Payette, H., Gueye, N.D.R., Gaudreau, P., Morais, J. A., Shatenstein, B., & Gray-Donald, K. (2011). Trajectories of physical function decline and psychological functioning: the québec longitudinal study on nutrition and successful aging (nuage). *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences, 66B(S1)*, i82–i90, doi:10.1093/geronb/gbq085

Trajectories of Physical Function Decline and Psychological Functioning: The Québec Longitudinal Study on Nutrition and Successful Aging (NuAge)

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Background. Decline of physical function with age is associated with substantial health consequences. Physical and psychological functioning is linked, but the temporal nature of this association remains unclear.

Methods. Three-year follow-up data from men and women (n = 1,741), aged 68–82 years, in the longitudinal study on nutrition and successful aging (NuAge; Québec, Canada) were used. Growth curve modeling was performed to examine trajectories of a global physical performance score across time as conditioned by cognition and depression.

Results. Significant decline in physical function was observed ($p < .0001$). Rate of decline in physical performance score was accelerated in the older participants (>77 years; age^2: $p < .01$) but not affected by slight decline in cognition or depression. Yet, people with lower cognition level and more depressive symptoms show lower physical capacity throughout the entire follow-up period ($p < .0001$).

Conclusions. Physical function significantly declined over 3 years, in particular in the oldest group. A subtle decline in psychological health paralleled decline in physical function but did not accelerate it.

Key Words: Cognition—Depression—Longitudinal change—Physical fitness—Quantitative methods.

PHYSICAL function declines with age, and this decline is associated with substantial health consequences. Whether measured by performance tests or reported capacity, decline in physical function precedes weight change (St-Arnaud-McKenzie Payette, & Gray-Donald, 2010) and is associated with increased risk of frailty (Kuh et al., 2005), disability (Onder et al., 2005), institutionalization (Cesari et al., 2005), and early mortality (Cesari et al., 2005, Rolland et al., 2006). Because disability and frailty place a heavy burden on the health care system (Economic Policy Committee of the European Commission, 2001), there are significant benefits to identifying modifiable individual and environmental factors associated with sustained high functioning and optimal health during aging.

Physical function and cognitive status are known to be linked in cross-sectional studies of both patients with Alzheimer's disease (Auyeung et al., 2008) and among high-functioning free-living older adults (Fitzpatrick et al., 2007). Both longitudinal studies examining muscle strength (Boyle, Buchman, Wilson, Leurgans, & Bennett, 2009) or gait (Deshpande, Metter, Bandinelli, Guralnik, & Ferrucci, 2009) as early predictors of cognitive decline, and studies of cognitive status as a predictor of decline in physical performance (Inzitari et al., 2008; Tabbarah, Crimmins, & Seeman, 2002) have indicated that the temporal nature of this association remains unclear. Declines in cognitive and physical functioning appear to occur together in older adults and prevalence of both ranges from 15% to 25% (Hajjar et al., 2009).

Risk factors of impaired physical performance and cognitive decline have been identified. Older age, lower education, comorbidity, low initial cognitive status, and smoking are well documented. Importantly, depression predicts both physical performance decline (Dalle Carbonare et al., 2009) and cognitive decline (Turvey, Schultz, Beglinger, & Klein, 2009). In addition, in spite of known interrelationships between healthy eating or good nutritional status and optimal physical or mental functioning (Bartali et al., 2008; Koster et al., 2007; Payette, 2005), most analyses have not controlled for nutrition attributes.

Intervention studies to improve physical function and cognition have been carried out. Improving physical function results in improvement in cognitive function in free-living (Liu-Ambrose et al., 2010), frail (Dorner et al., 2007), and cognitively impaired (Carral & Perez, 2007) older adults.

Received April 13, 2010; Accepted September 5, 2010
Decision Editor: Sherry Willis, PhD

Interventions to improve cognition do not appear to lead to improve physical function, but these studies are rare (You et al., 2009).

In the nutrition and successful aging (NuAge) cohort of generally healthy older adults aged 68–82 years, we have had the opportunity to examine change in performance measures of physical function over three years in relation to cognitive status. Using trajectories of decline in physical function by level of psychological functioning measured over time, we examined the extent to which mild cognitive decline and/or mild depression were associated with the rate of decline in physical function while controlling for potential confounders. By tracing the natural history of declines in physical function and factors influencing this decline, the present study provides a better understanding of the associations between trajectories of cognition, depression, and physical decline as people age.

Participants and Methods

Study Sample

Three-year follow-up data from men and women participating in the longitudinal study NuAge were used for these analyses. NuAge is a five-year observational study of 1,793 men and women aged 68–82 years in good general health at recruitment. A random sample, stratified by age and sex, from a population-wide health insurance list (Quebec Medicare database RAMQ), was used to identify participants. Community-dwelling men and women, living in the regions of Montreal, Laval, and Sherbrooke in Quebec, Canada, were included if they spoke French or English, were free of disabilities in activities of daily living, had no cognitive impairment (Modified Mini-Mental State Examination [3MS] score, >79; Teng & Chui, 1987), were able to walk one block or to climb one flight of stairs without rest, and were willing to commit to a five-year study period. Those who had heart failure greater than or equal to Class 2, chronic obstructive pulmonary disease requiring oxygen therapy or oral steroids, inflammatory digestive diseases, or cancer treated by radiation therapy, chemotherapy, or surgery in the past five years were excluded. The number of participants recruited in each age strata are as follows: 70 ± 2 years: 337 women (W), 329 men (M); 75 ± 2 years: 305 W, 289 M; 80 ± 2 years: 298 W, 235 M. Participation rate among eligible participants was 65.3%. Starting December 2003, participants were followed annually and underwent a series of nutritional, functional, medical, biological, and social measurements in four annual follow-ups. Computer-assisted interviews were carried out by trained research dietitians and nurses following rigorous standardized procedures (Gaudreau et al., 2007).

The study was approved by the ethics committees of both the University Institutes of Geriatrics of Sherbrooke and the Institut universitaire de gériatrie de Montréal.

Variables and Procedure

A sex-specific global measure of physical performance was computed as the sum of scores in four tests: standing balance, walking speed (normal and fast), chair stands, and timed “Up & Go” according to a slightly modified method proposed by Guralnik and colleagues (1994). The validity of this global measure has been previously reported in this population (Avila-Funes, Gray-Donald, & Payette, 2006). Four levels of physical performance were created for each of the five tests. A score from 1 (*slowest*) to 4 (*fastest*) was assigned according to the quartile of time needed to carry out the test. With the exception of standing balance, the lowest quartile indicates the best (shorter duration) score. The reverse is true with respect to standing balance. A score of 0 was assigned to those who could not do or did not complete the test because they felt unable to do so. Possible scores range from 0 (*worst*) to 20 (*best*). Seventy-five percent of participants did all four tests, 24% did three, and 1% did two. Some participants refused to do the standing balance test because they were afraid to stand on one foot.

Standing balance.—This is a valid and reliable test measuring maximum time a participant can stand on one foot with hands placed on the waist (Guralnik et al., 1994). The participant, without shoes, is positioned approximately 1 m from a wall and is instructed to stand on one foot lifting the dominant leg to calf level for as long as possible. The test is repeated for the other leg. Timing starts when the participant takes his leg off the ground and stops when the foot touches the ground, the arm position is modified, or if 60-s elapse. The best time is recorded. Only 3% of participants were completely unable to do this test.

Walking speed.—Three lines are marked on the floor (two red lines at 0 and 4 m and one white line at 1 m) according to previous studies (Nelson et al., 2004). Participants are asked to walk twice over the 4-m course at their usual pace. Timing starts when the participant crosses the second line, and time to complete the entire path is recorded. The best time of the two trials is recorded and expressed as meter per second calculated on 3 m. The participant may use a cane, a walker, or walking aid if necessary, but they may not use the aid of another person.

Chair stands.—This test assesses lower extremity function, balance, and coordination. The participant is asked to stand up and sit down from a standard chair as quickly as possible, five times in a row, with arms folded across his chest. Timing starts from the initial sitting position and ends at the final standing position at the end of the fifth stand (Guralnik et al., 1994). Four participants were unable to do this test.

Timed “Up & Go”.—This test evaluates mobility and balance. In its modified version (Podsiadlo & Richardson,

Table 1. Values at Baseline and Mean Changes in Independent and Confounding Variables Over Three-Year Follow-up

	Women (n = 906)			Men (n = 835)		
Variables	Baseline	T4–T1	p	Baseline	T4–T1	p
Age (n = 1,741)	74.5 ± 4.3			74.2 ± 4.1		
Years of education (n = 1,741)	11.3 ± 3.9[a]			11.9 ± 5.0		
Burden of diseases score (0–60; n = 1,741)	4.6 ± 3.1	−0.4 ± 4.0	.138[b]	3.5 ± 2.7	−0.1 ± 3.2	.3989
Physical activity score (0–793; n = 1,737)	90.3 ± 44.9	−12.0 ± 45.5	<.0001	113.0 ± 56.1	−6.5 ± 53.5	.0030
BMI (kg/m^2; n = 1,739)	27.6 ± 4.8	−0.01 ± 1.6	.8157	28.0 ± 4.0	−0.2 ± 1.3	.0008
Cognition (MMMS score: 0–100; n = 1,738)	94.4 ± 4.2	−1.8 ± 5.0	<.0001	93.2 ± 4.5	−2.5 ± 5.0	<.0001
Depression symptoms (GDS score: 0–30; n = 1,735)	5.5 ± 4.4	0.1 ± 3.4	.4782	4.4 ± 3.8	0.05 ± 3.2	.7199

Note: BMI = body mass index; GDS = Geriatric Depression Scale.
[a] Mean ± *SD*.
[b] p Derived from nonparametric test (Wilcoxon); all other p values were for paired t tests.

1991), the participant is seated in a chair with his back against the back of the chair and places his hands on the armrests. He is asked to rise from the chair, walk 3 m at a comfortable and safe pace, return to the chair, and sit down. Use of a cane, a walker, or walking aid is permitted but not the aid of another person. Timing begins when the command is given to rise and stops when the participant is re seated. Criterion and content validity of the Timed "Up & Go" have been established (Podsiadlo & Richardson, 1991).

Cognitive status was measured each year using the 3MS (Bravo & Hebert, 1997; Teng & Chui, 1987). Internal consistency alpha was very good for both French (.82) and English (.87) versions (McDowell et al., 1997). Depressive symptoms were assessed using the 30-item Geriatric Depression Scale (GDS), a valid and reliable instrument for use with older persons. Within a range of 0–30, a score ≥11 and ≤20 indicates "mild depression" with a sensitivity of 84% and specificity of 95% (Brink et al., 1982). Alpha coefficients reported in community-living elderly and nursing home residents ranged from .94 (Yesavage et al., 1983) to .84 (Lesher, 1986), respectively.

Sociodemographic variables included age, sex, educational level (years), marital status, living alone, satisfaction with present income, and smoking status (nonsmoker, former smoker, or current smoker).

Standing height (meters) and weight (kilograms; stadiometer and beam balance, respectively) were measured and used to calculate body mass index (BMI = weight [kilogram]/height [meter]^2).

Burden of disease was measured by assessing reported chronic conditions, which were assessed using the physical health dimension of the OARS Multidimensional Functional Assessment Questionnaire. Level of burden of 20 self-reported chronic conditions (arthritis, high blood pressure, diabetes, etc.) was summarized from a 4-point rating scale of each conditions; a higher score indicates greater burden of disease (Fillenbaum & Smyer, 1981).

Current physical activity, including leisure time, household, and work-related activities carried out in the past week, was quantified using the PASE questionnaire (Physical Activity Scale for the Elderly; Washburn, Smith, Jette, & Janney, 1993). Daily activities are first scored according to the intensity and duration of reported activities and then added to produce a global performance test. Possible scores range between 0 and 793; a higher score indicates a higher level of activity. "Healthy eating" is a multidimensional concept, and its definition generally requires several variables. Appetite was shown to be strongly associated with both diet quality and adequacy in frail (Morley, 2001; Morley & Silver, 1995; Payette, Gray-Donald, Cyr, & Boutier, 1995) and generally healthy (Payette et al., 2007) elderly populations. Quality of appetite was assessed by the following question: "Do you have good appetite? Often, sometimes, never." Those reporting "sometimes or never" were classified as having a "poor appetite" (Payette, 2005; Payette et al., 2007).

Statistical Analyses

Descriptive statistics (means and standard deviations or percentages) for baseline data and difference between baseline (T_1; 2003–2005) and the fourth time point (T_4; 2007–2008) were used to summarize data for male and female participants. A paired Student's t test was used to compare changes from T_1 to T_4. The no-parametric Wilcoxon test was also used for these comparisons as normality of the distributions could not be presumed in most cases. Results were similar for all variables except for burden of diseases score in women, and the nonparametric result was thus reported in Table 1. Analyses were conducted using growth curve modeling to examine trajectories of physical performance across time and impact of cognitive function and depression on these trajectories, after adjustment for potential confounding variables (Bryk & Raudenbush, 2002; Singer & Willett, 2003).

Growth modeling, also called multilevel models for change, takes into account the available measures of participants with incomplete follow-up. It addresses within-person and between-person variability simultaneously from a pair of submodels. The Level 1 submodel describes how physical performance changes over time for each person. The Level 2 submodel describes how these changes differ across people. At each annual measurement, time was scaled as participant's annual assessment date minus his birth date, allowing the number and spacing of measurement occasions to vary from one participant to another (Singer & Willett, 2003). Physical performance score was modeled on a quadratic function of participants' age. As all models were unchanged when men and women were analyzed separately, results are presented for the combined models. Continuous variables were centered at their mean value. Three main steps of analyses were carried out and parameters were estimated with the method of maximum likelihood using SAS PROC MIXED, version 9.1 (SAS Institute Inc., Cary, NC).

Unconditional growth model.—This first step uses an unconditional growth model to describe change in physical performance score. This model partitions and quantifies physical performance score variation across both participant and time. Slopes for age and age^2 defined as random effects reflect changes in physical performance score according to each unit increase in age and provide rate of change in physical performance. The two level submodels were as follows:

$$1: \quad Y_{ij} = \pi_{0i} + \pi_{1i}T_{ij} + \pi_{2i}T_{ij}^2 + \varepsilon_{ij}, \qquad (1)$$

$$\begin{aligned} &2a: \quad \pi_{0i} = \gamma_{00} + \xi_{0i}, \\ &2b: \quad \pi_{1i} = \gamma_{10} + \xi_{1i} \quad . \qquad (2) \\ &2c: \quad \pi_{2i} = \gamma_{20} + \xi_{2i} \end{aligned}$$

Where Y_{ij} is physical performance score variable; T_{ij} = Age − 68 is the measure of age centered at his minus for people i at measurement j; π_{0i}, π_{1i}, and π_{2i} are, respectively, the intercept, slopes for time, and time squared of physical performance score defined as random; γ_{00}, γ_{10}, and γ_{20} are, respectively, average intercept (average of π_{0i}) and average slopes (averages of π_{1i} and π_{2i}) over all participants with no predictor in the Level 2 submodels; We assume that the Level 1 random error $\varepsilon_{ij} \sim N\left(0, \sigma_\varepsilon^2\right)$ The Level 2 errors terms ξ_{0i}, ξ_{1i}, and ξ_{2i} stand for individual differences in Level 1 parameters not explained by Level 2 predictors. We assumed that distributions of (ξ_{0i}, ξ_{1i}, and ξ_{2i}) were multinormal, and their variances and covariances were estimated in the model.

Conditional model with cognition and depression as covariables.—At Step 2, we conditioned the previous model with main independent variables (depression [GDS] and cognition [3MS] scores). In order to estimate how these predictors affect change in physical performance score, they were added in the Level 1 submodel as time-varying variables (Singer & Willett, 2003), and interactions between these variables and age or age^2 were tested. As no interaction term was significant at 5% level, they were removed from the final Model 2 described below.

$$\begin{aligned} &1: \quad Y_{ij} = \pi_{0i} + \pi_{1i}T_{ij} + \pi_{2i}T_{ij}^2 + \gamma_3\text{GDS}_{ij} + \gamma_4\text{MMMSE}_{ij} + \varepsilon_{ij}, \\ &2a: \quad \pi_{0i} = \gamma_{00} + \xi_{0i}, \\ &2b: \quad \pi_{1i} = \gamma_{10} + \xi_{1i} \\ &2c: \quad \pi_{2i} = \gamma_{20} + \xi_{2i}. \end{aligned}$$

Conditional model with independent and control covariables.—At Step 3, control variables were added in the previous model. Time-varying variables such as burden disease (Burden), physical activity (PASE), body mass index (BMI), and appetite (Appetite) were added in the Level 1 submodel. Level of education (Education) and year of birth (yearsB), which are constant over the period for each participant, were entered in the Level 2 submodels, specifically equation 2a for main effect. Interactions with age and age^2 were tested for all confounding variables. Only BMI × Age^2 term was statistically significant and entered into Model 3 described below.

$$\begin{aligned} &1: \quad Y_{ij} = \pi_{0i} + \pi_{1i}T_{ij} + \pi_{2i}T_{ij}^2 + \gamma_3\text{GDS}_{ij} + \gamma_4\text{MMMSE}_{ij} \\ &\qquad + \gamma_5 \mathit{Burden}_{ij} + \gamma_6\text{PASE}_{ij} + \gamma_7\text{BMI}_{ij} + \gamma_8\text{Appetite}_{ij} \\ &\qquad + \gamma_{11}\text{BMI}_{ij} \quad T_{ij} + \gamma_{21}\text{BMI}_{ij} \quad T_{ij}^2 + \varepsilon_{ij}, \\ &2a: \quad \pi_{0i} = \gamma_{00} + \gamma_{01}\text{Education}_i + \gamma_{02}\text{yearsB}_i + \xi_{0i}, \\ &2b: \quad \pi_{1i} = \gamma_{10} + \xi_{1i} \\ &2c: \quad \pi_{2i} = \gamma_{20} + \xi_{2i}. \end{aligned}$$

Results

The study sample consisted of 906 women and 835 men between the ages of 67 and 84 years. Virtually all participants were Caucasian, the vast majority were Canadian-born, and over 75% were native French speakers. At recruitment and on average, 75% of the males were married as compared with 43% of the females, with a lower proportion in the older age group (78+years), especially in women. As a consequence, living alone was observed more frequently in women (40%) than in men (18.6%). Very few participants were current smokers (6%–10%), although almost 60% of men and 30% of women reported being ex-smokers. Most participants (more than 90%) declared themselves to be satisfied with their level of income. Educational attainment was high among cohort members, ranging from 11 to 12 years of schooling on average (Table 1).

Baseline values and change over the three years of follow-up for MMMS, depression, and potential confounders are shown in Table 1. At entrance into the study, all participants had 3MS scores more than 79 with a mean of 94.4 ± 4.2 for women and 93.2 ± 4.5 for men. Depressive symptoms were low in most participants and prevalence of mild depression (score ≥11 and ≤20) was 9.9% overall but higher in women than in men (12.0% vs. 7.6%; p = .002). Score >20 potentially indicating "moderate or severe depression" was observed in only 0.1% and 0.6% of men and women,

Table 2. Values at Baseline and Mean Changes in Physical Performance Variables Over Three-Year Follow-up

	Women (n = 906)			Men (n = 835)		
Variables	Baseline	T4–T1	p[a]	Baseline	T4–T1	p
Timed Up & Go (s)	10.8 ± 2.4[b]	0.8 ± 2.1	<.0001	10.3 ± 2.2	0.8 ± 2.2	<.0001
Standing balance (s)	14.9 ± 17.2	−4.5 ± 13.9	<.0001	22.0 ± 21.5	−6.1 ± 17.4	<.0001
Chair stand test (s)	11.8 ± 4.2	1.4 ± 4.3	<.0001	10.6 ± 3.6	1.4 ± 3.6	<.0001
Normal walking speed (m/s)	1.1 ± 0.2	−0.03 ± 0.2	.0004	1.2 ± 0.3	−0.02 ± 0.2	.0689
Fast walking speed (m/s)	1.4 ± 0.3	−0.05 ± 0.2	<.0001	1.6 ± 0.3	−0.04 ± 0.3	<.0001
Physical performance (0–20)	12.6 ± 4.2	−1.4 ± 3.0	<.0001	12.5 ± 4.1	−1.2 ± 3.1	<.0001

[a] p Value for paired t tests.
[b] Mean ± SD.

respectively. Burden of disease was low, although arthritis was reported in 16.5% of women and 10.9% of men. At baseline, most commonly reported chronic conditions in the total cohort were arthritis (53%), hypertension (47%), circulatory/cardiac problems (46%), and digestive problems (28%). Osteoporosis was also reported by 34% of women. Levels of reported physical activity were moderate in this high-functioning cohort. Nevertheless, poor appetite was reported by 19.7% of women and 15.2% of men. Physical activity levels and 3MS scores declined over time but depressive symptoms did not change significantly. Declines in BMI were observed in men only.

Baseline values for the different performance tests, the composite score of physical performance, and the change in these measures over three years are presented in Table 2. A significant decline in all performance tests was observed with the exception of normal walking speed in men. The global physical performance score significantly declined by 11% in women and 9.6% in men over three years.

Rate of decline and acceleration in that rate of decline in physical performance according to age was statistically significant as shown in Model 1, Table 3 (see parameters for age and age^2). In Figure 1, the association of estimated physical performance scores with age is plotted. Each participant is portrayed with its regression curve representing their three-year contribution to the total picture of decline by age. The thick dark line in Figure 1 represents estimated average physical performance scores and indicates more pronounced declines in the oldest age group. Indeed, regression curves were stable until the age of 77 years and began to decline at an accelerated rate thereafter (Figure 1). This interaction of age with time in physical performance is not unexpected and shows the inevitable problem of greater decline in the older participants.

In contrast, rate of decline in physical performance was not affected by level of cognition in this well-functioning cohort (Figure 2) as no significant interaction between age and cognition was observed (Table 3, Model 2). The parallel trajectories indicate that people with lower cognitive performance on 3MS show lower physical capacity (see intercept, Table 3, Model 2), and this relationship remains present and statistically significant throughout the entire follow-up period (see cognition coefficient, Model 2). Those with a lower cognition coefficient (Table 3, Model 2) level at baseline had the lowest level of physical performance three years later. Similarly, rate of decline in physical performance was not affected by level of depressive symptoms (Table 3, Model 2, and Figure 3). Those with mild or moderate

Table 3. Repeated Multivariate Analysis of Changes in Physical and Cognitive Functions

	Parameter	Model 1	Model 2	Model 3
Fixed effects				
Intercept	γ_{00}	15.1763***	15.1106***	14.7405***
Depression	γ_3		−0.1007***	−0.0690***
Cognitive impairment	γ_4		0.0424***	0.0434***
Controls variables				
Level of education	γ_{01}			0.0599***
Burden disease	γ_5			−0.1281***
Physical activity	γ_6			0.0053***
Body mass index	γ_7			−0.1716***
Appetite (sometime or never)	γ_8			0.4036***
Year of birth				0.0406
Rate of change				
Age[a]	γ_{10}	−0.2971***	−0.3165***	−0.2562***
Age^2	γ_{20}	−0.0072**	−0.0047†	−0.0046†
Age × IMC	γ_{11}			−0.01901†
Age^2 × IMC	γ_{21}			0.0013*
Variance component				
Level 1				
Within-person	σ^2_ε	3.3409***	3.3922***	3.4529***
Level 2				
Initial status	σ^2_0	7.4898***	7.6055***	6.3667***
Variance linear term	σ^2_1	0.1916*	0.2049*	0.2513*
Covariance linear term with initial status	σ_{01}	0.7475†	0.5392	0.2197
Variance quadratic term	σ^2_2	0.0001	0.0002	0.0004
Covariance quadratic term with initial status	σ_{02}	−0.1444***	−0.1185**	−0.0898*
Covariance linear term with quadratic term	σ_{12}	−0.0005	−0.0025	−0.0060
Goodness of fit				
Deviance[b]		29,137.0	28,414.4	26,723.4
AIC		29,157.2	28,438.4	26,763.4
BIC		29,212.1	28,504.0	26,873.0

Note: AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion.
[a] Age = participant's annual assessment date minus his birth date.
[b] Deviance = −2LL, where LL is the log-likelihood value.
†p < .10; *p < .05; **p < .01; ***p < .001.

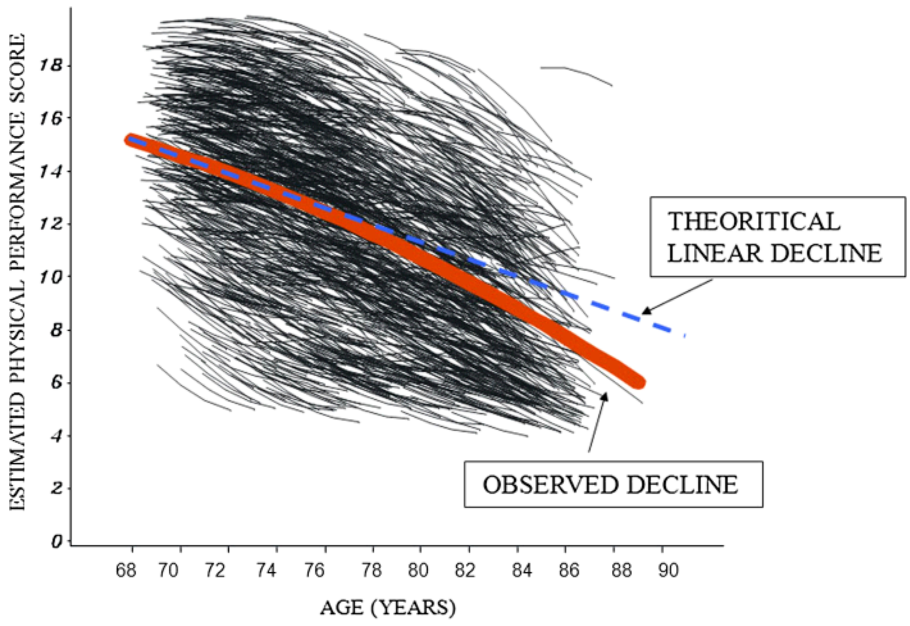

Figure 1. Association of age with physical performance trajectory.

depression show lower physical functioning; however, the slope of this relationship did not change over time whether the person was more or less depressed. Finally, acceleration in the rate of decline in physical performance, as assessed by age^2, was no longer statistically significant with the introduction of main predictors, cognition, and depression, indicating that this acceleration disappears when psychological variables are introduced in the model.

Adjusting for confounders did not change the associations of cognition or depression with physical performance (Table 3, Model 3). Both higher levels of education and physical activity were significantly associated with higher physical functioning, whereas higher BMI, poor appetite, and heavier burden of disease were independently associated with lower physical performance. None of the confounders were found to be associated with rate of decline in physical performance score with the exception of BMI where the negative impact of high BMI on physical performance was found to be attenuated as people aged, as indicated by the significant interaction term (Age^2 × BMI, Table 3, Model 3).

Discussion

In this well-functioning cohort, we found that physical function significantly declined by an average of 11% in women and 9.6% in men over three years and that age was a significant predictor of this decline. Indeed, the oldest participants decline more rapidly than younger ones. This was illustrated by a clear statistical interaction between age and time in relation to change in physical performance.

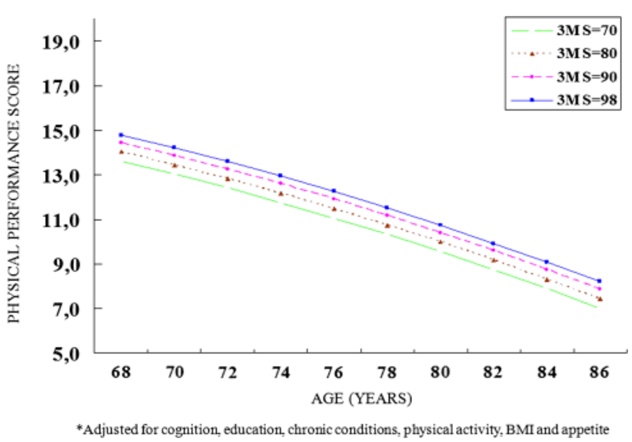

Figure 2. Association of age with physical performance by level of cognitive function.

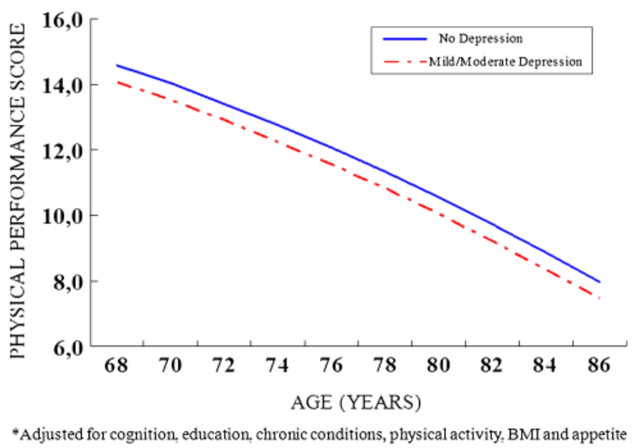

Figure 3. Association of age with physical performance by level of depressive symptoms.

On the other hand, three-year gradual changes in cognitive status, as measured by the 3MS, were small in this cognitively healthy cohort at recruitment. Indeed, the mean decrease in 3MS score was only 1.9% in women and 2.7% in men. This may explain the lack of association of cognition with rate of decline in physical function. The same was true with respect to depressive symptoms where mild depression (score ≥11 and ≤20) was observed in less than 10% of the study participants and moderate or severe (score >20) in less than 1%. Furthermore, we did not observe a significant increase in depressive symptoms in the course of the follow-up.

Nevertheless, despite the absence of clinically significant cognitive or depressive symptoms, both conditions were shown to be significantly related to physical function over the course of the study. This indicates that a subtle but not clinically significant decline in psychological health parallels decline in physical function, suggesting promising avenues for intervention. Slowing down decline in psychological functioning observed in the course of aging could be associated with maintenance of better physical functioning. However, one could not exclude that, although models were adjusted for known risk factors, it is still possible that an unknown factor related to both psychological and physical functioning be responsible for the observed relationship. Furthermore, the causal order of adjusted covariates cannot be clarified by analyses carried out in this study. Indeed, cognitive decline and depression symptoms could have been consequences rather than causes of the observed age-related decline in physical function. However, our results show that very little of the latter is associated with psychological functioning.

Our results also highlight that the effect of age on rate of decline in physical function (see Model 2, coefficient of age^2) is confounded by other participants' characteristics, such as cognitive and depressive status. These results emphasize the often-mentioned difference between chronological and biological age and also important role of modifiable health or lifestyle factors in the quality of aging (Bortz, 2010).

As shown previously, education (Gjonca, Tabassum, & Breeze, 2009) and chronic conditions (Chang, Weiss, Xue, & Pried, 2010) were associated with physical function. More importantly, potentially modifiable lifestyle factors, such as physical activity, BMI, and appetite, were found to be independent predictors of physical function. Hence, encouraging increased physical activity and improving nutrition may attenuate decline in physical performance even in very old people. Furthermore, in a previous study, maintenance of a good appetite in aging was shown to be unrelated to body weight or chronic conditions but to reflect diet quality, good mental health and functional capacity, and a more satisfying social network and quality of life (Payette et al., 2007). Appetite could represent a marker of healthy eating that is very easily measured in a clinical or population setting.

Obesity was shown to be associated with limitations in physical functioning, such as mobility (Koster et al., 2007). Our results suggest that the negative impact of high BMI on physical performance attenuates at older ages. In view of the present uncertainty with respect to health consequences of obesity, as measured by BMI, in the elderly (Rejeski, Marsh, Chmelo, & Rejeski, 2010), our results emphasize the need for further research in this area.

It is worth mentioning that, as observed in all longitudinal studies, reasons for lost to follow-up are likely to be related to exacerbation of chronic conditions or occurrence of health event that are closely linked to the outcomes of interest. This has probably caused underestimation of the decline in physical and psychological functioning observed in our study as well as their relationship. However, the magnitude of this underestimation is likely to be low as the total proportion of lost to follow-up over the three-year period was only 13.3%, including 8.1% refusals, 3.7% deaths, and 1.5% other reasons.

In conclusion, declines in functional status in a well-functioning cohort are consistently present over a three-year follow-up with the greatest declines seen in the older participants. However, taking into account psychological factors (cognition and depression), this acceleration in decline in physical function with age is no longer apparent. Those with lower cognitive scores or more depressive symptoms had poorer physical function at baseline and over the course of the study, but this was not exacerbated over time.

Funding

This work was supported by the Canadian Institutes of Health Research (Funding Reference Number 62842) and the Fonds de la Recherche en santé du Québec.

Acknowledgments

The authors express their sincere thanks to the 1,793 enthusiastic men and women enrolled in this longitudinal study and to the research personnel involved in the NuAge study (coordinators, dieticians, nurses, laboratory technicians, and secretaries) for their dedicated work.

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