Physical functioning inconsistency as a marker for mild cognitive impairment

by

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ABSTRACT

Current classification systems for identifying individuals at the earliest stages of dementia, based primarily on cognitive measures, may be limited in scope. The present study examined physical functioning in a sample of 304 nondemented, older adults, classified based on presence and severity of mild cognitive impairment. In general, lower levels of physical functioning and greater inconsistency in physical functioning were found in older participants and in participants with increasing severity of cognitive impairment. Evaluation of the combined and unique contributions of level of and inconsistency in physical functioning to predicting cognitive status group membership revealed that, for some physical measures, inconsistency in physical functioning provided unique information beyond level of performance. These results are consistent with the notion that inconsistency in performance may be a behavioural marker of compromised neurological functioning and that information regarding physical functioning may prove useful for identifying individuals at the earliest stages of dementia.

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Introduction

Cognitive Decline

Substantial controversy surrounds current opinion on the early stages of cognitive decline in elderly individuals. Although it is no longer believed that all individuals will experience the same downward trajectory once a certain threshold age is attained, the risk for developing dementia undeniably increases as we approach old age. Thus, at age 85 the odds of having a significant cognitive impairment are one in three (Petersen, 2003). Given the costs to society, family, and the affected individual, the hope of many in the health care field is to develop safe and effective treatments that may prevent or delay the onset of dementia in individuals deemed to be at risk.

Unfortunately, it remains difficult to distinguish those individuals in the earliest stage of dementia from those showing age-associated normative decline. The terms benign senescent forgetfulness, mild neurocognitive disorder, borderline dementia, cognitive impairment no dementia (CIND), and mild cognitive impairment (MCI), are a few of the many labels that have been used to describe elderly individuals showing signs of cognitive impairment insufficient to meet criteria for dementia (Collie & Maruff, 2002). There is much debate as to what criteria must be met to differentiate these mildly impaired individuals from normals. There is equal controversy concerning the prognosis of individuals deemed to be slightly impaired.

A recent review of longitudinal studies demonstrated highly variable outcomes for elderly individuals showing signs of impairment (Tuokko & Frerichs, 2000). The authors found that across studies, approximately 50% of individuals identified as CIND (an umbrella term encompassing objective evidence of cognitive impairment according to

various criteria sets) progressed to dementia over five years. However, the rate of progression to dementia across studies ranged from 12% to 72%. Issues that have limited the relevance and generalizability of these findings were identified. These issues include inconsistencies in sample definition, limitations in sample selection, and methodological problems with studying change over time. Despite these limitations, however, one robust finding that has emerged is that individuals identified as CIND do progress to dementia at a markedly higher rate than healthy controls. Across studies, the rate of progression to dementia in CIND groups was approximately five times that of normals.

In a similar review, Palmer, Fratiglioni, and Winblad (2003) reported comparable variation in conversion from MCI (variously defined) to dementia across longitudinal studies. These authors also highlighted evidence of differential evolution of individuals identified as cognitively impaired. Recent results of longitudinal studies have suggested that an impaired individual's risk of developing dementia may be time dependent. Specifically, the risk of progressing to dementia may be highest over about a three-year period, after which the progression rates show evidence of decline (Braekhus, Laake, & Engedal, 1995; Johanson, Zarit, & Berg, 1992; Palmer, Wang, & Baeckman, 2002). Furthermore, a large number of individuals identified as impaired have been found to improve over follow-up intervals of one to three years at rates ranging from 7% to 25% (Larrieu et al., 2002; Palmer et al, 2002; Ritchie, Artero, & Touchon, 2001; Wolf et al. 1998).

Following the 1999 Current Concepts in Mild Cognitive Impairment conference, Petersen et al. (2001) proposed a specific diagnostic criteria set for MCI (Amnestic) as a likely precursor of Alzheimer's disease. This criteria set includes subjective and

objective evidence of memory impairment, a key feature in Alzheimer's disease diagnosis, and intact activities of daily living. The authors propose that other types of MCI may exist and may represent precursors to other forms of dementia or disease. For example, a diagnosis of MCI (Single Nonmemory Domain) with a language deficit could be a precursor to a primary progressive aphasia. A diagnosis of MCI (Multiple Domains Slightly Impaired) could lead to a variety of disorders including Alzheimer's disease or other dementias.

Petersen et al.'s (2001) criteria for MCI (Amnestic) are based on a similar criteria set used in a longitudinal study reported by Petersen et al. in 1999. The authors found clinic-referred individuals identified as MCI (Amnestic) progressed to Alzheimer's disease at a rate of 12% per year. The rate of progression in the MCI group was intermediate to the rate of progression in a healthy control group and a mild Alzheimer's disease group. While these results seemed promising, a population-based validation study using the same criteria sets found conversion rates of only 11% over three years (Ritchie et al., 2001). Furthermore, a recent attempt to validate the Petersen et al. (2001) proposed subtypes of MCI as predictors of specific disorders in a sample of 1045 elderly individuals over 2.6 years did not show positive results (Busse, Bischkopf, Reidel-Heller and Angermeyer, 2003b).

Although the Peterson et al. (2001) MCI criteria set has become increasingly prevalent in the literature, there is still no consensus as to the best criteria for identifying individuals at risk for dementia. The comparative predictive value of a number of criteria sets for MCI has been reported in recent longitudinal investigations. Larrieu et al. (2002) compared the dementia conversion rates for individuals identified as MCI (Amnestic)

according to the Petersen et al. (2001) criteria and a group of individuals showing cognitive impairment, but failing to meet criteria for MCI or dementia (including individuals with no subjective impairment). The authors found that conversion rates for Alzheimer's disease was similar in both groups, but that the second group had higher rates of conversion to any dementia.

Busse et al. (2003b) compared dementia conversion rates using the three Petersen et al. (2001) MCI subgroups. They found the best positive predictive value and sensitivity to specificity ratios in a modified, merged MCI group that encompassed all three subtypes and excluded the criterion of a subjective cognitive complaint. Similarly, a second investigation comparing the predictive validity of Petersen et al.'s (2001) MCI (Amnestic) and Levy et al.'s (1994) more broadly defined Aging-Associated Cognitive Decline (AACD) found the best sensitivity to specificity ratios in a modified AACD group that excluded the criterion of a subjective cognitive complaint (Busse et al., 2003a)

Tuokko et al. (2003) examined the status of a large, population-based sample of individuals with either no cognitive impairment (NCI) or CIND at baseline after a five-year follow-up interval. Diagnoses of CIND at baseline were based on clinical evidence of cognitive impairment and exclusion of dementia. Individuals identified as CIND at baseline were further classified according to the presumed cause of impairment (e.g. age-associated memory impairment, long-term alcohol use, mental retardation, vascular conditions, etc.). Consistent with previous reports, the authors found that slightly less than half of the CIND sample progressed to dementia over five years. The rates of conversion to dementia were the same across all CIND subgroups. However, when the

analyses were restricted to include only those who developed Alzheimer's disease, indicators of baseline memory impairment emerged as a single significant predictor.

In general, these findings support the utility of using memory-based diagnostic criteria for identifying individuals most likely to develop Alzheimer's disease. These results also suggest that a broader MCI definition has utility for identifying individuals most likely to develop any dementia diagnosis. Still, as Palmer et al. (2003) conclude, "it is currently still impossible to identify with high predictivity, subjects that are at risk of progressing to dementia by only using a psychological test battery" (p. 19). In order to better identify individuals at the earliest stages of cognitive decline, it may serve to reexamine the problem through a wider lens. The proposed study will investigate the relationship between MCI and physical status in hopes that a broader assessment will lead to more accurate identification of individuals most likely to develop dementia. For the purposes of the present study the term MCI will be used to refer to individuals with objectively evident impairment in any cognitive domain.

Physical Decline

In parallel to the commonly observed cognitive decline in elderly individuals is the often more visible physical decline. As with mental decline, extensive research has been conducted to determine the optimal practices for slowing progressive physical decline. Physical exercise is a well-established means to maintain function and promote general good health. The benefits of regular physical activity have even been reported to extend to cognitive function.

Spirduso (1975) published a classic study of racquet sportsmen and reaction time. His research compared young and old, active and nonactive men on measures of simple

and choice reaction time. The most striking finding was that older active men had reaction times and movement times similar to younger active and nonactive men, and dramatically faster than older nonactive men. Although these findings are limited by the correlational nature of the research, Spirduso proposed that the faster processing time in the active individuals may be due to overall positive health benefits of a healthy cardiovascular system, or due to increased stimulation of neuronal cells during physical activity.

In a related study, Rikli and Edwards (1991) followed previously sedentary exercising and non-exercising women aged 57-85. They found that the performance of exercisers on tasks of simple and choice reaction time tended to improve over the course of three years of aerobic activity, while the performance of non-exercisers declined over the same time period. Unfortunately, the lack of random assignment of participants to exercise and non-exercise groups limits the conclusions that can be drawn from these findings. However, research has continued in this vein and positive cognitive effects of exercise continue to be demonstrated.

Dustman et al. (1994) conducted a four month controlled study of the cognitive effects of aerobic exercise in sedentary individuals aged 55-70. Participants were assigned to an aerobic exercise group, a non-aerobic strength and flexibility training group, or a non-exercise group. The aerobic training group demonstrated significant gains on neuropsychological tests of response time, visual organization, memory, and mental flexibility. On average, the non-aerobic group demonstrated test score gains on a milder scale and the non-exercise group showed no significant test score improvement. Based on the lack of improvement in sensory threshold measures in the aerobic exercise

group, the authors proposed that aerobic exercise has direct benefits on central rather than peripheral nervous system mechanisms. The mechanism for improved neuropsychological test performance in the exercisers was proposed to be the increased availability and utilization of oxygen in the brain and other tissues that occurs as a result of aerobic and, to a lesser extent, non-aerobic training.

A recent report based on data from the Canadian Study of Health and Aging (Laurin, Verreault, Lindsay, MacPherson, & Rockwood, 2001) is noteworthy. The authors studied a large community sample of individuals age 65 and over and assessed levels of physical activity and the incidence of cognitive impairment and dementia at baseline and at five-year follow-up. Results suggested that regular physical activity significantly reduced the risk of developing cognitive impairment or dementia over a five-year period. This pattern was especially strong in the female population where a significant trend was observed between higher levels of physical activity and decreased risk of cognitive decline. However, this study is also limited by its correlational nature.

The link between the physical and the mental domains in the study of aging has received attention from another angle. Strong correlations observed between physiological decline and cognitive decline have led some authors to believe in a 'common cause' theory of aging (Lindenberger & Baltes, 1994). These researchers suggested that both cognitive and physical decline in aging are symptoms of the same (single) general mechanism of aging. This theory evolved out of results of an interdisciplinary study of aging whose finding suggested that age-related variance in intelligence can almost completely be accounted for by measures of visual and sensory acuity. A larger, follow-up study supported this assertion (Baltes & Lindenberger, 1997).

Furthermore, comparisons between young and old adults supported the notion that the link between sensory and intellectual functioning is much stronger in old age. Consistent with their 'common cause' hypothesis, the authors reported a high correlation between measures of sensory acuity and a measure of sensorimotor functioning (balance/gait).

The link between the physiological and the cognitive components in aging has been examined in other studies. Anstey and Smith (1999) looked at the relationship between a comprehensive measure of physiological integrity or biological age called BioAge (comprised of measures of vision, hearing, forced expiratory volume, and grip strength) and cognitive test performance. The authors studied a group of aging women and found their data supported a structural equation model in which BioAge explained all of the age-related variance in a general cognitive factor, comprised of measures of fluid and crystallized intelligence, spatial ability, working memory, and perceptual speed. Physical activity and health were found to have direct effects on BioAge. In terms of the five tested cognitive domains, regression analyses showed considerable overlap between the BioAge- and age-related variance in each domain except crystallized intelligence, in which BioAge accounted for a significant proportion of variance (12%) after controlling for age. The authors claimed that these results support the notion that biological age can be considered a better index of physical status and maturation than chronological age alone.

Data from a recent longitudinal study (MacDonald, Dixon, Cohen, & Hazlitt, 2002) offer further support for the application of biological age as a predictor of cognitive change, independent of chronological age. In a group of 125 adults aged 67-95, the authors found that a composite biomarker factor (indexing vision, hearing, grip strength,

and peak expiratory flow) predicted cognitive decline over a 12 year period over and above chronological age.

Taken together, the exercise/cognition literature and the physical/mental aging literature demonstrate a strong link between cognitive function and physical status. Furthermore, this research offers support for the possibility that those showing early signs of cognitive impairment may also show signs of accelerated physical decline.

Inconsistency

Another area of study potentially relevant to the differentiation of individuals at risk for developing dementia is that of intraindividual variability or inconsistency. Research in this area has demonstrated that short-term inconsistency in an individual's performance in certain tasks is a measurable trait and may be indicative of general neurological impairment (Hultsch, MacDonald, Hunter, Levy-Bencheton, & Strauss, 2000). A number of studies have demonstrated higher levels of inconsistency in reaction time tasks in elderly individuals compared with younger individuals (Salthouse, 1993; Fozard, Vercruysse, Reynolds, Hancock, & Quilter, 1994; Anstey, 1999; Hultsch, MacDonald, & Dixon, 2002). Inconsistency in sensorimotor status in the elderly has also been documented (Ferrandez, Durup, & Farioli, 1996; Li, Aggen, Nesselroade, & Baltes, 2001).

One theory that has been proposed to explain increased inconsistency in the elderly suggests that age-related decreases in the efficiency of neural transmission could account for the behavioral manifestation of inconsistent performance (Li and Lindenberger, 1999). Consistent with this idea are elevated levels of variability observed in individuals with neurological disorders. This phenomenon has been documented in

reaction time tasks performed by individuals with epilepsy (Bruhn & Parsons, 1977) and traumatic brain injury (Bruhn and Parsons, 1977; Collins & Long, 1996; Stuss et al., 1989; Bleiberg, Garmoe, Halpern, Reeves, & Nadler, 1997; Hetherington, Stuss, & Finlayson, 1996). Elevated cognitive variability has also been observed in individuals with Alzheimer's disease (Knotek, Bayles, & Kaszniak, 1990) and mild dementia (Hultsch et al., 2000).

With the demonstrated link between elevated inconsistency on cognitive tasks in both elderly and neurologically impaired populations, it is plausible that individuals identified as MCI might also show elevated cognitive intraindividual variability. Indeed, there is evidence that this is the case. Dixon et al. (2004) found that not only were individuals classified as MCI more inconsistent in cognitive tasks, the amount of inconsistency demonstrated increased with increasing levels of impairment.

Inconsistency has also been studied in the physical domain. Elevated variability in physical status measures has been documented in patients with mild dementia (Strauss, MacDonald, Hunter, Moll, & Hultsch, 2002), Alzheimer's disease (Nakamura et al., 1997) and traumatic brain injury (Burton, Hultsch, Strauss, & Hunter, 2002). Strauss et al. (2002) examined the physical, affective, and cognitive status in three groups of older adults. The authors compared the level of performance and variability in a neurologically impaired (dementia), a non-neurologically impaired control (arthritis), and a healthy control group of individuals. In general, increased inconsistency on physical and affective measures was associated with a lower mean level of cognitive performance. Elevated inconsistency was demonstrated in the neurologically impaired group in both physical performance and cognitive performance. Inconsistency in the physical and

cognitive domains was highly correlated in the neurologically impaired group, but not in the control groups, suggesting the operation of a pathological mechanism affecting both domains. Discriminant function analysis revealed that variability in the physical domain was the most consistently important factor for differentiating group membership.

This research suggests that individuals identified as MCI may show elevated inconsistency in measures of physical status. Indeed, it may be possible to identify individuals with MCI on the basis of variability in physical performance.

Research Questions

The early identification of individuals likely to progress to dementia is an important goal. Despite substantial research in the area, no consensus has been reached as to specific criteria that will effectively capture those individuals at the earliest stage of this downward cognitive trajectory. As most classification systems are based solely on objective and subjective cognitive measures, it is possible that a more complete assessment that includes physical measures will facilitate the identification of individuals in early-stage decline. The link between mental abilities and physical status, especially in aging individuals, is well established. The link between variability in cognitive and physical domains and compromised neurological functioning is also well established.

This research addresses the following questions: (1) Are there age and cognitive status group differences in mean level of physical functioning? (2) Are there age and cognitive status group differences in inconsistency in physical functioning? (3) If so, does inconsistency in physical functioning predict cognitive group status above knowledge of mean level of physical functioning?

If any of these possibilities exist, the application of those findings would have important implications for the study of early dementia. If decreased physical function or increased physical inconsistency reliably differentiates individuals identified as MCI based on cognitive criteria from normals, then the criteria sets for MCI may be refined to incorporate physical criteria. A refined, more comprehensive criteria set for MCI would serve to identify individuals likely to progress to dementia at an even earlier stage than is currently possible.

Method

Participants

Participants in this study were 304 community dwelling elderly individuals between the ages of 64 and 92. Participants were recruited through local media advertisements seeking persons who were concerned about their cognitive functioning, but had not been diagnosed with any neurological disorder. Basic demographic information was obtained at a group testing session along with self-reported health and medication status. Participants also completed cognitive tests of perceptual speed, reasoning, episodic memory, verbal fluency, and vocabulary. A series of standard cognitive measures were administered during an individual intake interview including the mini-mental state exam (MMSE; Folstein, Folstein, & McHugh, 1975), the North American Adult Reading Test (NAART; Blair & Spreen, 1989), the Wechsler Adult Intelligence Scale-III (WAIS-III: Psychological Corporation, 1997) Block Design and Vocabulary subtests, a hand preference test, and the Trail Making Test. Exclusionary criteria included MMSE score of 23 or below.

Procedure

The procedure of the present study was originally reported by Hultsch et al (2000) and Strauss et al (2002). Following a single group testing session and an individual intake interview, participants were tested on five weekly occasions. During each weekly session, participants were assessed on a battery of cognitive, physical, and emotional measures. Order of administration was held constant over the five sessions. Efforts were made to distribute the weekly sessions across the days of the week to the extent that each participant's schedule allowed. Group testing was conducted at the University of Victoria, while intake and weekly sessions were conducted at participant's homes.

Cognitive Measures

Cognitive status was assessed in a single group testing session using measures of perceptual speed, reasoning, memory, verbal fluency, and vocabulary. Descriptions of the specific tasks used to measure cognitive status follow.

Perceptual speed: The WAIS-R Digit Symbol Substitution task (Wechsler, 1981) was used to assess perceptual processing speed. A coding key pairing nine numbers (1 through 9) with nine symbols was presented. Underneath the key were rows of randomly ordered numbers with empty boxes below. The participant was asked to copy as many symbols as possible into the empty boxes based on the digit-symbol pairings in the coding key for 90 seconds. The number of correctly completed items was recorded.

Reasoning: The Letter Series test (Thurstone, 1962) was used to assess inductive reasoning. A series of letters following a distinct pattern was presented. The participant was asked to decipher the pattern in the target string and provide the next letter in the sequence. The number of correct responses out of 20 was recorded.

Episodic memory: A word recall task (Hultsch, Hertzog, & Dixon, 1990) was used to assess episodic memory. One list of 30 English words selected from a total set of six lists was presented. The list contained six words from each of five taxonomic categories typed on a single page in unblocked order. The participant was given two minutes to study the list and five minutes to write the words they could recall. The number of correctly recalled words was used as the measure.

Verbal fluency: The Controlled Associations test from the ETS kit of factor-references cognitive tests (Ekstrom, French, Harman, & Dermen, 1976) was used to assess verbal fluency. The participant was given six minutes to generate as many synonyms as possible in response to a set of target words. The total number of correct synonyms was recorded.

Vocabulary: A recognition vocabulary test was used to assess vocabulary. The test was composed by combining three 18-item tests from the ETS kit of factor-references cognitive tests (Ekstrom et al., 1976). The participant was given 15 minutes to complete a 54-item multiple-choice task. The number of correct items was recorded.

Physical Measures

Physical performance was assessed weekly by measures of balance/gait, grip strength, tapping speed, fine motor dexterity, blood pressure, and respiratory function. Descriptions of the specific tasks used to measure physical performance follow.

Timed walk: The participant was asked to walk a distance of ten feet, turn around, and return to the starting point as quickly as possible. Time to complete the task was recorded.

Turn 360: The participant was asked to turn a full 360-degree turn from a standing position. Total time and number of steps required to complete the turn was recorded.

Grip strength: A dynamometer was used to take a reading from each hand of the participant.

Tapping speed: The participant was asked to repeatedly press a key on a response console as quickly as possible first with their left hand, then with their right. One test session of 48 key presses was administered for each hand following a practice trial of 24 key presses. A laptop computer was used to inform participant of their progress in each test session and to record latency for each key press.

Finger dexterity: The participant was asked to touch each of their fingers to their thumb beginning with their little finger. Time to complete three entire sequences was recorded for each hand.

Blood pressure and pulse: Systolic and diastolic blood pressure and pulse were measured using an electronic monitor. Measures were taken from above the elbow of the right arm with the participant in a seated position.

Peak expiratory flow: The participant was asked to blow as hard as possible into a peak flow meter. The volumes of three successive attempts were recorded.

Group Classification

Age and cognitive status group membership were assigned according to the procedures outlined by Dixon et al. (2004). Participants aged 74 and younger were classified as Young-Old (60 male, 110 female). Participants aged 75 and older were classified as Old-Old (36 male, 98 female). Cognitive status classification was based on

scores from tests of perceptual speed, reasoning, episodic memory, verbal fluency, and vocabulary. Individuals with scores more than one standard deviation below norms in a single cognitive domain were classified as Mild Cognitive Impairment – Single Domain (MCI-S – 23 male, 65 female). Individuals with scores more than one standard deviation below norms in two or more cognitive domains were classified as Mild Cognitive Impairment – Multiple Domains (MCI-M - 34 male, 46 female). All remaining individuals were classified as Not Cognitively Impaired (NCI - 39 male, 97 female). Normative data for cognitive status classification was based on a separate sample of community dwelling older adults between the ages of 65 and 94 (M= 72.75, SD = 5.55) drawn from the Victoria Longitudinal Study of Aging. Norms for perceptual speed, reasoning, verbal fluency and vocabulary tasks were based on data from 445 participants (282 women, 163 men) and norms for the episodic memory task were based on data from 194 participants (125 women, 69 men). The average education of the sample was 14.57 years (SD = 2.95).

An age by cognitive status MANOVA was performed to examine group differences in demographics. Mean scores by age and cognitive status groups are shown in Table 1. The omnibus effects for age ($F(10,286) = 4.577$, $p < .001$, $\eta^2 = 0.138$) and cognitive status ($F(20,572) = 6.026$, $p < .001$, $\eta^2 = 0.161$) were significant. The interaction of age by cognitive status was not significant.

In terms of age differences, univariate analyses revealed that the Old-Old participants had fewer years of education ($F(1,295) = 10.423$, $p < .005$, $\eta^2 = 0.034$), scored lower on the MMSE ($F(1,295) = 20.535$, $p < .001$, $\eta^2 = 0.065$), reported more chronic health conditions ($F(1,295) = 15.159$, $p < .001$, $\eta^2 = 0.049$), and reported more

problems on a self-report of memory functioning ($F(1,295) = 4.970$, $p < .05$, $\eta^2 = 0.017$) than the Young-Old group. The age groups did not differ significantly on NAART IQ discrepancy score, WAIS-III estimated full scale IQ score, self-reported health relative to a perfect state, self-reported health relative to same aged peers, total score on a depression inventory, or gender.

In terms of cognitive status, univariate analyses revealed significant group differences for education ($F(2,295)= 3.705$, $p < .05$, $\eta^2 = 0.025$), total MMSE score ($F(2,295) = 9.919$, $p < .001$, $\eta^2 = 0.063$), NAART IQ Discrepancy score (estimated premorbid IQ minus estimated current IQ) ($F(2,295) = 20.030$, $p < .001$, $\eta^2 = 0.120$), WAIS-III estimated full scale IQ score ($F(2,295) = 43.510$, $p < .001$, $\eta^2 = 0.228$), a self-report measure of participant health relative to a perfect state of health ($F(2,295) = 5.489$, $p < .01$, $\eta^2 = .036$), and total number of chronic health conditions ($F(2,295) = 3.203$, $p < .05$, $\eta^2 = .021$). Post hoc analyses using Tukey's pairwise procedure revealed that the MCI-M group had significantly fewer years of education and scored significantly lower on the MMSE compared to the MCI-S and the NCI groups, which did not differ. All three groups differed on NAART IQ discrepancy and WAIS-III estimated full scale IQ scores with the smallest discrepancy between expected and obtained WAIS-III IQ scores in the NCI group and the largest discrepancy between expected and obtained WAIS-III IQ scores in the MCI-M group. The MCI-M group differed from the NCI group in terms of self-reported relative health and total number of chronic health conditions, but neither group was different from the MCI-S group. The cognitive status groups did not differ significantly on self-reported health relative to same aged peers, total number of chronic

health conditions, self-reported memory functioning, total score on a depression inventory, or gender.

Table 1

Demographic Variables by Age and Cognitive Status

Variable	Young-Old			Old-Old		
	NCI	MCI-S	MCI-M	NCI	MCI-S	MCI-M
Years of Education						
M	16.24	15.43	15.12	14.79	14.91	13.51
SD	2.85	3.15	2.95	3.14	3.01	3.33
MMSE Total						
M	29.28	28.94	28.73	28.77	28.44	27.77
SD	0.80	0.94	1.32	1.27	1.33	1.53
Estimated WAIS-III FSIQ						
M	125.27	119.31	112.29	125.36	116.94	108.58
SD	10.85	11.20	11.62	11.52	12.23	10.18
NAART Estimated IQ Decline						
M	-5.78	-3.79	2.93	-7.44	0.31	1.67
SD	10.29	10.15	9.35	9.46	11.14	9.96
Health Self-Report						
M	4.37	4.22	4.10	4.31	4.12	3.97
SD	0.61	0.54	0.70	0.65	0.81	0.78
Health Compared to Peers						
M	4.55	4.43	4.49	4.52	4.41	4.31
SD	0.55	0.54	0.64	0.59	0.66	0.73

(table continues)

Table 1 continued

	Young-Old			Old-Old		
Variable	NCI	MCI-S	MCI-M	NCI	MCI-S	MCI-M
Number of Chronic Illnesses						
M	17.79	17.48	18.51	18.36	19.38	19.28
SD	2.38	1.80	2.44	2.15	2.74	2.81
Memory Self-Report						
M	25.79	25.70	23.71	24.69	23.03	22.62
SD	5.86	5.93	5.35	6.15	6.39	7.43
Depression Self-Report						
M	7.57	8.22	7.98	8.05	8.03	8.28
SD	1.69	1.91	2.86	2.24	2.26	2.60

Note. NCI = No cognitive impairment; MCI-S = Mild cognitive impairment - Single; MCI-M = Mild cognitive impairment - Multiple.

Data Preparation and Statistical Analyses

Three participants were unable to complete the dominant hand grip strength task and two were unable to complete the nondominant hand grip strength task. Three participants were unable to complete the 360-degree turn task and two were unable to complete the ten-foot walk task. Seven participants did not complete the peak expiratory flow task. Data for these tasks from these participants were not included in the analyses. However, scores were imputed for participants who were missing data from one or more sessions, but who had completed the task on at least one session. Missing values were imputed based on the relationships among responses across trials and within each task using a regression procedure. The percentage of missing values for each physical task ranged from 0.99% for heart rate to 2.96% for peak expiratory flow. Across all physical tasks, 1.65% of values were imputed. As the estimation and substitution of missing data is likely to reduce intraindividual variability, this procedure represents a conservative approach to exploring the issue.

As a preliminary step, outliers were removed from the tapping speed task raw data according to the procedure outlined by Hultsch et al. (2000). Unusually slow responses may reflect participant distraction and dropping such responses minimized error variance. An upper bound was established by computing the mean and standard deviation for each of the age and cognitive status groups. Trials exceeding the mean score by more than three standard deviations were dropped. A regression procedure was used to impute values for outlier trials based on the relationships among responses across trials and occasions. A total of 1.33% of trials were imputed according to this procedure. As noted above, the removal of outlier scores and the estimation and substitution of missing data

are likely to reduce intraindividual variability. Accordingly, these procedures represent a conservative approach to data analysis.

To address the research questions posed, a number of analyses were performed. The first research question asked if there were age and cognitive status group differences in mean level of physical functioning. To answer this question, age by cognitive status by occasion repeated measures ANOVAs were performed for each of the physical measures assessed. Significant differences were probed using Tukey's pairwise procedure.

The second research question asked if there were age and cognitive status group differences in inconsistency in physical functioning. To analyze intraindividual variability, it is necessary to statistically remove from the data any group differences in mean level of performance as well as any systematic effects (e.g. practice effects) (Hultsch et al. 2000, Strauss et al. 2002). Therefore, if group differences in level of performance, occasion effects or the interaction of the two exist, it is necessary to purify the data of these differences. This goal was accomplished by regressing the dependent measures on the age, cognitive status and occasion variables and their interactions, and using the residual scores produced in further analyses. These residual scores were standardized over the entire sample and converted to T-scores to allow comparison of tasks in the same metric. Following the procedures of Hultsch et al. (2000) and Strauss et al. (2002), intraindividual standard deviations (ISD) were computed on the residualized T-scores. To examine possible group differences in intraindividual variability, age by cognitive status ANOVAs were performed for each physical measure using these ISD scores. Significant differences were probed using Tukey's pairwise procedure.

The third research question asked if inconsistency in physical functioning could predict cognitive group status above knowledge of mean level of physical functioning. To this end, logistic regression was used to examine the unique contribution of variability in physical performance to predicting cognitive status group membership.

Results

Mean Level of Performance

To examine group differences in mean level of physical functioning, age by cognitive status by occasion repeated measures ANOVAs were performed for each of the physical measures. Mean performances by age and cognitive status group for each task are shown in Table 2. Significant group differences were probed using Tukey's pairwise procedure. To control for possible confounding effects of demographic variables, age by cognitive status by occasion repeated measures ANCOVAs were run using each demographic variable individually as a covariate. Demographic variables that produced significant variable by occasion interactions were used as covariates in the final age by cognitive status by occasion repeated measures analyses. In accordance with this procedure, participant sex was used as a covariate in the analysis of peak expiratory flow and self-reported health (compared to a perfect state) was used as a covariate in the analysis of dominant hand grip strength.

Results of these analyses showed significant main effects for age for systolic ($F(1,298) = 9.208$, $p < .005$, $\eta^2 = 0.030$) and diastolic ($F(1,298) = 10.233$, $p < .005$, $\eta^2 = 0.033$) blood pressure, grip strength (dominant: $F(1,294) = 26.648$, $p < .001$, $\eta^2 = 0.083$; nondominant: $F(1,296) = 26.318$, $p < .001$, $\eta^2 = 0.082$), steps ($F(1,295) = 33.532$, $p < .001$, $\eta^2 = 0.102$) and time ($F(1,295) = 44.599$, $p < .001$, $\eta^2 = 0.131$) to turn in a circle,

time to walk ten feet ($F(1,296) = 51.229, p < .001, \eta^2 = 0.148$), finger dexterity (dominant: $F(1,298) = 32.063, p < .001, \eta^2 = 0.097$; nondominant: $F(1,298) = 21.097, p < .001, \eta^2 = 0.066$), peak expiratory flow ($F(1,290) = 37.875, p < .001, \eta^2 = 0.116$), and finger tapping speed (dominant: $F(1,298) = 31.925, p < .001, \eta^2 = 0.097$; nondominant: $F(1,298) = 29.298, p < .001, \eta^2 = 0.090$). Young-Old participants had significantly lower systolic blood pressure and higher diastolic blood pressure compared to Old-Old participants. They took fewer steps and less time to turn in a circle and took less time to walk ten feet. Young-Old participants had higher peak expiratory flow than Old-Old participants. Young-Old participants also showed better performance on grip strength, finger dexterity, and finger tapping speed compared to Old-Old participants.

Main effects for cognitive status group were observed for number of steps ($F(2,295) = 3.460, p < .05, \eta^2 = 0.023$) and time to turn in a circle ($F(2,295) = 10.428, p < .001, \eta^2 = 0.066$), time to walk ten feet ($F(2,296) = 17.960, p < .001, \eta^2 = 0.108$), finger dexterity (dominant: $F(2,298) = 12.024, p < .001, \eta^2 = 0.075$; nondominant: $F(2,298) = 11.588, p < .001, \eta^2 = 0.072$), peak expiratory flow ($F(2,290) = 3.486, p < .05, \eta^2 = 0.023$), and nondominant finger tapping speed ($F(2,298) = 4.280, p < .05, \eta^2 = 0.028$). The MCI-S group took fewer steps to turn in a circle than the MCI-M group but the other groups did not differ. The MCI-M group took significantly longer to turn in a circle and to walk ten feet than the MCI-S and the NCI groups, which did not differ. The MCI-M group performed more poorly on finger dexterity and peak expiratory flow than the MCI-S and the NCI groups, which did not differ. The MCI-M group was significantly slower on nondominant hand finger tapping than the NCI group, but the other groups did not differ.

Age by cognitive status group interactions were observed for number of steps ($F(2,295) = 6.617, p < .005, \eta^2 = 0.043$) and time ($F(2,295) = 5.177, p < .01, \eta^2 = 0.034$) to turn in a circle, and time to walk ten feet ($F(2,296) = 4.322, p < .05, \eta^2 = 0.028$). For number of steps and time to turn in a circle, the Old-Old MCI-M group performed significantly more poorly than both the Old-Old NCI and the Old-Old MCI-S groups, which did not differ. Cognitive status group differences were not observed in the Young-Old age group. For time to walk ten feet, the Young-Old MCI-M group performed significantly more poorly than the Young-Old NCI group. In the Old-Old group, however, the MCI-M group performed significantly more poorly than both the NCI and the MCI-S groups, which did not differ.

Occasion effects were found for systolic blood pressure ($F(4,1192) = 10.988, p < .001, \eta^2 = 0.036$), diastolic blood pressure ($F(4,1192) = 5.331, p < .001, \eta^2 = 0.018$), dominant hand grip strength ($F(4,1176) = 3.311, p < .05, \eta^2 = 0.011$), number of steps ($F(3.502,1033.237) = 4.726, p < .005, \eta^2 = 0.016$) and time ($F(4,292) = 9.446, p < .001, \eta^2 = 0.115$) to turn in a circle, time to walk 10 feet ($F(4,293) = 5.564, p < .001, \eta^2 = 0.071$), finger dexterity (dominant: $F(4,295) = 41.219, p < .001, \eta^2 = 0.359$; nondominant: $F(4,295) = 31.827, p < .001, \eta^2 = 0.301$), and peak expiratory flow ($F(4,287) = 4.954, p < .005, \eta^2 = 0.065$). An occasion by age interaction was observed for dominant finger tapping speed ($F(4,295) = 3.159, p < .05, \eta^2 = 0.041$). An occasion by sex interaction was observed for peak expiratory flow ($F(4,287) = 3.551, p < .01, \eta^2 = 0.047$). An occasion by self-reported health (compared to a perfect state) interaction was observed for dominant hand grip strength ($F(4,1176) = 3.209, p < .05, \eta^2 = .011$).

Table 2

Mean Physical Task Performance by Age and Cognitive Status

	Young-Old			Old-Old		
Physical Task	NCI	MCI-S	MCI-M	NCI	MCI-S	MCI-M
Systolic Blood Pressure						
M	134.04	132.71	137.85	138.40	140.08	142.98
SD	14.39	15.15	15.09	16.02	18.13	15.57
Diastolic Blood Pressure						
M	79.52	77.42	80.00	74.67	75.29	76.97
SD	8.58	9.43	9.03	8.17	9.28	8.15
Pulse						
M	69.55	72.47	69.30	69.50	69.21	70.44
SD	9.51	10.16	8.75	8.49	9.56	8.83
D. Grip Strength						
M	34.34	30.74	33.91	26.75	25.85	27.45
SD	9.81	10.61	11.83	8.84	7.39	12.27
N. Grip Strength						
M	32.40	28.89	32.13	25.02	23.99	25.95
SD	9.95	10.34	10.71	8.55	7.35	12.68

(table continues)

Table 2 continued

	Young-Old			Old-Old		
Physical Task	NCI	MCI-S	MCI-M	NCI	MCI-S	MCI-M
360 Turn - Steps						
M	5.93	5.72	5.51	6.72	6.16	7.75
SD	1.65	1.47	1.13	2.09	1.10	2.05
360 Turn - Time						
M	1.94	1.93	2.07	2.34	2.33	3.13
SD	0.40	0.53	0.50	0.75	0.50	1.64
10 Foot Walk - Time						
M	5.25	5.43	5.93	6.14	6.41	8.05
SD	0.90	1.07	1.39	1.35	1.09	3.15
D. Finger Dexterity						
M	3.79	3.89	4.25	4.27	4.52	5.21
SD	0.65	0.76	0.98	0.94	1.01	1.81
N. Finger Dexterity						
M	3.71	3.79	4.33	4.13	4.50	4.95
SD	0.62	0.79	1.34	0.74	0.89	1.94
Peak Expiratory Flow						
M	394.26	392.73	384.44	320.24	300.78	320.56
SD	118.75	126.00	115.49	103.17	80.11	134.70

(table continues)

Table 2 continued

	Young-Old			Old-Old		
Physical Task	NCI	MCI-S	MCI-M	NCI	MCI-S	MCI-M
D. Finger Tap						
M	184.71	192.20	194.19	209.02	215.52	218.14
SD	24.87	31.62	35.00	40.75	34.78	47.92
N. Finger Tap						
M	208.14	217.97	220.13	231.07	246.11	251.22
SD	32.15	39.57	54.34	42.92	39.57	50.76

Note. Mean scores were calculated across performance at each of five occasions. NCI = No cognitive impairment; MCI-S = Mild cognitive impairment - Single; MCI-M = Mild cognitive impairment - Multiple. D = Dominant Hand; N = Nondominant Hand.

Inconsistency in Performance

The systematic effects associated with age, cognitive status, occasion and the interactions of these variables were statistically removed from the data according to procedures described previously and an index of intraindividual variability was computed (ISD) for each physical measure. Separate age by cognitive status ANOVAs were performed on the ISD scores for each physical measure. Significant group differences were probed using Tukey's pairwise procedure. Mean ISDs by age and cognitive status group for each task are shown in Table 3.

Results of these analyses showed significant main effects for age for systolic ($F(1,298) = 11.868, p < .001, \eta^2 = 0.038$) and diastolic ($F(1,298) = 4.160, p < .05, \eta^2 = 0.014$) blood pressure, time to turn in a circle ($F(1,295) = 15.386, p < .001, \eta^2 = 0.050$), time to walk ten feet ($F(1,296) = 18.706, p < .001, \eta^2 = 0.059$), finger dexterity (dominant: $F(1,298) = 17.641, p < .001, \eta^2 = 0.056$; nondominant: $F(1,298) = 15.324, p < .001, \eta^2 = 0.049$), and finger tapping speed (dominant: $F(1,298) = 9.952, p < .005, \eta^2 = 0.032$; nondominant: $F(1,298) = 11.871, p < .005, \eta^2 = 0.038$). Young-Old participants showed less inconsistency for each of these measures compared to Old-Old participants.

Significant main effects for cognitive status group were found for time to turn in a circle ($F(2,295) = 5.164, p < .01, \eta^2 = 0.034$), time to walk ten feet ($F(2,296) = 9.873, p < .001, \eta^2 = 0.063$), finger dexterity (dominant: $F(2,298) = 4.686, p < .01, \eta^2 = 0.030$; nondominant: $F(2,298) = 8.269, p < .001, \eta^2 = 0.053$), peak expiratory flow ($F(2,291) = 6.836, p < .05, \eta^2 = 0.029$), and finger tapping speed (dominant: $F(2,298) = 4.791, p < .01, \eta^2 = 0.031$; nondominant: $F(2,298) = 5.607, p < .005, \eta^2 = 0.036$). Examination of significant group differences revealed that the MCI-M group was more inconsistent in

time to turn in a circle, time to walk ten feet, and nondominant hand finger dexterity than the NCI and MCI-S groups, which did not differ. The MCI-M group was more inconsistent in dominant hand finger dexterity, peak expiratory flow, and finger tapping compared to the NCI group.

Age by cognitive status group interactions were observed for number of steps to turn in a circle ($F(2,295) = 6.240, p < .005, \eta^2 = 0.041$), time to turn in a circle ($F(2,295) = 3.606, p < .05, \eta^2 = 0.024$) and time to walk ten feet ($F(2,296) = 3.710, p < .05, \eta^2 = 0.024$). For number of steps to turn in a circle, the Old-Old MCI-M group was more inconsistent than the Old-Old NCI and MCI-S groups, which did not differ. The cognitive status groups did not differ within the Young-Old age group for this measure. For time to turn in a circle and time to walk ten feet, the Old-Old MCI-M group was more inconsistent than the Old-Old NCI group. The cognitive status groups did not differ within the Young-Old age group.

Table 3

Mean Physical Task ISDs by Age and Cognitive Status

	Young-Old			Old-Old		
Physical Task	NCI	MCI-S	MCI-M	NCI	MCI-S	MCI-M
Systolic Blood Pressure						
M	5.23	5.23	4.61	5.99	6.09	6.08
SD	2.19	2.24	2.25	2.84	2.51	3.16
Diastolic Blood Pressure						
M	5.71	5.73	5.01	6.43	6.26	6.23
SD	3.23	3.50	2.39	3.70	4.07	3.30
Pulse						
M	5.16	4.96	5.30	5.58	5.57	5.96
SD	2.55	2.16	2.83	3.25	3.00	3.70
D. Grip Strength						
M	2.24	2.05	2.06	1.99	1.84	1.84
SD	1.14	1.25	1.22	1.02	1.09	1.01
N. Grip Strength						
M	1.99	1.95	2.09	1.78	1.89	2.01
SD	1.07	1.15	1.01	0.80	0.82	0.80

(table continues)

Table 3 continued

	Young-Old			Old-Old		
Physical Task	NCI	MCI-S	MCI-M	NCI	MCI-S	MCI-M
360 Turn - Steps						
M	4.69	4.47	3.96	4.56	3.86	6.35
SD	3.31	2.33	2.31	2.73	2.54	3.89
360 Turn - Time						
M	2.78	2.86	3.14	3.79	4.11	7.64
SD	1.32	1.43	1.42	2.37	3.33	12.62
10 Foot Walk - Time						
M	2.27	2.48	3.03	2.80	3.85	5.99
SD	1.25	1.76	2.05	1.86	2.07	7.54
D. Finger Dexterity						
M	3.39	3.32	3.74	4.11	5.06	7.09
SD	1.71	2.40	2.10	3.88	3.55	8.01
N. Finger Dexterity						
M	2.80	3.03	3.68	3.23	4.70	5.65
SD	1.54	1.86	2.41	1.84	3.93	5.67
Peak Expiratory Flow						
M	1.83	2.13	2.26	1.95	2.35	2.50
SD	1.01	1.31	1.37	1.18	1.19	1.60

(table continues)

Table 3 continued

	Young-Old			Old-Old		
Physical Task	NCI	MCI-S	MCI-M	NCI	MCI-S	MCI-M
D. Finger Tap						
M	2.82	3.30	3.88	3.65	4.49	4.76
SD	2.01	2.26	3.00	2.22	3.52	2.98
N. Finger Tap						
M	3.07	3.42	4.27	4.43	4.00	5.37
SD	1.75	2.04	3.36	2.57	2.82	2.71

Note. ISDs were calculated across performance at each of five occasions. NCI = No cognitive impairment; MCI-S = Mild cognitive impairment - Single; MCI-M = Mild cognitive impairment - Multiple. D = Dominant hand; N = Nondominant hand.

Predicting Group Membership

Logistic regression was used to determine if inconsistency in physical functioning could predict cognitive status group membership over and above knowledge of mean level of physical functioning. This technique is analogous to a linear regression with dichotomous dependent variables. The odds ratio statistic (*OR*) is the increase in the odds of being in the reference group for every unit increase in a given predictor. An odds ratio greater than one indicates that the independent variable increases the odds of an individual being in the reference group, while an odds ratio less than one indicates that the independent variable decreases the odds of being in the reference group.

Separate analyses were performed for each physical measure. A first set of analyses examined the contribution of mean level of and inconsistency in physical performance to predicting membership in either the NCI group ($n = 136$) or a combined MCI group (comprised of individuals identified as MCI-S or MCI-M; $n = 168$). A second set of analyses was performed within the combined MCI group to determine the contribution of mean level of and inconsistency in physical performance to predicting membership in either the MCI-S ($n = 88$) or MCI-M group ($n = 80$). In both sets of analyses, the more severely impaired group was chosen as the reference group. Results of these analyses are shown in Tables 4 and 5.

The first set of analyses indicated that both mean level of and inconsistency in physical functioning made unique contributions to predicting NCI versus MCI group membership for some measures. Omnibus tests of model coefficients were significant for time to walk ten feet (X^2 (2) = 17.281, $p < .001$), finger dexterity (dominant: X^2 (2) = 11.537, $p < .001$; nondominant: X^2 (2) = 18.167, $p < .001$), peak expiratory flow (X^2 (2)

= 8.614, $p < .05$), and finger tapping speed (dominant: X^2 (2) = 7.901, $p < .05$; nondominant: X^2 (2) = 7.495, $p < .05$).

Mean level of physical performance made significant unique contributions to predicting group membership for dominant finger dexterity ($b = .391$, $OR = 1.479$, $p < .05$) and nondominant finger tapping speed ($b = .006$, $OR = 1.006$, $p < .05$) such that slower performance indicated greater odds of being in the MCI group. Inconsistency in performance made significant unique contributions to predicting group membership for peak expiratory flow ($b = .283$, $OR = 1.327$, $p < .01$) and dominant finger tapping speed ($b = .119$, $OR = 1.127$, $p < .05$) such that higher levels of inconsistency indicated greater odds of being in the MCI group. Neither mean level nor inconsistency in performance made significant unique contributions to predicting group membership for time to walk ten feet and nondominant finger dexterity.

The second set of analyses indicated that both mean level of and inconsistency in physical functioning made unique contributions to predicting MCI-S versus MCI-M group membership for some measures. Omnibus tests of model coefficients were significant for number of steps (X^2 (2) = 7.423, $p < .05$) and time (X^2 (2) = 12.706, $p < .005$) to turn in a circle, time to walk ten feet (X^2 (2) = 15.060, $p < .005$), finger dexterity (dominant: X^2 (2) = 10.386, $p < .01$; nondominant: X^2 (2) = 8.799, $p < .05$), and nondominant finger tapping speed (X^2 (2) = 7.867, $p < .05$).

Mean level of physical performance made significant unique contributions to predicting group membership for time to turn in a circle ($b = .826$, $OR = 2.284$, $p < .05$), time to walk ten feet ($b = .364$, $OR = 1.439$, $p < .01$), and finger dexterity (dominant: $b = .462$, $OR = 1.588$, $p < .05$; nondominant: $b = .423$, $OR = 1.527$, $p < .05$) such that longer

time to complete tasks indicated greater odds of being in the MCI-M group. Inconsistency in performance made a significant unique contribution to predicting group membership for nondominant finger tapping speed ($b = .179$, $OR = 1.196$, $p < .05$) such that higher levels of inconsistency indicated greater odds of being in the MCI-M group. Neither mean level nor inconsistency in performance made significant unique contributions to predicting group membership for number of steps to turn in a circle.

Table 4

Logistic Regressions for NCI vs. MCI Group Membership

Physical Task	*Percent Classified Correctly*	*B*	*SE B*	*OR*	*p*
Systolic Blood Pressure	53.9				
M		.008	.007	1.008	.284
ISD		-.024	.046	.976	.593
Diastolic Blood Pressure	55.3				
M		.004	.013	1.004	.786
ISD		-.024	.034	.977	.492
Pulse	56.9				
M		.012	.013	1.012	.336
ISD		.002	.040	1.002	.968
D. Grip Strength	54.5				
M		-.007	.011	.993	.545
ISD		-.115	.108	.891	.286
N. Grip Strength	55.0				
M		-.016	.012	.985	.195
ISD		.163	.131	1.178	.212

(table continues)

Table 4 continued

Physical Task	*Percent Classified Correctly*	*B*	*SE B*	*OR*	*p*
360 Turn - Steps	54.8				
M		-.031	.076	.970	.685
ISD		.011	.046	1.011	.807
360 Turn - Time	53.5				
M		.189	.230	1.208	.412
ISD		.051	.062	1.052	.416
10 Foot Walk - Time	60.3				
M		.188	.105	1.207	.075
ISD		.132	.076	1.142	.082
D. Finger Dexterity	56.9				
M		.391	.156	1.479	.012
ISD		.011	.045	1.011	.800
N. Finger Dexterity	59.9				
M		.310	.166	1.363	.062
ISD		.134	.069	1.144	.051
Peak Expiratory Flow	58.6				
M		-.001	.001	.999	.506
ISD		.283	.102	1.327	.005

(table continues)

Table 4 continued

Physical Task	*Percent Classified Correctly*	*B*	*SE B*	*OR*	*p*
D. Finger Tap	56.9				
M		.001	.004	1.001	.762
ISD		.119	.058	1.127	.039
N. Finger Tap	56.6				
M		.006	.003	1.006	.041
ISD		.035	.053	1.036	.506

Note. NCI = No cognitive impairment; MCI = Mild cognitive impairment (Combined MCI - Single and MCI - Multiple groups). D = Dominant hand; N = Nondominant Hand.

Table 5

Logistic Regressions for MCI-S vs. MCI-M Group Membership

Physical Task	*Percent Classified Correctly*	*B*	*SE B*	*OR*	*p*
Systolic Blood Pressure	56.0				
M		.019	.010	1.019	.052
ISD		-.045	.062	.956	.468
Diastolic Blood Pressure	57.1				
M		.026	.018	1.026	.142
ISD		-.040	.048	.961	.405
Pulse	52.4				
M		-.018	.017	.982	.292
ISD		.059	.055	1.061	.281
D. Grip Strength	56.6				
M		.017	.015	1.017	.245
ISD		-.050	.140	.951	.721
N. Grip Strength	59.9				
M		.015	.015	1.016	.313
ISD		.081	.171	1.084	.637

(table continues)

Table 5 continued

Physical Task	*Percent Classified Correctly*	*B*	*SE B*	*OR*	*p*
360 Turn - Steps	59.4				
M		.221	.119	1.247	.062
ISD		.038	.067	1.039	.572
360 Turn - Time	61.8				
M		.826	.319	2.284	.010
ISD		-.027	.069	.974	.697
10 Foot Walk - Time	59.0				
M		.364	.131	1.439	.006
ISD		.005	.059	1.005	.938
D. Finger Dexterity	62.5				
M		.462	.195	1.588	.018
ISD		.006	.051	1.006	.906
N. Finger Dexterity	60.7				
M		.423	.198	1.527	.033
ISD		.003	.057	1.003	.957
Peak Expiratory Flow	51.9				
M		.000	.001	1.000	.764
ISD		.094	.116	1.098	.420

(table continues)

Table 5 continued

Physical Task	*Percent Classified Correctly*	*B*	*SE B*	*OR*	*p*
D. Finger Tap	53.0				
M		.001	.005	1.001	.916
ISD		.062	.065	1.064	.341
N. Finger Tap	56.5				
M		-.001	.004	.999	.691
ISD		.179	.072	1.196	.013

Note. MCI-S = Mild cognitive impairment - Single, MCI - M = Mild cognitive impairment - Multiple. D = Dominant hand; N = Nondominant Hand.

Discussion

The present study examined the relationships between physical functioning, age, and cognitive status in a sample of 304 nondemented, community-dwelling older adults. Participants were classified based on age and on the presence and severity of cognitive impairment. Analyses were conducted to examine age and cognitive status group differences in 1) mean level of physical performance and 2) intraindividual variability or inconsistency in physical performance. Finally, the combined and unique contributions of level of physical functioning and inconsistency in physical functioning to predicting cognitive status group membership were evaluated.

The first set of analyses used age by cognitive status repeated measures ANOVAs to investigate group differences in level of physical functioning. Results of these analyses revealed mean differences in level of physical functioning for age, cognitive status, and the interaction of these two variables. As expected, younger age and lower levels of cognitive impairment were associated with greater physical vigour. Age by cognitive status interactions were observed for some measures such that cognitive status group differences were greatest in the Old-Old group.

The second set of analyses used age by cognitive status ANOVAs to investigate group differences in inconsistency in physical functioning. As expected, younger age and lower levels of cognitive impairment were associated with decreased levels of inconsistency in physical performance. Age by cognitive status group interactions were observed for some measures such that cognitive status group differences were greatest in the Old-Old group.

A third set of analyses used logistic regression to determine if inconsistency in physical functioning could predict cognitive status group membership over and above knowledge of mean level of physical functioning. Results revealed that inconsistency in both mean level of and inconsistency in physical functioning made unique contributions to predicting cognitive group membership for some measures. Inconsistency in peak expiratory flow and dominant finger tapping speed made significant unique contributions to predicting group membership over and above mean level of performance information, such that higher levels of inconsistency indicated greater odds of being in a combined MCI (MCI-S and MCI-M) group. Inconsistency in nondominant finger tapping speed made a significant unique contribution to predicting group membership such that higher levels of inconsistency indicated greater odds of being in the MCI-M group.

The present study contributes to the growing body of literature seeking to define and clarify the nature of the early stages of dementia disorders. Despite substantial research in the area, no consensus has been reached as to specific criteria that will most effectively capture those individuals at the earliest stage of these neurodegenerative processes. Current classification systems, based primarily on objective and subjective cognitive measures, may be limited in scope. The results of the current study indicate that groups of nondemented individuals show statistically significant differences both in mean level and in inconsistency of physical performance. Furthermore, level and inconsistency of physical performance make statistically significant combined and unique contributions to predicting cognitive status.

These findings have potential clinical relevance and indicate that a broader assessment of function that includes both physical and cognitive functioning may be

useful in identifying those with MCI. Strauss et al. (2002) examined the contribution of level and inconsistency in cognitive, physical, and affective status to predicting group membership in dementia, arthritis, and healthy control groups. They found that inconsistency in the physical domain was the most consistently important factor for differentiating group membership. An avenue for future research would be the examination of the relative contributions of level of and inconsistency in cognitive, physical, and affective status to predicting MCI status. Longitudinal study would be useful to examine the relationship of these variables to long-term outcome (e.g. conversion to dementia).

The present study provides support for the common cause theory of functional decline in aging (Lindenberger & Baltes, 1994). This theory, based on strong observed correlations between physiological and cognitive decline in aging, proposes that both cognitive and physical decline are symptoms of the same (single) general mechanism. As would be expected if cognitive and physical functioning are increasingly related in old age, lower levels of physical functioning were observed in older individuals and individuals with greater degree of cognitive impairment in the elderly sample under investigation. Furthermore, select interactions between age and cognitive status were observed such that cognitive status group differences in level of physical functioning were greatest in the older age group.

The current study also serves to elucidate the relationship between increasing age and inconsistency in physical functioning. As expected, older adults in this study showed lower mean levels of physical performance. A novel finding of this study is that older individuals also show higher levels of intraindividual variability in the physical domain.

A number of studies have demonstrated elevated inconsistency in cognitive and reaction time tasks in older individuals (Salthouse, 1993; Fozard, Vercruysse, Reynolds, Hancock, & Quilter, 1994; Anstey, 1999; Hultsch, MacDonald, & Dixon, 2002). Other studies have demonstrated elevated variability in physical tasks in individuals with neurological impairment (Burton, et al., 2002; Nakamura et al., 1997; Strauss et al., 2002). The results of the present study are consistent with past research and support the theory that elevated inconsistency in the physical domain is a behavioural marker of increased neurological compromise.

Finally, the results support the notion that measures of physical inconsistency provide interesting and clinically relevant information beyond measures of mean level of performance. Logistic regression analyses revealed that data for both mean level of physical functioning and inconsistency in functioning made unique contributions to predicting NCI versus MCI group membership and MCI-S versus MCI-M group membership. In some cases, inconsistency in physical performance made a significant unique contribution to predicting group membership while mean level of performance did not make significant unique contribution. In particular, inconsistency in peak expiratory flow and dominant finger tapping speed was associated with higher odds of membership in the combined MCI group (MCI-S and MCI-M) and inconsistency in nondominant finger tapping speed was associated with higher odds of membership in the MCI-M group.

Limitations

Potential limitations to the application of these findings include the criteria by which cognitive status group membership was assigned. Considerable controversy and

conflicting research findings exist in regards to the parameters of an optimal criteria set for identifying individuals most likely to progress to dementia. The classification scheme chosen for this study did not require a subjective report of cognitive impairment or objective evidence of a specific impairment in memory. While a number of other existing classification schemes require subjective cognitive complaints and objective memory impairment (e.g. Petersen et al., 2001), results of recent longitudinal studies have shown that conversion rates to dementia are higher when a subjective report of impairment is not required to assign MCI status (Busse et al., 2003a; Busse et al., 2003b; Larrieu et al., 2002). Furthermore, while some studies have shown that specific impairment in memory may yield higher rates of conversion to Alzheimer's disease (Tuokko et al., 2003), research has also shown that broader definitions of mild impairment that do not rely on specific memory impairment yield the highest conversion rates to any form of dementia (Busse et al., 2003a).

Further potential limitations related to the assigning of cognitive group status include the selection of cutoffs for impairment and the designation of severity of impairment. Cutoffs in this study were set at one standard deviation below age and education-based norms. This represents a relatively liberal strategy for identifying impaired individuals and may explain why statistically significant group differences between the not impaired NCI group and the most mildly impaired MCI-S group emerged infrequently in data analysis despite a trend towards poorer performance in the MCI-S group. Whether or not the MCI-S classification truly identifies individuals at a higher risk of dementia than normals is a question that may be answered through longitudinal study.

Severity of impairment in the present study was assigned based on number of cognitive domains impaired rather than severity of cognitive impairment within a domain. Since one of the goals of this study was to examine inconsistency in physical functioning as a marker of general neurological compromise, this strategy fits with the assumption that individuals showing impairment in a greater number of cognitive domains are displaying a greater degree of general neurological impairment than individuals with a severe impairment in a single cognitive domain.

Limitations to the clinical relevance of these findings include the relatively small effect sizes associated with group differences in both mean level and inconsistency of physical performance and the practical difficulties associated with obtaining repeated measures of physical status in a clinical setting. However, given the subtlety of differences in cognitive functioning between the cognitive status groups, the existence of statistically significant group differences in physical functioning is noteworthy. This novel finding warrants future study to examine the potential for measures of physical status and inconsistency to prove useful in identifying individuals at the earliest stage of dementia.

Future Directions

The results of the current study suggest areas for further exploration. Given the cross-domain links between inconsistency in cognitive and physical domains observed in neurologically impaired (dementia) individuals by Strauss et al. (2002), it would be worthwhile to examine if correlations between cognitive and physical inconsistency exist in individuals with less severe neurological impairment (MCI). Results of a recent study

showing higher levels of inconsistency in the cognitive domain according to increasing severity of cognitive impairment (Dixon et al., 2004) suggest that this would be the case.

An investigation of the relationships between level and inconsistency in both cognitive and physical performance longitudinally with the aim of identifying the best combination of variables for optimal identification of individuals likely to progress to dementia is a second area of future study. Measures of change in level and inconsistency over a relatively short-term period (e.g. one to two years) could be investigated as a possible predictor of change over a longer time span. The comparative utility of measures of both physical and cognitive baseline level of performance, level change, baseline inconsistency in performance, and inconsistency change to predict long-term cognitive decline should be evaluated.

Conclusions

In conclusion, the results of the present study are relevant to a number of different bodies of literature. These findings add to research seeking to clarify the nature of early stages of dementia in older adults and are of potential clinical relevance in that area. Results of this study also contribute to the growing understanding of the increasing association between cognitive and physical functioning with increasing age. Further, the results are consistent with the notion that intraindividual variability in performance can be considered a behavioural indicator of neurological compromise. Finally, the results support the notion that measures of physical inconsistency provide interesting and clinically relevant information beyond measures of mean level of performance. These findings suggest a number of avenues for future study including longitudinal follow-up to examine the relationship between physical functioning and impending cognitive decline.

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