have shown that many of the same sociodemographic and health status risk factors that were found previously to predict risks for "disability" also appear to differentiate levels of physical performance ability outside the "disabled" range (5). Predictors of declines in physical performance over a 2.5-year period included older age, non-White race, lower income, higher relative weight and lower lung function, presence of high blood pressure or diabetes, and worse cognitive performance at baseline. Data from the larger, community-based EPESE studies have also found similar predictors of higher levels of physical performance (6).

Identification of such risk factors as determinants of physical performance is, however, only a first step. Optimally, such information can be used to identify potential targets for interventions for primary and secondary prevention. The value of identifying risk factors for earlier, less severe declines lies in the potentially greater effectiveness of interventions targeted earlier in the process of functional decline. Many of the risk factors for functional decline identified to date, however, are unlikely or difficult candidates for intervention efforts, including such immutable characteristics as gender, race or age, or characteristics such as chronic health problems that are indicative of already existing pathophysiology.

In the following analyses, data from the MacArthur Studies of Successful Aging are used to investigate three categories of risk factors that are potentially modifiable and may thus offer opportunities for intervention to promote higher levels of physical functioning. They include: (a) *behavioral factors* such as moderate and strenuous exercise; (b) *social network characteristics*; and (c) *psychological characteris-*

tics such as self-efficacy beliefs. These characteristics are examined as potential predictors of changes in physical performance over a 2.5-year follow-up.

METHODS

The data used in these analyses come from the MacArthur Research Network on Successful Aging Community Study, a three-site longitudinal study of successful aging in men and women aged 70–79 years. Details of the study design are available elsewhere (1). Briefly, subjects were subsampled from three larger, community-based studies of individuals aged 65 years and older on the basis of age and physical and cognitive function at the time of their 1988 interviews for these larger studies. Age was restricted to minimize its effect in subsequent analyses of predictors of maintenance of better health and functioning. Age-eligible men and women (N = 4030) were screened on the basis of six criteria to identify a relatively high-functioning cohort [i.e., approximately the top third of the age group in terms of physical and cognitive function; see (1) for criteria]. Of the 1,313 subjects who met criteria, 1,189 (90.6%) agreed to participate. Baseline data were collected between May 1988 and December 1989 based on a 90-minute, face-to-face interview with detailed assessments of physical and cognitive performance, health status, and social and psychological characteristics. The first follow-up of the cohort began in May 1991; the majority of the cohort was reinterviewed between 24 and 32 months after their baseline interview (mean = 28 months; SD = 4 months). Of the original 1,189 subjects, 1,015 (85%) completed the follow-up interview, 59 (5%) had partial or proxy interviews, 45 (4%) refused the follow-up interview, and 73 (6%) had died.

Physical performance. — A summary measure of physical performance, based on five separate tests of physical ability, was used in the following analyses. Details regarding creation of this summary scale are available elsewhere (5). The five abilities assessed included timed measures of balance, gait, chair stands, foot taps, and manual ability. Two-month test/retest data for these protocols indicate that they have generally good reliability (5). Scores for each of the subscales were rescaled to indicate the proportion of the best possible score that a subject achieved (i.e., rescaled scores range from 0 (worst possible performance) to 1 (best possible performance). The 1991 scores were rescaled using the 1988 denominators to permit meaningful evaluation of change over time. Summary measures of performance in 1988 and 1991 were created by adding the rescaled subscale scores for the respective years (range each year = 0–5). Although there is no "gold standard" against which to validate this measure, evidence for its construct validity is provided by its significant correlation with self-reported functional status and its apparent sensitivity to changes in health status [e.g., increased morbidity and/or hospitalization have been shown to predict declines in performance scores (5)].

Behavioral factors. — Levels of physical activity were assessed based on self-reported frequency of current leisure- and work-related activity. Each activity mentioned was classified as light, moderate, or strenuous based on intensity codes (kcal/min) adapted from Paffenbarger et al. (7) and Taylor et al. (8). Summary scales were derived by multiplying the frequency of activity (5 categories, ranging from never to 3+ times per week) by the intensity code and summing over all activities within a given category of intensity. For the analyses reported here, these measures of the amount of moderate and strenuous activity were recategorized as "any" versus "none" due to the skewed nature of the distributions. Two dichotomous variables plus a "Moderate by Strenuous" interaction term were used to estimate the effects of participation in moderate level activities *only*, participation in strenuous level activity *only*, and participation in both moderate and strenuous level activities. Separate questions asked about participation in volunteer work, child care, and paid employment. Responses regarding each of these types of activity were coded as "yes/no" for these analyses.

Cigarette smoking was assessed by self-report and subjects were classified as current, former, or never smokers as of their 1988 baseline interview. Alcohol consumption was assessed in terms of the monthly frequency and quantity of beer, wine, and hard liquor consumption. A summary measure of ethyl alcohol consumption was created based on the quantity and frequency of each type of alcohol consumed (9).

Social network characteristics. — Details regarding the various scales developed from the MacArthur Battery assessments of network characteristics have been reported elsewhere (10). Briefly, a summary measure of social network ties was used, representing the total number of children, close friends, and relatives reported by the respondent. Presence or absence of a spouse was measured separately. Emotional support and instrumental support were assessed by summary scores reflecting the average frequency of each type of support from spouse, children, and close friends/relatives. The perceived adequacy of this emotional and instrumental support was assessed by dichotomous indicator variables. A summary score reflecting the average frequency of demands and criticism from network members was also examined.

Psychological characteristics. — Self-efficacy beliefs were assessed based on subjects' perceptions of their own self-efficacy in nine separate life domains found to be of particular relevance to older adults (11). Personal mastery beliefs were measured using a scale developed by Pearlin and Schooler (12). Brief measures of life satisfaction and happiness were also adapted from work at the University of Michigan's Institute for Social Research (13). Psychological "symptomatology" was measured by a 50-item version of the Hopkins Symptom Checklist (14).

Covariates. — Sociodemographic characteristics and health status covariates included in the multivariable analyses included those found to be significant predictors of change in physical performance in previous analyses (5). Sociodemographic characteristics included gender, race, education, and annual household income. Baseline biomedical, health status, and cognitive measures included pulmonary function (peak expiratory flow rate using a mini-wright meter (15), body mass index (kg/m²), presence of diabetes or hypertension, and cognitive function. Baseline presence of physician-diagnosed diabetes was determined from self-reports, and hypertension was assessed based on a measured average of > 140/90 mmHg or reported use of blood pressure medication. Cognitive performance was measured by summing scores on tests measuring memory, abstraction, spatial recognition, and spatial ability (copying) (16). Measures of changes in health status between 1988 and 1991 were ascertained from the 1991 follow-up interviews. Incidence of seven conditions (cancer, stroke, myocardial infarction, high blood pressure, diabetes, broken hip, other broken bones) was measured from respondents' reports of newly diagnosed conditions since their baseline interview. A count of new conditions was created as there were insufficient events for analyses of any single condition. Hospitalizations between 1988 and 1991 were assessed from self-reports; a dichotomous (none/any) measure was used here.

Analyses

For the analyses of change in performance, only subjects with both 1988 and 1991 physical performance data could be examined. Comparison of these subjects with those excluded due to death or incomplete 1991 physical performance data indicated that those included in the longitudinal analyses had somewhat higher baseline physical performance scores (5). Those excluded due to mortality were also more likely to be males, to have higher waist-hip ratios, and to have experienced negative health events between 1988 and 1991. Those alive but missing 1991 performance data showed similar but nonsignificant trends.

Changes in physical performance were examined from two perspectives, analogous to previous analyses (5). First, since the 1988 and 1991 summary scores for physical performance were continuous and approximately normally distributed, changes in performance were analyzed via linear regression models with the 1991 summary physical performance scores as the outcome and 1988 performance scores included as a covariate in all models. This strategy results in a modeling of residualized change (i.e., change adjusted for baseline level of physical performance) (17). Each of the three sets or categories of predictors (i.e., behavioral, social or psychological predictors) was evaluated separately to identify variables that were significant predictors of change in physical performance (independent of sociodemographic and baseline health status characteristics). Multivariable models were developed using a backward stepping procedure (18). Risk factors were retained for the final model if they achieved a significance level of $p \leq .10$. Possible gender-by-risk factor interactions were also tested, and significant findings are reported. All significant behavioral and/or psychosocial factors were then tested simultaneously in a single model. This combined model was then examined with further adjustments for intervening health events between 1988 and 1991. Forward stepping procedures were also examined to evaluate the possibility of improving the models; no additional significant covariates were found.

Nominal logistic regression was also used to model two specific types of change in performance: declines and improvements. Parameters from the nominal logistic models provide odds ratio estimates for two sets of comparisons: "declined" vs "no change" and "improved" vs "no change" (19). The "no change" group included those whose 1991 score was within 0.30 units of their 1988 score. "Decliners" were those whose score *decreased* by 0.30 or more points, while "improvers" were those whose score *increased* by 0.30 or more points. Because performance measures such as ours have only recently begun to be used in community-based research, there are no established clinical or other criteria for "declines" or "improvements" based on such measures. Our criteria approximate the first and third quartiles of the distribution of change scores. The rationale for these criteria were: (a) to identify groups whose changes in performance were as large as possible (i.e., so that they would more likely reflect "real or significant" changes), and (b) at the same time, avoid setting the criteria for "change" so restrictively that the resulting groups would be too small for analysis. Analyses using other cutpoints in this general range produced comparable results.

RESULTS

The mean change in physical performance scores over the 2.5-year follow-up was essentially zero (mean = –.02) as was the median change value (–.01), indicating considerable stability, with a majority of the cohort continuing to score relatively high on the performance tests. However, closer examination of the distribution of change scores revealed that about 23% (n = 195) of the sample had a net *decline* of –.30 or more points, while 22% of the sample (n = 183) showed an equivalent degree of improvement in performance.

Potential behavioral predictors of change in physical performance were examined first. As shown in Table 1, participation in moderate and/or strenuous activity was associated with significant, positive changes in physical performance, independent of sociodemographic and baseline health status. The regression coefficients for participation in either moderate or strenuous activity or both were essentially equivalent, indicating that participation in either or both types of activity conveys the same degree of advantage. Thus, we included a single term indicating participation in either or both of these types of activities in subsequent models.

Table 1. Multivariable Linear Regression Models for Behavioral Predictors of Change in Physical Performance

Behavioral Variables*	b	p-value
Moderate leisure activity (y/n)	.138	.002
Strenuous leisure activity (y/n)	.138	.002
Interaction:		
Moderate × Strenuous Activity	–.137	.04
Ethyl alcohol (oz/month)	–.003	.073
Volunteer work (y/n)	.061	.096
Child care activity (y/n)	–.069	.060
Model R^2	.44	

*Model covariates included baseline physical performance, sociodemographic characteristics (gender, age, race, education, and income) and baseline health status characteristics (body mass index, pulmonary peak flow, cognitive performance, presence of high blood pressure, diabetes, and/or cancer).

For the remaining behavioral measures, only marginal or nonsignificant associations with performance were seen in the multivariable model. However, smoking did have a significant, negative association with change in performance in a simpler model, without adjustments for baseline health status. This effect, however, was reduced to nonsignificance with adjustment for peak lung function.

Among the social network variables, emotional support had the strongest effect on physical performance. An initial, main effects model revealed a marginal, positive association ($b = .055$; $p = .07$). However, inclusion of instrumental support in the model (despite its own nonsignificant association with change in performance) increased the strength of the emotional support effect. Moreover, the association between the two types of support and their respective associations with performance suggested the possibility of an interaction, as the two types of support were positively correlated but their respective associations with changes in performance were in opposite directions: positive for emotional support, negative for instrumental. As shown in Table 2, the "emotional-by-instrumental support" interaction term was significant, contributing to a significant improvement in the fit of the model [$F(2,842) = 3.05$; $p = .05$ comparing models with and without the interaction]. The interaction indicated that greater frequency of emotional support was related to improvements in performance only among those reporting low frequency of instrumental support. This effect is illustrated when separate coefficients for emotional support are calculated for those classified into the "low" and "high" instrumental support groups. In the "low" instrumental support group (where "low" support = average score of < 1 on a scale ranging from 0 [never] to 3 [frequently] and 1 equals "rarely"), the coefficient for emotional support is .172 ($p = .005$). In the "high" instrumental support group, the coefficient for emotional support was .025 ($p = .49$).

Perceived adequacy of emotional support also appeared to be associated with change in performance. In this case, a marginally significant gender interaction was observed ($p = .09$), perceptions of adequacy being associated with declines in performance only among women (see Table 2). Calculation of the gender-specific effects revealed a beta coefficient of −.127 ($p = .01$) for women versus −.015 ($p = .77$) for men.

Table 2. Multivariable Linear Regression Models for Social Predictors of Change in Physical Performance

Social Environment Variables*	b	p-value
Frequency of emotional support (0–3)	.175	.004
Frequency of instrumental support (0–3)	.177	.09
Interaction:		
Emotional × Instrumental Support	−.083	.04
Perceived adequacy of instrumental support (y/n)	.073	.06
Perceived adequacy of emotional support (y/n)	−.130	.01
Interaction:		
Gender × Adequacy of Emotional Support	.111	.09
Model R^2	.432	

*Model covariates included baseline physical performance, sociodemographic characteristics (gender, age, race, education, and income) and baseline health status characteristics (body mass index, pulmonary peak flow, cognitive performance, presence of high blood pressure, diabetes, and/or cancer).

This negative effect of perceived adequacy of emotional support on performance was unexpected. More detailed examination of patterns of change in performance by perceived adequacy revealed that the overall effect was the result of two underlying patterns of change in perceived adequacy. First, among women who reported adequate emotional support at baseline, the largest declines in performance were seen among those whose perceptions of adequacy also declined over time (mean change = −.100, $p = .08$). Second, among women who reported inadequate emotional support at baseline, significant *improvements* in performance were seen among those whose perceptions of the adequacy of their emotional support also improved (mean change = +.14, $p = .04$). Among men, there were no significant differences in change across the subgroups defined by baseline and follow-up perceived adequacy.

Neither network size nor marital status was associated with change in performance; nor was the measure of network conflicts and demands. And, none of the psychological characteristics was associated with changes in physical performance either.

Inclusion of all of the behavioral and social support variables meeting the $p < .10$ criteria in a single, multivariable regression model did not alter the findings (see Table 3, Model 1). They also remained unaltered by further adjustments for interim, negative health events (i.e., incident health conditions and hospitalizations between baseline and follow-up; see Table 3, Model 2). Each of the behavioral and support measures identified previously contributes independently to the prediction of changes in physical performance.

As a final step, nominal logistic modeling of "declines" and "improvements" was examined. As shown in Table 4, testing of a "baseline" model indicated that risk factors for "declines" in performance were generally similar to those identified in the linear regressions. Those reporting any moderate and/or strenuous leisure activities were only half as likely to experience declines in performance. The two social network interactions remained evident as well. Emotional support was associated with reduced risk of decline, but only among those reporting low levels of instrumental support. The gender interaction for perceived adequacy of emotional support again indicated that, among women, perceived adequacy of emotional support was associated with a greater than twofold increased risk of decline in performance. Adjusting for post-baseline, incident conditions and hospitalizations resulted in no notable change in the patterns of association. None of the behavioral or social network measures was significantly related to "improvement."

Discussion

These analyses have identified two potentially modifiable risk factors for change in physical performance. Both physical exercise and emotional support from one's social network were found to predict better physical performance over a 2.5-year follow-up, independent of sociodemographic and health status characteristics. These findings augment our previous report in which significant predictors of better physical performance included younger age, male gender,

Table 3. Multivariable Linear Regression Models for Combined Behavioral and Social Predictors of Change in Physical Performance

	Model 1		Model 2	
	b	*p*-value	*b*	*p*-value
Behavioral Variables*				
Moderate and/or strenuous activity	.135	.001	.138	.0004
Ethyl alcohol (oz/month)	−.004	.05	−.003	.16
Volunteer work (y/n)	.056	.12	.034	.34
Child care activity (y/n)	−.057	.12	−.060	.10
Social Environment Variables*				
Frequency of emotional support (0–3)	.150	.01	.134	.03
Frequency of instrumental support (0–3)	.147	.16	.143	.16
Interaction:				
Emotional × Instrumental Support	−.069	.09	−.066	.09
Perceived adequacy of instrumental support (y/n)	.077	.05	.073	.06
Perceived adequacy of emotional support (y/n)	−.128	.01	−.127	.01
Interaction:				
Gender × Adequacy of Emotional Support	.129	.05	.142	.03
Interim Health Events				
Incident chronic conditions (y/n)			−.096	.01
Hospitalizations (y/n)			−.151	.0001
Model R^2	.446		.466	

*Model covariates included baseline physical performance, sociodemographic characteristics (gender, age, race, education, and income) and baseline health status characteristics (body mass index, pulmonary peak flow, cognitive performance, presence of high blood pressure, diabetes, and/or cancer).

Table 4. Odds Ratios Estimated From a Nominal Logistic Model of Significant Change in Physical Performance

		Decline			Improve		
	p-value	Odds* Ratio	95% CI		Odds* Ratio	95% CI	
1988 Physical performance:†							
Female	.000	1.53	1.07	2.18	0.22	0.16	0.32
Male	.000	1.01	0.66	1.54	0.29	0.19	0.44
Age in 1988 (76 vs 72)	.010	1.32	1.00	1.73	0.77	0.58	1.03
Race (Black vs White)	.110	1.40	0.86	2.26	1.65	0.99	2.77
Education (<12 yrs vs 12+)	.003	1.78	1.18	2.70	0.74	0.47	1.16
Income‡	.017	0.78	0.51	1.18	1.73	1.07	2.79
Body mass index (28 vs 23)	.087	1.13	0.91	1.40	0.82	0.64	1.05
Best peak flow (460 vs 310)	.001	0.71	0.54	0.94	1.50	1.07	2.11
High blood pressure (Y/N)	.004	1.67	1.14	2.44	0.77	0.52	1.14
Diabetes (Y/N)	.045	1.33	0.82	2.16	0.57	0.31	1.05
Cancer (Y/N)	.112	0.63	0.38	1.04	1.16	0.71	1.89
1988 Cognitive score (61 vs 47)	.002	0.78	0.56	1.07	1.63	1.15	2.31
Alcohol§	.133	1.01	0.97	1.06	0.96	0.90	1.01
Average emotional support:‖							
Low instrumental	.044	0.46	0.22	0.95	1.32	0.64	2.71
High instrumental	.276	0.73	0.50	1.08	0.85	0.55	1.31
Adequacy instrumental support	.467	0.81	0.52	1.26	1.15	0.71	1.86
Adequacy emotional support:							
Female	.007	2.30	1.29	4.11	0.85	0.47	1.53
Male	.688	0.84	0.46	1.52	0.78	0.41	1.48
Volunteer activities (Y/N)	.016	0.68	0.44	1.04	1.48	0.97	2.28
Moderate or strenuous activities (Y/N)	.010	0.52	0.34	0.79	0.85	0.53	1.37
Child care (Y/N)	.091	1.35	0.90	2.00	0.75	0.47	1.19

*Odds Ratios reflect comparison of the 25th vs 75th percentile for continuous variables.
†3.13 vs 2.53.
‡$10,000 per year or more.
§2 oz/month vs 0.
‖Per unit change.

higher income, better peak lung function, lower relative weight, absence of high blood pressure or diabetes, and better cognitive performance (8). The fact that the behavioral and social factors remain significant predictors, independent of intervening health events, indicates that they influence performance above and beyond any associations they may also have with changes in health status.

The findings for both moderate and strenuous exercise activity are consistent with previous research showing associations with lower risks for disability and mortality (20–22). Our finding that moderate levels of exercise activity (e.g., walking leisurely) appear to convey similar advantages to strenuous levels of activity (e.g., brisk walking) is also consistent with findings from an exercise intervention study in older adults (23). Most importantly, our data indicate that such behaviors are among the important predictors of maintaining higher levels of physical performance at older ages.

The findings for emotional support are also of interest. While the main effect for emotional support was significant, the significant interaction between emotional and instrumental support indicated that emotional support was most strongly associated with better performance among those reporting the lowest levels of instrumental support. One might speculate that emotional support has a stronger impact on performance in this latter group because it comprises individuals with particularly robust health and ability (i.e., they do not require or solicit much instrumental help). However, since our findings are controlled for levels of baseline physical performance, those reporting high frequency of instrumental support may not differ so much in their actual "instrumental capacities" as in their psychological and/or behavioral patterns of dependency on others. Such patterns may be associated with less self-reliance and "activity" and thereby greater risk of decline in physical performance. Whatever the ultimate explanation, the observed interaction highlights the importance of examining the joint effects of social network characteristics on health outcomes.

To our knowledge, our findings regarding the positive association between emotional support and physical performance are the first such data to be reported. Several possible explanations for this association can be suggested. First, there may be direct physiologic effects of emotional support. Our own data have shown that frequency of emotional support is negatively correlated with levels of neuroendocrine activation as indexed by urinary cortisol, norepinephrine, and epinephrine (10), an association that may reduce risks for various types of pathophysiology and may also influence physical performance, either directly or secondarily. Second, frequency of emotional support may have a positive effect on physical performance through its associations with general patterns of behavior (e.g., exercise and/or social activities). In our case, the association between emotional support and performance was independent of actual exercise activity. However, if frequency of emotional support is associated with greater participation in other activities (e.g., getting together with others to visit or participate in various activities), this could promote better physical performance ability.

Our other finding that, among women, changes in perceptions of the adequacy of emotional support appear to parallel changes in performance suggests again that there may be important links between the social environment and performance. Our two waves of data, however, do not permit determination of the temporal sequencing of these patterns of change.

The potential value of these findings lies in their implications for interventions. Both exercise behaviors and social support represent factors that are amenable to change, although previous attempts at intervention in these areas have met with mixed success with respect to altering health outcomes (23–26). However, the potential value of continued efforts to develop more effective programs is suggested by the apparent, widespread health effects of these factors, including lower risks for "disability" (20,27,28), morbidity (7,29,30), and mortality (21,30). Interventions targeted at these factors thus have the potential to convey multiple health benefits. Our findings suggest that efforts to promote maintenance or improvement in physical functioning might effectively target exercise behaviors and social support in older individuals who may be at higher risk for physical decline but who, as yet, remain relatively healthy.

The strengths of this study include its extensive assessment of subjects' behavioral, social, and psychological characteristics, its use of performance-based measures of physical abilities, and its longitudinal design. The fact that our cohort was initially selected to represent only relatively high-functioning 70–79 year-olds can be viewed as a limitation. However, the observed risk factor associations for sociodemographic, health status, and exercise characteristics are consistent with data from samples with more heterogeneous age and functional status distributions. This suggests that our findings with respect to predictors of higher levels of physical performance ability may generalize beyond the age and functional ranges included in this study.

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