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DECLINE ACROSS DIFFERENT DOMAINS OF COGNITIVE FUNCTION IN NORMAL AGEING: RESULTS OF A LONGITUDINAL POPULATION-BASED STUDY USING CAMCOG

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ABSTRACT

Dementia is an important cause of disability in the elderly. There is evidence that cognitive impairment in dementia is on a continuum with cognitive impairment in the non-demented elderly. In order to investigate this possibility, we need detailed knowledge about the population distribution of cognitive function and change in cognitive function. The aim of this study is to describe the change in different domains of cognitive function over 4 years in a population-based sample of non-demented elderly people, and to investigate the effect of sociodemographic variables and baseline cognitive function on change in each of the cognitive domains. Respondents from two group general practice lists ($n = 503$) were interviewed using the Cambridge Cognitive Examination (CAMCOG) at the incidence wave of the Cambridge City Over-75 Cohort Study and after a mean time period of 3.9 years. One hundred and thirty five of 212 non-demented subjects seen at follow-up completed the CAMCOG at both interviews. The annual rate of change in total CAMCOG score was -1.6 points per year ($p < 0.001$). There was statistically significant decline in all of the CAMCOG subscales. Greater decline in the Memory subscale was associated with less education ($p = 0.03$). Greater decline in the Attention/Calculation subscale was associated with manual social class ($p = 0.05$). Greater decline in the Perception subscale was associated with older age ($p = 0.03$). Decline in specific cognitive domains may indicate a reversible phase of cognitive impairment and deserves further investigation. Copyright © 2000 John Wiley & Sons, Ltd.

KEY WORDS—epidemiology; longitudinal; population-based cohort; aged; cognition; neuropsychology; CAMCOG/CAMDEX

INTRODUCTION

Cognitive decline in 'normal ageing' is becoming an area of increasing interest due to the possibility that it may represent a less severe but similar process to that in dementia (Brayne and Calloway, 1988). In Alzheimer's disease there is a sequential decline across specific cognitive domains that reflect the neuropathological changes in the disease. Almkvist and Baeckman (1993) described an initial slow decline in episodic memory followed by a more rapid decline in psychomotor speed, semantic memory and visuospatial function. To accurately compare the cognitive decline in 'normal ageing' with that seen in dementia, we need to investigate change within separate domains of cognitive function, using a sufficiently comprehensive and sensitive instrument. Most studies have applied neuropsychological test batteries to either groups of healthy volunteers that may not be representative of the non-demented elderly, or to entirely unselected population groups that may have included individuals with dementia (Schaie,

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1983; Cornoni-Huntley *et al.*, 1985; Finch and Schneider, 1985). The population-based cohort studies that have examined cognitive decline in non-demented elderly populations are summarised in Table 1. Most of these have reported a decline in global cognitive function as measured by brief dementia screening instruments such as the Mini Mental State Examination or MMSE (Folstein *et al.*, 1975), but have been unable to shed much light upon domain-specific cognitive decline. The MMSE encompasses a number of different domains of cognitive function including orientation, attention, and immediate and short-term memory recall. However, the MMSE cannot be used to measure domain-specific change, because most of the domains are represented by only one or two items, resulting in floor and ceiling effects and insensitivity to change within each area of cognitive function.

Very few population-based studies of cognitive decline in normal ageing have used sufficiently sensitive and broad-ranging tests of cognitive function to enable investigation of change in different cognitive domains. The aim of this study is to describe the change and determinants of change in different domains of cognitive function in non-demented subjects interviewed in a longitudinal population-based study, using a comprehensive measure of cognitive function: the Cambridge Cognitive Examination (CAMCOG). The CAMCOG forms part of the Cambridge Mental Disorders of the Elderly Examination (CAMDEX) (Roth *et al.*, 1986, 1988, 1999). It includes eight subscales that assess different cognitive domains: Orientation, Language, Memory, Attention, Calculation, Praxis, Abstract thought and Perception, allowing investigation of decline in different cognitive domains. In contrast to the MMSE, the CAMCOG is a sensitive measure of cognitive function and has little 'ceiling effect' in the non-demented elderly (Huppert *et al.*, 1995).

METHODS

The subjects

The Cambridge City Over-75 Cohort (CC75C) is an on-going longitudinal study of a population sample of elderly people living in Cambridge (Brayne *et al.*, 1997a). Fig. 1 is a diagrammatic representation of the whole study population and the subsample selected for the study presented in this paper ('CAMCOG subsample').

In 1985, a prevalence survey of dementia was carried out, using the MMSE as a screening instrument (O'Connor *et al.*, 1989). The sample was selected from six group general practice lists and one in three from a seventh general practice list. Two thousand six hundred and nine individuals agreed to participate, which constituted 40% of the population of Cambridge aged 75 or over at that time. Those individuals who scored below 24 on the MMSE, and one in three of those who scored 24 or 25 were interviewed using the diagnostic interview schedule Cambridge Mental Disorders of the Elderly Examination (CAMDEX). The non-demented survivors were re-screened with the MMSE in the incidence wave carried out in 1988–1989 (Paykel *et al.*, 1994). Those who scored below 22, all those whose score dropped by 4 or more points, those scoring 29 or 30 on both occasions, those over age 86 and a random stratified sample of those who scored 22 or above on the MMSE were re-interviewed with the CAMDEX schedule at two separate time points as part of an intensive follow-up programme.

In the incidence wave of the study, participants from the first two general practices (the CAMCOG subsample, $n = 503$) were offered the CAMCOG examination instead of the MMSE at re-screening. Of the participants who consented to use of the CAMCOG, 418 were able to complete the entire test. Of the CAMCOG subsample, 233 were re-interviewed after a mean time period of 3.9 years and 165 of these completed the full CAMCOG. Altogether, 147 participants completed CAMCOGs at the incidence wave and at follow-up. Dementia was diagnosed using the CAMDEX in 12 of the 147 between the two interviews. This paper reports the decline in cognitive function in the 135 subjects who had complete CAMCOGs at both interviews and did not have dementia.

The interviews

All participants were interviewed in their own home or other place of residence at the time of interview. Institutionalised subjects were also included. Trained lay interviewers administered the screening interviews and regular quality control meetings were held. Inter-rater reliability has been reported as satisfactory (Brayne *et al.*, 1995). The diagnostic interviews were carried out by psychiatrists or by a nurse supervised by a psychiatrist. Items that were not answered were coded according to the reason for non-completion. If physical

Table 1. Cognitive decline in normal ageing: population-based studies

Author	Baseline sample size	Follow-up sample size	Test used	Time interval	Change in score for time interval (SD, SE or 95% CI if given)	Comments
OCTO study (Johannson *et al*., 1992)	309 Age 84–90	193	MMSE	2 years	−1.9	Dementia not excluded
Zutphen study (Feskens *et al*., 1994)	544 Men Age 70–89	378	MMSE	3 years	−0.8 in apoE4 carriers −0.1 in non-carriers (adjusted for age and education)	Dementia not excluded
CPLL (Brayne *et al*., 1995)	1741 Age 75+	1111	MMSE	2.4 years	−1.3 (SE 0.09)	Dementias at baseline excluded
MoVIES project (Ganguli *et al*., 1996)	1366 Age 65+	1017	MMSE CERAD	2 years	−0.71 (SD 2.1)	Dementias at baseline excluded
Soham study (Brayne *et al*., 1997b)	365 women Age 70+	237	MMSE CAMCOG	5 years	MMSE: −1.0 (−0.7, −1.4) CAMCOG: −4.7 (−3.4, −5.9)	Dementias at baseline excluded
Canberra (Korten *et al*., 1997)	1135 Age 70+	614	MMSE	3.6 years	−0.5 (SD 2.0)	Dementias at baseline and during study excluded
Bordeaux (Jacqmin-Gadda *et al*., 1997)	2574 Age 65+	1033 seen at 4 visits	MMSE	1, 3 & 5 years	Age 65* −0.02/yr Age 85* −0.5/yr	Dementias at baseline and during study excluded, institutionalised excluded
Edinburgh (Starr *et al*., 1997)	603 Age 70–88	429	MMSE	4 years	−0.3	Subjects with health problems or taking medications excluded
AMSTEL study (Jonker *et al*., 1998)	787 Age 65–84	405	CAMCOG	3 years	−1.35/yr in apoE4 carriers (−0.9, −1.8) −0.4/yr in non-carriers (0.16, −0.64)**	Dementias at baseline and during study excluded

* predicted from model; ** adjusted for age and education.

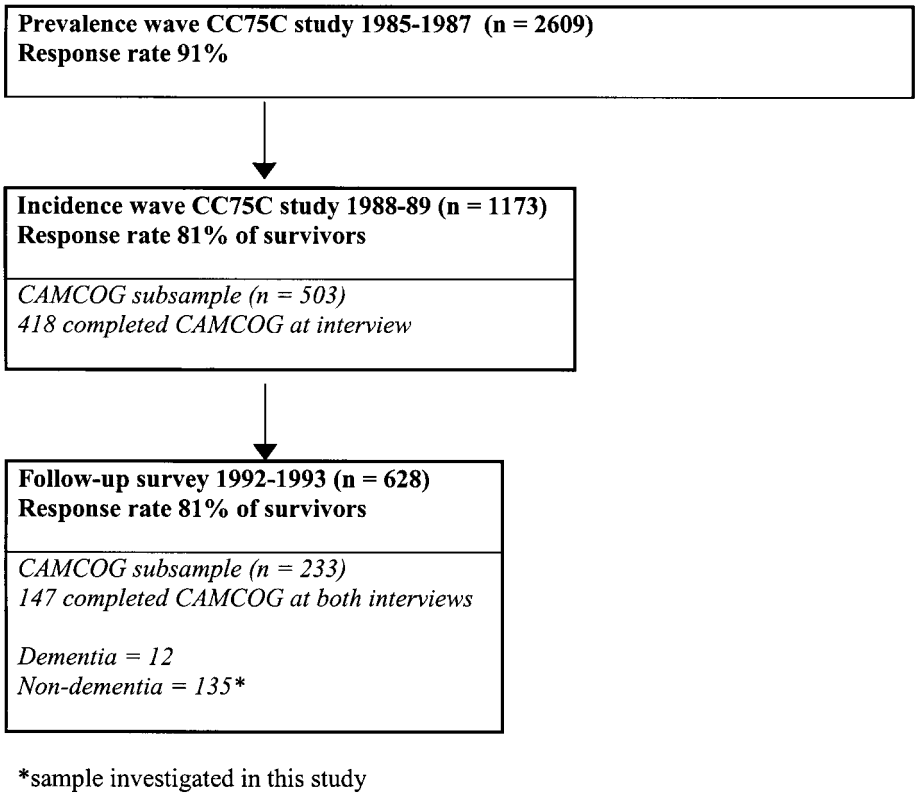

Fig. 1. Diagrammatic representation of CC75C study and CAMCOG subsample

or sensory impairment (for example, stroke or blindness) prevented the individual from completing an item, it was coded as not applicable. Refusal to attempt an item, 'don't know' answers and nonsense answers were all coded separately. As the interviews were conducted in the community, one item in the CAMCOG Perception subscale (asking if the respondent recognises two people in the room) was omitted, thereby reducing the total score from 107 to 106.

The CAMDEX schedule has been reported as a valid and reliable diagnostic interview in this population (O'Connor *et al.*, 1991), and the reliability of the individual CAMCOG subscales has also been reported as acceptable (Huppert *et al.*, 1996).

Statistical methods

Analyses were performed on the data from non-demented subjects in the CAMCOG subsample with complete CAMCOGs at both interviews. Two sample *t*-tests and chi-square tests were used to compare the distributions of sociodemographic characteristics and baseline scores of (i) the group with complete CAMCOG data ($n = 135$) and the remainder of the CAMCOG subsample ($n = 77$) and (ii) the total CAMCOG subsample ($n = 212$) and the remainder of the CC75C study population with no dementia seen at both time points ($n = 353$). Change in CAMCOG subscale score was tested using paired *t*-tests and, due to the skewed distribution of change scores, also with the non-parametric equivalent of the paired *t*-test, the Wilcoxon matched-pairs signed-ranks test. The CAMCOG subscales have different sensitivities to change and therefore quantitative comparison of change is not meaningful. For this reason, the data for the CAMCOG subscales were dichotomised into decline and no decline/improvement in score and entered into a logistic regression model. Age at incidence wave was categorised into two age-groups (75–79, 80+), educational level was categorised into school leaving age < 15 or 15 and

over; social class was grouped into manual and non-manual; and total CAMCOG scores at the incidence wave were grouped as 0–89, 90–106. Due to their brevity and the fact that they measure similar aspects of cognitive function, the Attention and Calculation subscales were combined to form one subscale. All missing items were recoded to zero for statistical analysis. Statistical analysis was performed using STATA, version 5.0.

RESULTS

Of the 503 subjects seen in the CAMCOG subsample at incidence wave, 233 were re-assessed at follow-up between 3.4 and 5 years later. Of the 270 not seen, 159 had died. The remaining 111 were refusals, too ill to be interviewed or lost to follow-up.

Representativeness of the sample

The distribution of age, sex, educational level, social class and MMSE score of the CAMCOG subsample at the incidence wave are shown in Table 2. There were no statistically significant differences in sociodemographic characteristics or initial MMSE score between the group with full CAMCOG data ($n = 135$) and the rest of the CAMCOG subsample with no dementia ($n = 77$). There were also no significant differences in the distribution of sex, educational level, social class and initial MMSE score between the total CAMCOG subsample ($n = 212$) and the remainder of the study population without dementia at follow-up ($n = 353$). The mean age of the total CAMCOG subsample at incidence wave ($n = 212$) was 0.8 years younger than the remainder of the study population who survived to be seen at the follow-up survey ($p < 0.01$, unpaired t-test).

Table 2. Distribution of sociodemographic characteristics and incidence wave MMSE scores in the CAMCOG subsample

	Percentage of CAMCOG subsample with complete data (*n*)	Percentage of the rest of CAMCOG subsample (*n*)	Percentage of total CAMCOG subsample (*n*)	Percentage of the remainder of study population at follow-up (*n*)
Age at incidence wave				
75–79	43 (58)	45 (35)	44 (93)	35 (123)
80–84	44 (59)	43 (33)	43 (92)	43 (153)
85+	13 (18)	12 (9)	13 (27)	22 (77)
Gender				
Males	27 (36)	27 (21)	27 (57)	34 (120)
Females	73 (99)	73 (56)	73 (155)	66 (233)
School leaving age				
<15 years	64 (86)	61 (47)	63 (133)	61 (215)
15+ years	36 (49)	39 (30)	37 (79)	39 (138)
Social class				
Manual	56 (75)	62 (48)	58 (123)	55 (196)
Non-manual	44 (60)	38 (29)	42 (89)	45 (157)
Age at incidence wave				
Mean (SD)	81.5 (3.45)	81.2 (2.98)	81.4 (3.28)	82.2 (3.51)*
MMSE score at incidence wave				
Median (IQR)	27 (24,29)	27 (24,28)	27 (24,28)†	27 (24,28)†
Mean (SD)	26.1 (3.14)	25.8 (3.45)	26.2 (3.00)†	26.0 (2.86)†

* $p = 0.005$ (unpaired two-tailed t-test.
† Only for participants with full data: 195/212 CAMCOG subsample and 316/353 rest of study population.

Table 3. Change in the total CAMCOG score and CAMCOG subscale scores in the CAMCOG subsample ($n = 135$)

	Score at incidence wave Median (IQR) Mean (SD)	Follow-up score Median (IQR) Mean (SD)	Difference Median (IQR) Mean (95% CI)
Total CAMCOG max score = 106	89 (83,95) 87.7 (9.22)	85 (74,92) 81.7 (14.3)	−3 (−12,0) −6.0 (−7.6,−4.4)***
Orientation max score = 10	10 (9,10) 9.4 (0.82)	9 (8,10) 8.8 (1.57)	0 (−1,1) −0.6 (−0.9,−0.4)***
Language max score = 30	26 (24,27) 25.4 (2.41)	25 (23,27) 24.4 (3.21)	−1 (−2,1) −1.0 (−1.5,−0.5)***
Memory max score = 27	22 (21,23) 21.7 (2.84)	22 (19,23) 20.2 (4.73)	−1 (−3,1) −1.5 (−2.1,−0.9)***
Attention-calcualtion max score = 9	8 (6,9) 7.3 (1.82)	7 (5,8) 6.5 (2.24)	−1 (−2,0) −0.8 (−1.1,−0.5)***
Praxis max score = 12	11 (10,12) 10.5 (1.55)	10 (8,11) 9.6 (2.19)	0 (−2,1) −0.8 (−1.2,−0.5)***
Abstract thought max score = 8	6 (4,7) 5.4 (2.39)	6 (3,7) 4.9 (2.56)	0 (−1,1) −0.5 (−0.9,−0.1)***
Perception max score = 10	8 (7,9) 8.0 (1.54)	8 (6,9) 7.3 (2.06)	0 (−2,0) −0.7 (−1.0, −0.4)***

** $p < 0.05$; *** $p < 0.001$ (paired two-tailed t-tests on means of samples).

Change in total CAMCOG and CAMCOG subscale scores

The total CAMCOG and CAMCOG subscale scores at both interviews are summarised in Table 3. Total CAMCOG score declined by a mean of 6 points ($p < 0.001$). The mean annual rate of change in CAMCOG was −1.6 points per year (95% CI −2.0, −1.1). The distribution of the annual rate of change in total CAMCOG score is shown in Fig. 2.

The mean decline in the CAMCOG subscales varied from −0.5 points in Abstract thought to −1.5 points in Memory. All mean declines in the CAMCOG subscale scores were statistically significant. On non-parametric statistical analysis, the declines in the total CAMCOG and the CAMCOG subscales remained significant at $p < 0.001$ except for decline in Abstract thought ($p = 0.02$).

Effect of sociodemographic variables and baseline score on decline in the CAMCOG subscale scores

Table 4 shows the number of participants with decline or no decline for each CAMCOG subscale categorised by age, sex, education, social class, and baseline total CAMCOG score. Greater decline in the Memory subscale was associated with less education ($p = 0.03$). Greater decline in the Attention/Calculation subscale was associated with manual social class ($p = 0.05$). Greater decline in the Perception subscale was associated with older age ($p = 0.03$).

DISCUSSION

Mean findings

The main findings of this study were that the mean decline in total CAMCOG score over approximately 4 years was 6 points. There was also significant decline in all of the CAMCOG subscales. Decline in the Memory subscale was associated with less education, decline in the Attention/Calculation subscale was associated with lower social class and decline in the Perception subscale was associated with older age.

Comparison with previous findings

The mean decline in total CAMCOG score was consistent with the decline of 4.7 points over 5 years reported by Brayne *et al*. (1997b), and with

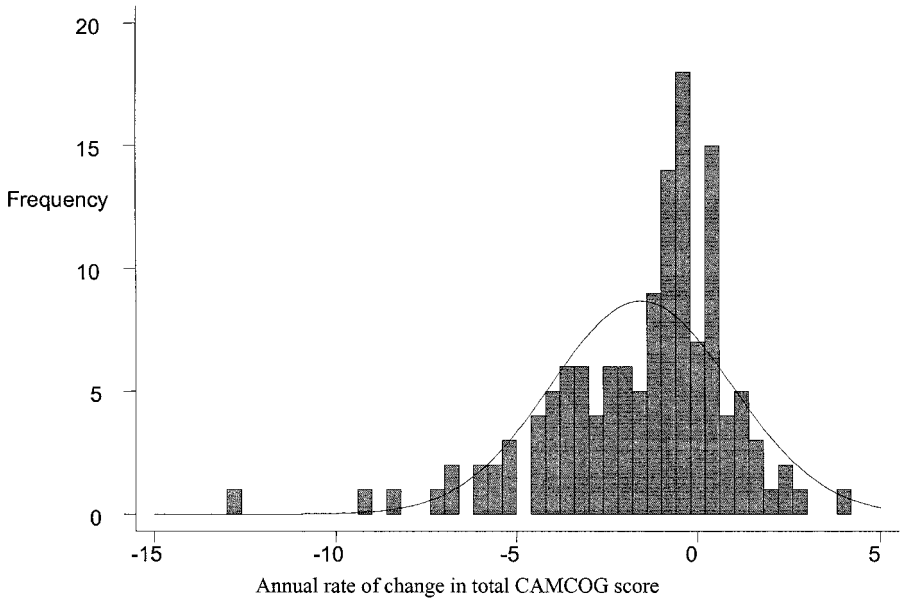

Fig. 2. The distribution of the annual rate of change in CAMCOG scores in the CAMCOG subsample with full CAMCOG data ($n = 135$)

that found by Jonker *et al.* (1998) who reported an annual decline of 1.4 points in apoE4 carriers and 0.4 points in non-carriers. The latter study also reported decline in both the memory and non-memory subscales of the CAMCOG, which is in accordance with our findings of significant decline in all of the CAMCOG subscales. Very few population-based studies have examined the effect of sociodemographic characteristics on decline in specific domains of cognitive function in the non-demented elderly. Korten *et al.* (1997) reported that memory decline was associated with older age and lower baseline score. The present study found that decline in the Memory subscale was associated with less education, but not with older age or lower baseline score.

Strengths and weaknesses

One explanation for the decline in some of the CAMCOG subscales might be due to the high number of individuals scoring the maximum score at baseline in some of the subscales (Orientation, Attention/Calculation and Praxis). As it is impossible to measure random improvement for those individuals at the top of the scale, the phenomenon of regression to the mean may have created the spurious impression of decline in these subscales (Morris *et al.*, 1999). Conversely, the ceiling effect could also have masked greater decline in high functioning individuals at baseline, which would have concealed the full extent of cognitive decline in some of the subscales.

An important question is whether the reported decline was entirely due to the effect of a small subgroup with early dementia or some other cause of cognitive impairment. As the CC75C study was unable to conduct another wave of diagnostic interviews, it is difficult to judge whether the decline was in fact prodromal of dementia. However, if the results were due to a subgroup with an early dementing process, we might expect to see decline in the memory subscale more commonly than in the other subscales, but this was not the case. In fact, over 50% of the sample showed decline in at least three areas of cognitive function and only seven of the 135 study participants showed no decline in any of the CAMCOG subscales. Even if decline were redefined as a drop of at least 2 points in each subscale, 35% of the sample still showed decline in at least three areas of cognitive function. It is unlikely that these results were solely due to early dementia, which suggests that cognitive decline across a range of cognitive domains is relatively common in normal ageing. However, the decline may still be due to

Table 4. Odds of decline in CAMCOG subscales by sociodemographic characteristics ($n = 135$)

Sociodemographic characteristics		Orient decline	Orient no decl	Lang decline	Lang no decl	Memry decline	Memry no decl	Att/cal decline	Att/cal no decl	Praxis decline	Praxis no decl	Abstr decline	Abstra no decl	Percep decline	Percep no decl
Age	>80	31	46	42	35	45	32	45	43	39	38	30	47	44	33
	75–79	27	31	30	28	33	25	26	32	27	31	28	30	23	35
	OR	0.77 (0.39–1.54)		1.12 (0.57–2.22)		1.07 (0.53–2.12)		1.73 (0.87–3.44)		1.17 (0.60–2.33)		0.68 (0.34–1.36)		2.03 (1.01–4.06)	
	OR adj*													1.97 (0.98–3.96) adj for education	
Sex	Female	46	53	54	45	59	40	51	48	52	47	44	55	48	51
	Male	12	24	18	18	19	17	20	16	14	22	14	22	19	17
	OR	1.74 (0.78–3.85)		1.20 (0.56–2.58)		1.32 (0.61–2.84)		0.85 (0.39–1.83)		1.74 (0.80–3.78)		1.26 (0.58–2.74)		0.84 (0.39–1.81)	
	OR adj*														
Age left school	>15 yrs	42	44	45	41	57	29	48	38	40	48	38	48	46	40
	15+ yrs	16	33	27	22	21	28	23	26	26	23	20	29	21	28
	OR	1.97 (0.95–4.09)		0.89 (0.44–1.80)		2.62 (1.27–5.39)		1.43 (0.71–2.89)		0.77 (0.38–1.55)		1.15 (0.56–2.34)		1.53 (0.76–3.11)	
	OR adj*					2.38 (1.07–5.32) adj for baseline score									
Social class	Manual	33	38	36	35	41	30	44	27	34	37	33	38	35	36
	Non-man	22	38	34	26	35	25	26	34	31	29	23	37	30	30
	OR	1.50 (0.74–3.02)		0.79 (0.39–1.57)		0.98 (0.49–1.96)		2.13 (1.06–4.29)		0.86 (0.43–1.71)		1.40 (0.69–2.81)		0.97 (0.49–1.93	
	OR adj*							2.00 (0.98–4.08) adj for base score							
								2.11 (1.04–4.28) adj for age							
Baseline CAMCOG score	<90	31	37	36	32	44	24	39	29	33	35	27	41	32	36
	90–106	27	40	36	31	34	33	32	35	33	34	31	36	35	32
	OR	1.24 (0.62–2.46)		0.97 (0.49–1.90)		1.78 (0.89–3.55)		1.47 (0.87–3.45)		0.97 (0.49–1.91)		0.76 (0.39–1.51)		0.81 (0.41 – 1.60)	
	OR adj*														

* OR adjusted for one other variable if lower limit of 95% CI > 1, adjusted for other variable only due to small numbers in cells.
Key: Orient: Orientation; Lang: Language; Memry: Memory; Att/cal: Attention/Calculation; Praxis: Praxis; Abstr: Abstract thought; Percep: Perception; no decl: no decline in subscale.

identifiable subgroups. The prevalence of 'cognitive impairment, no dementia' (CIND) in this study, defined by a total CAMCOG score below 80 at baseline, was 13%. This figure compares with 16.8% reported by the Canadian Study of Health and Ageing (Graham *et al*., 1997). Cognitive decline in the CIND subgroup was higher ($p = 0.01$, ANOVA adjusted for age), but was not completely responsible for the observed results, as the fall in CAMCOG still remained highly significant for the rest of the sample. Some of the study participants may have fulfilled criteria for non-progressive cognitive decline. Ageing-associated cognitive decline (AACD) requires evidence of decline in one or more of a broad range of cognitive domains, and has a prevalence of 27% in the 68–78 age group (Hanninen *et al*., 1996). Others may have met the criteria for age-associated memory impairment (AAMI), which has been shown to be clinically distinct from AACD (Richards *et al*., 1999). There are various ways to classify cognitive decline in normal ageing and the underlying causes are equally diverse. The majority of participants in this study were likely to have had risk factors that were related to cognitive impairment and dementia, such as hypertension. It has been argued that cognitive decline in elderly individuals with physical pathologies may be disease-related and not representative of cognitive decline in 'normal ageing' at all (Starr *et al*., 1997). Then again, these risk factors are so common in old age that a sample defined by absence of disease might be considered to be 'supernormal' (Petersen *et al*., 1997), and would not show the characteristics of 'typical ageing'.

The sample size in this report was relatively small for an epidemiological study, and may not have been large enough to detect an association between baseline factors and decline in cognitive function in the CAMCOG subscales. Even so, decline in three of the subscales was associated with specific sociodemographic features, albeit at a low level of statistical significance. Studies that have investigated the sociodemographic determinants of decline in *global* cognitive function, as measured by the MMSE, have reported associations with older age (Brayne *et al*., 1995; Ganguli *et al*., 1996; Jacqmin-Gadda *et al*., 1997; Korten *et al*., 1997), less education (Farmer *et al*., 1995; Ganguli *et al*., 1996; Jacqmin-Gadda *et al*., 1997), lower baseline score (Korten *et al*., 1997) and female sex (Brayne *et al*., 1995). It is possible that the effects of age, sex, education, social class and baseline score on cognitive decline are not the same in the different domains of cognition, but that these effects are masked when only global measures of cognition are reported. This hypothesis would explain the results of the current study, but does not explain why factors that are highly correlated such as social class and education do not show similar associations with decline in the separate subscales. In view of the small sample size and the multiple analyses, these results may be in part attributable to statistical artefact (type I error).

CONCLUSION

There is substantial research interest in differentiating progressive and non-progressive cognitive decline in the elderly. The important finding from this study is that the mean scores for each of the CAMCOG subscales in this population have declined over time. In addition, the majority of study participants showed evidence of decline in at least three of the cognitive domains measured by the CAMCOG subscales. If the results of epidemiological and intervention studies investigating cognitive decline in normal ageing are to be meaningful, the outcomes should be measured using instruments such as the CAMCOG that are sensitive to change across a range of domains of cognitive function.

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