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Original Article

Cognitive Ability in Midlife and Labor Market Participation Among Older Workers: Prospective Cohort Study With Register Follow-up

Emil Sundstrup [1,*], Åse M. Hansen [1,2], Erik L. Mortensen [2,3], Otto M. Poulsen [1], Thomas Clausen [1], Reiner Rugulies [1,2,4], Anne Møller [5,6], Lars L. Andersen [1,7]

[1] National Research Centre for the Working Environment, Copenhagen, Denmark
[2] Department of Public Health, University of Copenhagen, Denmark
[3] Center for Healthy Aging, University of Copenhagen, Denmark
[4] Department of Psychology, University of Copenhagen, Denmark
[5] Department of Occupational Medicine, Copenhagen University Holbæk, Denmark
[6] The Research Unit for General Practice and Section of General Practice, Department of Public Health, University of Copenhagen, Denmark
[7] Sport Sciences, Department of Health Science and Technology Aalborg University, Denmark

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ABSTRACT

Background: The study aimed to determine the association of individual cognitive ability in late midlife with labor market participation among older workers.
Methods: This prospective cohort study estimates the risk of long-term sickness absence, disability pension, early retirement, and unemployment from scores on the Intelligenz-Struktur-Test 2000R by combining data from 5076 workers from the Copenhagen Aging and Midlife Biobank with a register on social transfer payments. Analyses were stepwise adjusted for age, gender, physical and psychosocial work environment, health behaviors, occupational social class, education, and chronic diseases.
Results: In the fully adjusted model, low cognitive ability (≥1 standard deviation below the mean for each gender) and high cognitive ability (≥1 standard deviation above the mean for each gender) were not associated with risk of any of the four labor market outcomes.
Conclusion: Individual cognitive ability in late midlife was not associated with risk of long-term sickness absence, disability pension, early retirement, and unemployment in the fully adjusted model. Thus, no direct effect of individual cognitive ability in late midlife was observed on the risk of permanently or temporarily leaving the labor market.

1. Introduction

Owing to demographic changes, many industrialized countries are facing a growing proportion of older people. This is expected to lead to a significant decline in the proportion of people active at the labor market and consequently put economies and welfare systems under pressure due to reduced income taxes and extensive use of health-care services. To resist this pressure, increased labor market participation among older workers has gained great political awareness in recent years. However, this is not without challenges considering the rapidly changing labor market and the age-associated decline in health [1]. Furthermore, a decline in physical capacity sets in around the age of 30 years [2] and a decline in some cognitive abilities such as memory, reasoning, and processing speed becomes apparent around the age of 50 years after which it accelerates [3–7]. However, other cognitive abilities – such as verbal and numerical ability – seem more resistant to the age-associated decline and are therefore likely to reflect individual differences in basic cognitive ability which are to a large extent unaffected by age-related alterations [6]. Late midlife likely reflects a period in a working life career where people have found a job that suits their cognitive and physical abilities and where the job function is primarily determined by work-relevant experiences. However, in the context of a changing world of work, increasingly more jobs necessitate higher cognitive skills to process and organize complex information and to adjust to new technologies [8–10]. Hence, employees must show an even greater degree of cognitive adaptability to be able to handle the working life of the

* Corresponding author. National Research Centre for the Working Environment, Lersø Parkallé 105, 2100, Copenhagen, Denmark.
E-mail address: esu@nrcwe.dk (E. Sundstrup).

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future and its challenges, and some older workers may, therefore, lack the ability to cope with the cognitive demands at work [8–10]. This scenario could lead to an imbalance between individual capacity and work demands consequently reducing work ability and challenge work participation at an older age. Determining the direct role of an individual's cognitive ability level for labor market participation in late midlife could help to identify individuals who are more vulnerable to permanently or temporarily leaving the labor market and may help to target future preventive interventions [11].

Premature exit from the labor market represents a multifaceted interaction of both health and work-related factors, which could be influenced by cognitive ability. Hence, low cognitive ability has been related to poor health. Specifically lower cognitive ability in adulthood or during youth has been associated with both somatic and psychiatric disorders and all-cause mortality [12–17] and several longitudinal studies have found an association among men of lower cognitive ability in adolescence with a higher risk of obtaining a disability pension in adulthood [18–20]. Childhood cognitive ability has also been associated with adult long-term sickness absence (LTSA) and unemployment [21,22]. In addition, workers with low cognitive reserves (defined as the difference between the cognition job requirements and the individual's level of cognition) were more likely to exit the workforce and retire earlier than planned, compared with workers with high cognitive reserves [23]. Only a few studies have focused on the relationship between cognitive ability in late midlife and labor market participation. Stafford et al. [24] reported that higher cognitive ability in

Table 1
Baseline characteristics of the study sample

Characteristics	N	Percentage	Mean	SD
Age, years	5076		54.3	3.8
Gender				
Men	3537	70		
Women	1539	30		
Education				
Unskilled	366	7		
Skilled	1869	38		
Short higher education	509	10		
Medium higher education	1330	27		
Long higher education	902	18		
Lifestyle				
BMI (kg/m^2)	5076		26.0	4.1
Physical activity (1-5; high-low)	5076		2.7	0.7
Smoking (yes and ex-smoker)	1102	22		
Smoking (no)	3922	78		
Physical work environment during working life				
Sedentary work	2618	53		
Moderate physical work	1072	22		
Hard physical work	827	17		
Very hard physical work	414	8		
Psychosocial working conditions (1-5)				
Quantitative demands (low-high)	4967		3.4	1.0
Influence (high-low)	4972		2.2	0.8
Emotional demands (low-high)	4970		3.2	1.2
Time pressure (low-high)	4975		2.6	0.9
Role conflicts (high-low)	4945		3.6	0.9
Possibilities for development (high-low)	4972		1.9	0.8
Appreciation (high-low)	4914		2.4	0.9
Chronic diseases				
Back disease (have or have had)	1306	26		
No back disease	3705	74		
Cancer inclusive leukemia (have or have had)	212	4		
No cancer inclusive leukemia	4799	96		
Hypertension (have or have had)	1198	24		
No hypertension	3775	76		
Myocardial infarction or angina pectoris (have or have had)	103	2		
No myocardial infarction or angina pectoris	4896	98		
Stroke (have or have had)	71	1		
No stroke	4908	99		
Chronic depression or anxiety (have or have had)	516	10		
No chronic depression or anxiety	4497	90		
Cognitive performance				
IST total				
Mean	3265	65.2		
High (at least 1 SD above the mean for each gender)	833	16.6		
Low (at least 1 SD below the mean for each gender)	912	18.2		
Sentence Completion				
Mean	3228	64.4		
High (at least 1 SD above the mean for each gender)	975	19.5		
Low (at least 1 SD below the mean for each gender)	807	16.1		
Verbal Analogies				
Mean	3191	63.7		
High (at least 1 SD above the mean for each gender)	970	19.4		
Low (at least 1 SD below the mean for each gender)	849	17.0		
Number Series				
Mean	3068	61.2		
High (at least 1 SD above the mean for each gender)	966	19.3		
Low (at least 1 SD below the mean for each gender)	976	19.5		

SD = standard deviation; BMI = body mass index.

late midlife (at age 53) was related to participation in bridge employment and voluntary work in older age, whereas no association of cognitive ability with retirement reason and timing was observed. In addition, a study among 49,321 Swedish men found a graded relationship between cognitive ability in late adolescence and disability pension in late midlife (ages 40–59) [18].

Overall, the reasons for older workers to leave the labor market are complex and dynamic. Hence, it could be speculated that the role of individual's basic cognitive ability in late midlife may differ between the pathway of leaving the workforce (i.e. through LTSA, disability pension, unemployment, and early retirement). Poor health is an established risk factor for labor force exit as demonstrated by studies showing that sickness absence predicts disability pension [25,26]. In addition, some studies have reported sickness absence to be associated with unemployment and early retirement [27,28], whereas others have not [29]. Generally, disability pension seems to be preceded by sickness absence, whereas early retirement and unemployment to a larger extent could be entitled to other causes than poor health such as economic and social factors. Scrutinizing the association of cognitive ability in midlife with different labor market outcomes (i.e. LTSA, disability pension, early retirement, and unemployment) could help identify workers at risk of permanently or temporarily leaving the labor market.

In the present study, we, therefore, aim to determine the association of individual's cognitive ability level in late midlife with the risk of permanently or temporarily leaving the labor market, due to register-based disability pension, early retirement, LTSA, and unemployment. Individual cognitive ability level was assessed by selected subtests from the Intelligenz-Struktur-Test 2000 R (I-S-T 2000 R) that are relatively robust to age-related changes. We hypothesized that employees with low cognitive ability levels in midlife [1 standard deviation (SD) or more below the mean for each gender] would have an increased risk of leaving the labor market permanently (through disability pension and early retirement) and temporarily (through unemployment and LTSA). We further hypothesized that employees with high cognitive ability levels in midlife (1 SD or more above mean for each gender) would have a decreased risk of experiencing these labor market outcomes.

2. Methods

2.1. Study design

This prospective cohort study merges data on cognitive ability from the Copenhagen Aging and Midlife Biobank (CAMB) with a national register containing information on social security benefits on all Danish residents (e.g. sickness absence benefits, unemployment benefits, early retirement benefits, and disability benefits).

The CAMB cohort was established by merging three existing Danish cohorts: the Metropolit Cohort consists of 10,171 men born in 1953 in Copenhagen with an age range of 56–58 years at the CAMB establishment [30]; the Copenhagen Perinatal Cohort consists of 8,102 men and women born at the National University Hospital in Copenhagen in 1959–1961, that is, an age range of 49–52 years at the CAMB establishment [31]; and the Danish Longitudinal Study on Work, Unemployment, and Health consists of 11,082 men and women, born between 1949 and 1959 – constituting a random sample of the Danish population in 1999 – with an age range of 50–53 years and 60–63 years at the CAMB establishment [32]. At the time of the CAMB establishment, 4,604 individuals had died or had previously asked to be excluded from cohort follow-ups, which yielded a sample of 24,751 persons eligible for invitation into the CAMB. Owing to lack of resources, 6,814 persons (28% of those eligible) were further excluded as they lived in the western part of Denmark, too far from the study clinic [33]. Thus, a total of 17,937 persons were invited to participate in the CAMB study, and the selected cohort members were sent an invitation letter by regular mail including information about the study and a comprehensive questionnaire. Reminders were mailed 4 weeks after the first invitation. At the end of the data collection period, a final reminder was sent to those who had not responded to any of the previous letters. Of the invited persons, 7,190 (40%) filled in the accompanying questionnaire and 5,575 (31%) further participated in a clinical examination that took place from 2009–2011 [33]. The clinical examination included an interview on current illnesses and the use of medication, blood samples, basic examination (height, weight, percentage of body fat, blood pressure), physiological capability tests, oral health, and a cognitive ability test. The questionnaire included detailed questions about health and working environment. Individuals not affiliated with the labor market (i.e. receiving disability pension benefits, early retirement benefits, and statutory retirement benefits) at the point of data collection were excluded from the present study which yielded a study sample of 5,076 workers (age range: 49–63 years at baseline). Several substudies using data from the CAMB population have previously been reported. That includes articles on data collection and articles on the importance of different factors for aging. The present manuscript is part of a substudy setup using the CAMB database to investigating the influence of physical and psychosocial work environment throughout life and physical and cognitive ability in midlife on labor market participation among older workers. From this larger study setup, a study protocol and analyses on the physical and psychosocial work environment have previously been published [34–37]. The STROBE checklist was followed during the reporting of the study to ensure transparent and standardized reporting [38]. Baseline characteristics of the study sample are presented in Table 1.

2.2. Cognitive ability

As previously described by Mortensen et al. [6], cognitive ability was measured by three subtests from the I-S-T 2000 R [39]: In the Sentence Completion subtest, the participants were to select the correct word of five words to make a complete and correct sentence. The participants had 6 min to complete as many sentences as possible of 20 incomplete sentences. An example of an incomplete sentence is “the opposite of hope is …” with a choice among grief, despair, misery, love, and hate. In the Verbal Analogies subtest, the participants had 7 min to complete as many analogies as possible of the 20 possible analogies. In the Danish version, the analogies are presented in full sentences such as “the relationship between dark and light corresponds to the relationship between wet and …” with a choice between five alternatives: rain, day, damp, wind, and dry. In the Number Series subtest, the participants are presented with a series of seven numbers and must give the following number. The participants had 10 min to complete as many series as possible of 20 number series. An example is “9, 7, 10, 8, 11, 9, 12, ?” with the answer being 10. Thus, the participants were to deduce and write the correct answer [6]. For further analyses, the total cognitive ability score was calculated as the sum of the three subtests. Exploratory analyses were carried out with the sum of each individual subtest [6]. Mortensen et al. [6] conducted internal consistency analyses on the I-S-T 2000 R and found that Item 7 in the Sentence Completion test had very low correlations with the total score of the 19 remaining items in this subtest (.01) and with the total score of the remaining 59 items (.02) in the complete test. Consequently, the authors dropped the item from their cross-sectional analyses. Therefore, we did not include Item 7 in the Sentence Completion test in the present analyses, and the

Table 2
Overview of the seven items used to cover the psychosocial work environment. Participants were to reply to the following items when looking back on their entire working life

Scales	Items	Response categories
Quantitative demands	How often did you not have time to complete all your work tasks?	always; often; sometimes; seldom; never/hardly never
Influence	Did you have a large degree of influence concerning your work?	
Emotional demands	Did you have to relate to other people's personal problems as part of your work?	
Work pace	Did you have to work very fast?	
Role conflicts	Were contradictory demands placed on you at work?	to a very large extent; to a large extent; somewhat; to a small extent; to a very small extent
Possibilities for development	Did you know exactly which areas were your responsibilities?	
Recognition/appreciation	Was your work recognized and appreciated by the management?	

maximum possible score in that subtest was 19 and in the total test it was 59.

2.3. Outcome variables

Outcome variables were labor market participation to varying degrees extracted from the Danish Register for Evaluation and Marginalization (DREAM): LTSA, unemployment, disability pension, and early retirement. The DREAM contains information on all types of social transfer payments and other basic personal data on all Danish residents on a weekly basis [40]. During the study follow-up period, the days in which the employer received no reimbursement of sickness absence pay changed from 21 days to 30 days of sickness absence (January 2012). Because 30 calendar days represent more than 4 weeks, that is, it goes into the 5th week, and given the fact that sickness absence is recorded on a weekly basis in the DREAM, at least 6 consecutive weeks were used as a measure of sickness absence >30 calendar days. Thus, to define LTSA consistently throughout the follow-up period, it was defined as sickness absence >30 calendar days, corresponding to ≥6 consecutive weeks in the DREAM [36]. Unemployment was defined as being unemployed but available for the labor market [41]. Disability pension was defined as receiving a disability benefit within the follow-up period. Individuals with a permanent loss of work ability and working on special terms reflecting permanently reduced work ability were also classified as receiving disability pension (32). Early retirement allows for withdrawal from the labor market before official state pension age and is a voluntary retirement scheme for people who (1) are members of an unemployment insurance fund, (2) have paid retirement contributions for 30 years, (3) have the right to unemployment benefits, and (4) are available for the labor market and not being sick or unable to take on a job. The Danish state pension age is gradually increasing to 67 years in the period 2019–2022 and is further regulated to 68 years by 2030. At the time of the follow-up period in the present study, the official state pension age was 65 years.

2.4. Covariates

The following covariates were assessed at the time of establishment of the CAMB cohort (i.e. baseline measurements from 2009–2011) and are described as follows: age, gender, physical work environment, psychosocial work environment, leisure time physical activity, body mass index (obtained by the clinical staff), smoking, chronic diseases, education, occupational social class, and previous LTSA (i.e. ≥6 consecutive weeks 2 years before the baseline measurements).

Physical work environment was evaluated retrospectively to cover the whole working life by a general question about physical work demands from the CAMB questionnaire: "Looking back on your entire working life: For how many years of your working life have you had …, 1) mostly sedentary work without physical strain?, 2) mostly standing or walking work without major physical strain?, 3) mostly standing or walking work with some lifting and carrying?, 4) mostly heavy, fast or physically demanding work?". For each response category, participants listed the number of years during the working life with the specific work demands [36]. For further analyses, the data on exposure years in each of the 4 categories were transformed to a number between 0 and 100, where 0 indicates that all exposure years belong to category 1 (seated work) and 100 indicates that all exposure years belong to category 4 (very hard work), and anything in between was linearly scaled. The scaling, which has previously been described, was used to give a single-number indication of the amount of physical demands

Table 3
The prospective association of cognitive ability (I-S-T 2000 R Test Scores) with long-term sickness absence and disability pension. The exact number of participants included in each statistical model varies because not all participants completed all the survey questions (i.e. missing values in regard to the covariates exist)

Cognitive ability	Unadjusted number of cases (% of participants at baseline)	Model 1 (n = 5038)	Model 2 (n = 4766)	Model 3 (n = 4727)	Model 4 (n = 4660)
		HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Long-term sickness absence					
IST total					
Ref	607 (18.6)	1	1	1	1
High	113 (13.6)	0.69 (0.56-0.84)	0.77 (0.62-0.94)	0.80 (0.65-0.98)	0.86 (0.69-1.06)
Low	241 (26.4)	1.62 (1.39-1.88)	1.31 (1.11-1.54)	1.27 (1.08-1.50)	1.15 (0.97-1.36)
Sentence Completion					
Ref	597 (18.6)	1	1	1	1
High	147 (15.1)	0.78 (0.65-0.93)	0.88 (0.74-1.06)	0.90 (0.75-1.09)	0.95 (0.78-1.15)
Low	217 (26.9)	1.50 (1.29-1.76)	1.32 (1.12-1.56)	1.30 (1.10-1.53)	**1.22 (1.03-1.44)**
Verbal Analogies					
Ref	600 (18.8)	1	1	1	1
High	132 (13.6)	0.75 (0.62-0.90)	0.84 (0.69-1.01)	0.85 (0.70-1.04)	0.96 (0.78-1.17)
Low	230 (27.1)	1.66 (1.42-1.93)	1.36 (1.15-1.61)	1.35 (1.14-1.60)	**1.19 (1.01-1.42)**
Number Series					
Ref	580 (18.9)	1	1	1	1
High	140 (14.5)	0.79 (0.66-0.95)	0.85 (0.71-1.03)	0.87 (0.72-1.05)	0.93 (0.76-1.12)
Low	241 (24.7)	1.60 (1.38-1.86)	1.30 (1.11-1.53)	1.24 (1.05-1.46)	1.14 (0.96-1.35)
Disability pension					
IST total					
Ref	52 (1.6)	1	1	1	1
High	2 (0.2)	0.15 (0.04-0.61)	0.20 (0.05-0.84)	0.25 (0.06-1.05)	0.36 (0.09-1.52)
Low	32 (3.5)	2.34 (1.50-3.64)	1.46 (0.89-2.40)	1.40 (0.85-2.31)	1.16 (0.70-1.93)
Sentence Completion					
Ref	48 (1.5)	1	1	1	1
High	9 (0.9)	0.61 (0.30-1-25)	0.71 (0.33-1.51)	0.80 (0.37-1.71)	0.87 (0.40-1.92)
Low	28 (3.5)	2.37 (1.49-3.78)	1.60 (0.95-2.60)	1.50 (0.90-2.51)	1.27 (0.76-2.13)
Verbal Analogies					
Ref	54 (1.7)	1	1	1	1
High	6 (0.6)	0.37 (0.16-0.86)	0.49 (0.21-1.16)	0.46 (0.19-1.09)	0.60 (0.24-1.48)
Low	26 (3.1)	1.91 (1.19-3.06)	1.21 (0.72-2.04)	1.00 (0.58-1.74)	0.74 (0.42-1.31)
Number Series					
Ref	46 (1.5)	1	1	1	1
High	4 (0.4)	0.27 (0.10-0.75)	0.35 (0.12-0.97)	0.38 (0.13-1.06)	0.44 (0.15-1.25)
Low	34 (3.5)	2.38 (1.53-3.70)	1.65 (1.02-2.66)	1.43 (0.87-2.33)	1.38 (0.84-2.27)

Model 1: Adjusted for age and gender.
Model 2: Model 1 + psychosocial work environment, physical work environment.
Model 3: Model 2 + health behavior (lifestyle, chronic diseases).
Model 4: Model 3 + education, occupational socal class, previous LTSA.
HR = hazard ratio; 95% CI = 95% confidence interval. Significant associations in the fully adjusted Model 4 are marked in bold ($p < 0.05$)

during working life, within the following categories: “low physical work demands” (0-24.99), “moderate physical work demands” (25-49.99), “high physical work demands” (50-74.99), and “very high physical work demands” (75-100) [36].

Psychosocial work environment was assessed by seven dimensions from the Copenhagen Psychosocial Questionnaire [42] that was modified to retrospectively cover the participants' entire working life: (1) quantitative demands, (2) influence/decision authority, (3) emotional demands, (4) time pressure, 5) role conflicts, (6) possibilities for development, and (7) rewards/appreciation [36]. Table 2 illustrates the seven items and their associated 5-point response categories. For further analyses, the continuous score from one to five was used.

Leisure time physical activity was assessed by the following question: “What would you say best describes your spare time physical activities?” with the following response categories: (1) go for competitive sport regularly and several times a week; (2) go for physical training or heavy house or garden work at least 4 hours per week; (3) go for walks, biking, or other kinds of light exercise at least 4 hours a week (including Sunday excursions, lighter garden work, and biking/walking to and from work); and (4) read, watch television, or have other sedentary activities. For further analyses, a variable was generated with the number ranging from 1–4 representing the selected response category.

Chronic diseases were assessed by the question: “Do you have or have you had any of the following diseases?” with the response options “yes, have now”, “yes, previously”, or “no” to the following diseases: back disease, cancer including leukemia, chronic anxiety or depression, stroke, hypertension, myocardial infarction, and angina pectoris.

Education was assessed by the question: “What kind of vocational education and training do you have?” with the following response categories: (1) none; 2) semi-skilled worker; (3) skilled worker or similar level (e.g. carpenter, blacksmith, clerical training, hairdresser, nursing assistant, technical assistant); (4) less than 3 years theoretical education (e.g. market economist, mechanical engineer); (5) 3–4 years theoretical education (e.g. primary school teacher, journalist, bachelor of engineering, bachelor degree); and (6) long further and higher education (more than 4 years) (e.g. doctor, economist, upper secondary school teacher, master of engineering). Education was further categorized into five groups: unskilled (response category 1), skilled (response category 2 and 3), short higher education (response category 4), medium higher education (response category 5), and long higher education (response category 6) [43].

Table 4
The prospective association of cognitive ability (I-S-T 2000 R Test Scores) with unemployment and early retirement. The exact number of participants included in each statistical model varies since not all participants completed all the survey questions (i.e. missing values in regard to the covariates exist)

Cognitive ability	Unadjusted number of cases (% of participants at baseline)	Model 1 (n = 5038)	Model 2 (n = 4766)	Model 3 (n = 4727)	Model 4 (n = 4660)
		HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Unemployment					
IST total					
Ref	571 (17.5)	1	1	1	1
High	108 (13.0)	0.72 (0.58-0.88)	0.76 (0.61-0.93)	0.79 (0.64-0.98)	0.93 (0.75-1.15)
Low	246 (27.0)	1.72 (1.48-2.00)	1.48 (1.26-1.75)	1.40 (1.18-1.65)	1.14 (0.96-1.35)
Sentence Completion					
Ref	565 (17.5)	1	1	1	1
High	158 (16.2)	0.90 (0.75-1.07)	0.97 (0.81-1.16)	0.99 (0.82-1.19)	1.04 (0.86-1.26)
Low	205 (25.4)	1.52 (1.30-1.78)	1.29 (1.09-1.54)	1.25 (1.05-1.49)	1.13 (0.95-1.35)
Verbal Analogies					
Ref	565 (17.7)	1	1	1	1
High	140 (14.4)	0.81 (0.68-0.98)	0.87 (0.72-1.05)	0.92 (0.76-1.12)	1.07 (0.88-1.31)
Low	224 (26.4)	1.65 (1.41-1.92)	1.45 (1.23-1.72)	1.44 (1.21-1.71)	**1.24 (1.04-1.47)**
Number Series					
Ref	531 (17.3)	1	1	1	1
High	135 (14.0)	0.81 (0.67-0.98)	0.82 (0.68-1.00)	0.83 (0.68-1.00)	0.99 (0.81-1.20)
Low	262 (26.8)	1.87 (1.61-2.17)	1.59 (1.35-1.86)	1.49 (1.26-1.75)	**1.26 (1.07-1.48)**
Early retirement					
IST total					
Ref	333 (10.2)	1	1	1	1
High	58 (7.0)	0.69 (0.52-0.91)	0.77 (0.57-1.02)	0.80 (0.60-1.07)	0.85 (0.63-1.14)
Low	147 (16.1)	1.51 (1.25-1.83)	1.31 (1.07-1.61)	1.31 (1.06-1.61)	1.13 (0.91-1.40)
Sentence Completion					
Ref	339 (10.5)	1	1	1	1
High	83 (8.5)	0.87 (0.69-1.11)	0.92 (0.71-1.18)	0.90 (0.70-1.16)	0.95 (0.73-1.22)
Low	115 (14.3)	1.34 (1.08-1.65)	1.18 (0.95-1.47)	1.16 (0.93-1.45)	1.06 (0.84-1.33)
Verbal Analogies					
Ref	341 (10.7)	1	1	1	1
High	75 (7.7)	0.65 (0.50-0.83)	0.71 (0.55-0.92)	0.74 (0.57-0.96)	0.79 (0.61-1.03)
Low	124 (14.6)	1.25 (1.01-1.54)	1.00 (0.80-1.26)	1.00 (0.80-1.26)	0.89 (0.71-1.13)
Number Series					
Ref	304 (9.9)	1	1	1	1
High	75 (7.8)	0.87 (0.63-1.12)	0.92 (0.71-1.19)	0.95 (0.73-1.23)	0.99 (0.76-1.29)
Low	161 (16.5)	1.70 (1.40-2.05)	1.51 (1.23-1.85)	1.50 (1.22-1.84)	**1.32 (1.07-1.63)**

Model 1: Adjusted for age and gender.
Model 2: Model 1 + psychosocial work environment, physical work environment.
Model 3: Model 2 + health behavior (lifestyle, chronic diseases).
Model 4: Model 3 + education, occupational socal class, previous LTSA.
HR = hazard ratio; 95% CI = 95% confidence interval. Significant associations in the fully adjusted Model 4 are marked in bold ($p < 0.05$)

Occupational social class was divided into Social Classes I to VI according to the Danish Occupational Social Class classification [6,44]. Social Classes I to V represent economically active individuals alternating from unskilled occupation in Social Class V to professional occupation in Social Class I. Social Class VI represents economically inactive individuals who rely primarily on transfer income (e.g. disability pensioners, unemployed, and long-term sick-listed). The variables measuring education and occupational social class are statistically significantly correlated with a Pearson correlation coefficient of -0.58 ($p < 0.0001$) corresponding to R Square of 0.34. Thus, 34% of the variation in occupational social class can be explained by the measure of education.

2.5. Statistical methods

The Cox proportional hazard model (PHREG procedure in SAS, version 9.4; SAS Institute, Cary, NC, United States) was used to test the associations of the total intelligence score and its 3 subtests with register-based LTSA, unemployment, early retirement, and disability pension during the 4–6-year follow-up period (i.e. data collection was performed one time for each participant between 2009–2011 and register follow-up was in 2015) [45,46]. When individuals had an onset of any of the outcome measures within the follow-up period, the survival times were noncensored and referred to as event times. In the analyses with LTSA and unemployment as outcomes, the survival times were noncensored and referred to as event times when individuals had the first onset of LTSA or unemployment, respectively. In the analyses, we censored for all events of permanent dropout from the labor market within the follow-up period (i.e. early retirement, emigration, and death). Importantly, individuals staying in the labor market past 65 years (official retirement age but not mandatory) were kept in the analyses. Analyses were carried out separately for each outcome measure and stepwise adjusted for potential confounders: Model 1 was controlled for age and gender, Model 2 was additionally adjusted for work environment (psychosocial and physical), Model 3 was additionally adjusted for health behaviors (lifestyle and chronic diseases), and Model 4 was additionally adjusted for education, occupational social class, and previous LTSA. Because sickness absence may be on the causal pathway from low cognitive ability to disability pension, controlling the analyses for previous LTSA could be an overadjustment. Thus, a sensitivity analysis was performed without adjusting the final Model 4 (for all four labor market outcomes) for previous LTSA. The exact number of participants included in each analysis varies because not all participants completed all the survey questions. Thus, if there are missing values in regard to any of the covariates (e.g. psychosocial work environment, health behavior, or educational attainment), the PHREG

procedure in SAS used for the Cox regression does not include these data in the statistical models. The estimation method used was maximum likelihood, and the results are reported as hazard ratios (HRs) with 95% confidence intervals (CIs). The significance level was set at an α level of <0.05.

3. Results

During the follow-up period, the following number of outcome events occurred: 970 participants (19.3%) had at least one episode of LTSA, 933 participants (18.5%) had at least one episode of unemployment, 85 participants (1.7%) received disability pension benefits, and 538 participants (10.7%) received early retirement benefits.

3.1. Cognitive ability

Tables 3 and 4 show the prospective association of cognitive ability with the four labor market outcomes. In the minimally adjusted Model 1, low cognitive ability (at least 1 SD below the mean for each gender) was associated with an increased risk of LTSA [HR = 1.62 (95% CI = 1.39-1.88)], disability pension [HR = 2.34 (95% CI = 1.50-3.64)], unemployment [HR = 1.72 (95% CI = 1.48-2.00)], and early retirement [HR = 1.51 (95% CI = 1.25-1.83)], whereas high cognitive ability (at least 1 SD above the mean for each gender) was associated with a reduced risk of these labor market outcomes. Individual cognitive ability in late midlife was not associated with any of the labor market outcomes in the fully adjusted Model 4. Notable, some of the risk estimates in the analysis with disability pension as outcome measure are based on a low number of cases (Table 3).

3.2. Subtests of cognitive ability

Tables 3 and 4 show the prospective association of the three cognitive subtests from the I-S-T 2000 R with the four labor market outcomes. In the minimally adjusted Model 1, all subtests were associated with the four labor market outcomes. In the fully adjusted Model 4, low ability in sentence completion was associated with LTSA [HR = 1.22 (95% CI = 1.03-1.44)]; low ability in verbal analogies was associated with LTSA [HR = 1.19 (95% CI = 1.01-1.42)] and unemployment [HR = 1.24 (95% CI = 1.04-1.47)]; and low ability in number series was associated with unemployment [HR = 1.26 (95% CI = 1.07-1.48)] and early retirement [HR = 1.32 (95% CI = 1.07-1.63)]. In the fully adjusted Model 4, high cognitive ability in the three subtests was not associated with any of the labor market outcomes.

3.3. Sensitivity analysis

The sensitivity analysis (i.e. not adjusting the final Model 4 for previous LTSA) did not change the results to any statistically significant extent for any of the four labor market outcomes (not shown in tables). The analysis revealed only small changes for some of the risk estimates (between -0,04 to +0,03 points).

4. Discussion

In the fully adjusted model (i.e. adjusted for age, gender, physical and psychosocial work environment, health behaviors, occupational social class, education, and chronic diseases), no significant associations were observed between individual cognitive ability in late midlife and risk of LTSA, disability pension, early retirement, and unemployment. Hence, no direct effect of individual cognitive ability in late midlife was observed on the risk of leaving the labor market permanently (through disability pension and early retirement) or temporarily (through unemployment and LTSA).

4.1. Strengths and limitations

The CAMB version of the I-S-T 2000 R total score is based on only three selected subtests of the original nine subtests, and the total score should be interpreted with caution as a measure of general cognitive ability. However, the CAMB version of the I-S-T 2000 R should primarily be considered a measure of verbal reasoning, which is a central component of general cognitive ability, and the total score correlates substantially with other tests of intelligence [47]. As verbal cognitive ability may not be very sensitive to cognitive changes in midlife, the present version of the I-S-T 2000 R most likely reflects individual differences in cognitive ability that are relatively robust to age-related changes [6]. This is, however, considered a strength because it gives us the opportunity to investigate the direct effect of individual cognitive ability in midlife (i.e. to a large extent unaffected by age-related alterations) on the risk of permanently or temporarily leaving the labor market.

Recruitment of a large sample of older workers from the general working population in Denmark is a strength of the study. A weakness of the study is, however, the relatively low response rate − 31% of the invited participated in the cognitive ability test. Thus, the present results could have been influenced by selection bias. On the other hand, previous findings from the CAMB study found that participants and nonparticipants were comparable in regard to educational level and general health, whereas a larger proportion of participants were employed [33]. However, Møller et al. [43] reported that participants who attended the physical examination (i.e. also the study sample for the present study) had significantly higher education and were more likely to be employed, whereas no statistically significant difference existed in the use of the health-care system compared with the nonresponders. As cognitive ability in youth likely determines educational attainment, which is also strongly associated with cognitive ability later in life, it cannot be ruled out that the present study sample has higher cognitive abilities than nonparticipants. Although we only included currently employed individuals in the present study, it can be suggested that the study sample represents a partly selected group.

The generalizability of the results to employees in other countries with different schedules of social benefits, retirement age, and labor market protection needs to be investigated further. In line with this, it has previously been stated that the welfare system of Scandinavian countries is better at protecting against nonemployment due to illness than other systems in European countries [48]. Thus, the applicability of the present study seems to apply to workers in a welfare state.

A weakness of the study is that physical and psychosocial work environment was retrospectively evaluated to cover the whole working life and could, therefore, be prone to potential bias, in particular, recall bias. For the psychosocial working environment, asking participants to combine exposures during their working life in a single number for their average level of quantitative demands, decision authority, emotional demands, time pressure, role conflicts, possibilities for development, and appreciation is a very limited step toward a life course perspective [37]. In addition, for the physical work environment, we were not able to analyze this throughout the entire working life, as this was measured only once when we asked the participants in retrospect to assess exposure years during their working career [36]. The type and exposure time of the physical workloads may, therefore, be prone to recall bias. Overall, it is not

possible to evaluate the influence of the current work environment (i.e. at the point of data collection) on the association between cognitive ability and labor market participation. On the other hand, the variable of occupational social class is formed at the point of data collection and could be a proxy for the current physical work environment.

A strength of the study is the employment of objective (i.e. register based) data on four labor market outcomes (i.e. LTSA, unemployment, disability pension, and early retirement). The DREAM register has high validity as it contains weekly information on all social transfer payments for all Danish residents [49]. As the DREAM register contains no information on the cause of LTSA, unemployment, disability pension, or early retirement, there is no knowledge on the specific health-related causes (e.g. diagnoses) that led to these outcome events.

Retirement decisions are complex and dynamic, and existing literature shows an extensive range of variables affecting the decision to retire. Factors such as marital status (as couples tend to make joint decisions for retirement), family caregiving responsibilities, participating in cognitively challenging activities, income, and ethnicity have not been included in the analyses despite their possible role as confounders. Unmeasured confounding could, therefore, have been a problem in the present study even though an extensive amount of variables were included in the final and fully adjusted model (e.g. age, gender, education, occupational social class, work environment, chronic diseases, body mass index, smoking, physical activity, and previous LTSA).

4.2. Interpretation of results

Lower cognitive ability in late midlife was associated with an increased risk of all labor market outcomes in the minimally adjusted model. However, in the fully adjusted model, the risk estimates were substantially lower, and cognitive ability was not associated with either risk of LTSA, disability pension, early retirement, or unemployment. It seems possible that factors adjusted for in the fully adjusted model (i.e. work environment, health behaviors, education, occupational social class, and previous LTSA) were responsible for this lowered risk. However, it cannot be ruled out that the relationship could differ due to different analytical samples being used. Specifically, the exact number of participants included in each analysis varies because not all participants completed all the survey questions (i.e. missing values in regard to the covariates exist), and the PHREG procedure used for the Cox regression did not include these data in the statistical models. Thus, the fully adjusted model included 4.660 of the total sample of 5.076 participants at baseline.

Previous studies have shown associations of cognitive ability with LTSA, unemployment, disability pension, and early retirement. Most of these studies have used cognitive ability in childhood or adolescence as a predictor. For instance, Sörberg et al. [18] observed an association between low cognitive ability in adolescence and disability pension among 49,285 Swedish men. This association was considerably attenuated after the adjustment of socioeconomic, work-related, and personality factors, but in contrast to the present study results, the association remained statistically significant. Henderson et al. [21] observed a dose–response relationship between lower cognitive ability in childhood and increased odds of being on long-term sick leave in both younger and older age. In addition, low cognitive ability in the Aberdeen Children of the Nineteen Fifties Cohort independently predicted being permanently sick or disabled in adult life [50]. Other longitudinal studies on men have shown that lower cognitive ability in adolescence was associated with a higher risk of obtaining a disability pension in adulthood up to the age of 43 years [19,20].

Among the studies using cognitive ability in midlife, Belbase et al. [23] found that older workers (aged 55–69 years) from the Health and Retirement Study who experienced a steep cognitive decline over a 10-year period were more likely to exit the workforce and retire earlier than planned and “downshift” to a less demanding job than workers who experienced no cognitive decline. In that study, workers without cognitive reserves (defined as the difference between the cognition job requirements and the individual's level of cognition) were also more likely to exit the workforce and retire earlier than planned, compared with workers with cognitive reserves. In line with our results, Stafford et al. [24] found that cognitive ability in late midlife (at age 53) was not related to retirement reason (i.e. usual retirement age for the job, positive reasons, negative reasons, neutral, or other reasons) and timing of retirement.

Individual differences in cognitive ability are stable throughout a large part of the adult lifespan [51] and Osler et al. [47] observed that I-S-T scores at age 57 years correlated highly with intelligence scores at age 12 years ($r = 0.67$) and at age 18 years ($r = 0.70$). The differences in midlife cognitive ability in the present study could, therefore, reflect individual differences in middle childhood intelligence (i.e. basic intelligence) but also possible age-related changes in cognitive ability [6]. As mentioned earlier, our measure of cognitive ability is likely to be unaffected by age-related alterations, suggesting that the I-S-T score reflects individual differences in cognitive ability that also influenced the educational achievement [6] and in turn social class in midlife which further associates with adverse or less adverse working conditions [52]. With that in mind, the present study emphasizes the direct role of individual basic cognitive ability on labor market participation in late midlife. Seen from a life course perspective, the question is whether cognitive abilities in the youth affect education and occupational career in such a way that people with low cognitive abilities in midlife are in jobs with an increased risk of premature exit from the labor market or whether there is a direct effect of individual cognitive abilities in late midlife on this risk. Because the relationship between individual cognitive ability and risk of LTSA, unemployment, early retirement, and disability pension was not significant in the present study (after adjusting for potential confounders such as education, occupational social class, and work environment), no direct effect of individual cognitive ability in late midlife was observed on the risk of these labor market outcomes. Late midlife likely represents a point in life, where most people have found a job that suits their abilities and where the job function is primarily determined by work-relevant experiences. Thus, it may be that people with different cognitive abilities over the course of life have ended up in different types of jobs with different risk of LTSA, unemployment, early retirement, and disability pension.

It may be argued that the estimates presented in the fully adjusted Model 4 are highly conservative because some of the included covariates could actually be potential mediators in the association between cognitive ability in late midlife and the four outcomes. Thus, overadjustment could be a problem in the present study, leading to an underestimation of the risk estimates presented in the final Model 4. For instance, sickness absence may be on the causal pathway from low cognitive ability to disability pension and controlling for previous LTSA in the analysis with disability pension as outcome could, therefore, be an overadjustment. However, the final and fully adjusted Model 4 will form the base for the discussion of all labor market outcomes and the reader should be aware of the possible bias associated with overadjustment in the analyses on disability pension. We performed a sensitivity analysis without adjusting the final Model 4 for previous LTSA. Although we observed small changes for some of the risk

estimates (between -0,04 to +0,03 points), this did not change the results to any significant extent for any of the labor market outcomes.

Importantly, both education and occupational social class could confound or mediate the association of cognitive ability with fully or partly leaving the labor market through LTSA, disability pension, unemployment, or early retirement. Cognitive ability in youth likely determines educational level which is associated with the type of occupation later in life. Occupational social class may directly reflect the occupational and social circumstances of an individual in late midlife and likely encapsulate exposures through the life course along with the current life circumstances of the individual [6]. Thus, individual cognitive ability likely determines future social position [18,53], which further associates with adverse or less adverse physical and psychosocial working conditions [52] and thereby risk of sickness absence or premature exit from the labor market. This could also have been the case in the present study, where the risk estimates were nonsignificant after adjustment of education, occupational social class, and previous LTSA in Model 4. In line with this, Stafford et al. [24] found no association of cognitive ability in late midlife (at age 53 years) with retirement reason and timing when adjusting for selected covariates including education and occupational social class. In opposition to, Sörberg et al. [18] observed an association between low cognitive ability in adolescence and disability pension among 49,321 Swedish men. Although this association was considerably attenuated after the adjustment for education, adult social class, and personality factors, it remained statistically significant.

The exploratory analyses on the I-S-T subtests showed that low cognitive ability in sentence completion and verbal analogies (i.e. the verbal aspect of intelligence) predicted risk of LTSA in the fully adjusted model. Low ability in verbal analogies also predicted risk of unemployment. Furthermore, low ability in number series (i.e. numerical intelligence) was associated with both unemployment and early retirement. These results are in contrast to those of the total I-S-T score, which was somewhat unexpected given that strong intercorrelations between the subtest scores and the total I-S-T score have previously been observed on the CAMB population [6]. In addition, we observed no association of high cognitive ability in the subtests with any of the labor market outcomes in the fully adjusted model. The possibility exists that these associations are significant by chance. Thus, future studies should verify the results using nonexploratory analyses.

5. Implications

Identifying risk factors for leaving the labor market prematurely could provide politicians and practitioners with important information in their pursuit of keeping workers longer at the labor market. Previous studies on the CAMB cohort have shown the importance of physically demanding work and psychosocial working conditions (e.g. influence at work and recognition from managers) throughout working life for sickness absence and premature exit from the labor market [36,37]. The present study adds to this knowledge base by indicating no direct effect of individual cognitive ability in late midlife on the risk of LTSA, unemployment, early retirement, and disability pension. Thus, it may be that people with different cognitive abilities over the course of life have ended up in different types of jobs with different risk of LTSA, unemployment, early retirement, and disability pension. Because the present study used a measure of cognitive ability that to a large extent is unaffected by age-related alterations, future studies should investigate the role of the age-associated decline in cognitive ability on sustainable employment.

6. Conclusions

Individual cognitive ability in late midlife was not associated with the risk of LTSA, disability pension, early retirement, and unemployment in the fully adjusted model (i.e. adjusted for age, gender, physical and psychosocial work environment, health behaviors, occupational social class, education, and chronic diseases). Thus, no direct effect of individual cognitive ability in late midlife was observed on the risk of permanently or temporarily leaving the labor market.

Data availability

The data that support the findings of this study are available from the CAMB steering committee but restrictions apply to the availability of these data, which were used under license for the present study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of the CAMB steering committee.

Ethical approval

The study was approved by the Danish Data Protection Agency (j.nr. 2015-41-4232). The local ethical committee and the Danish Data Protection Agency have previously approved the CAMB as a database combining three cohorts: approval No. H-A-2008-126 and No. 2013-41-1814, respectively [33]. Participants were informed about the content and purpose of the CAMB study and gave their written informed consent to participate [33].

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Author contributions

L.L.A. obtained the funding for the study. L.L.A. and E.S. designed the study. A.M.H. and E.L.M. initiated and established the Copenhagen Aging and Midlife Biobank. A.M.H., E.L.M., O.M.P., T.C., R.R., and A.M. provided feedback to the study design. E.S. drafted the manuscript. All authors interpreted the results, critically revised the manuscript draft, and approved the final version of the manuscript for submission.

Conflicts of interest

The authors declare that they have no competing interests.

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