International Journal of Cardiology xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

Cognitive ability, lifestyle risk factors, and two-year survival in first myocardial infarction men: A Swedish National Registry study☆

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ARTICLE INFO

Article history:
Received 28 September 2016
Received in revised form 30 November 2016
Accepted 20 December 2016
Available online xxxx

Keywords:
Behaviour and behavioural mechanisms
Cardiovascular disease
Intelligence
Lifestyle
Risk factors
Secondary prevention

ABSTRACT

Background: General cognitive ability (CA) is positively associated with later physical and mental health, health literacy, and longevity. We investigated whether CA estimated approximately 30 years earlier in young adulthood predicted lifestyle-related risk factors and two-year survival in first myocardial infarction (MI) male patients.

Methods: Young adulthood CA estimated through psychometric testing at age 18–20 years was obtained from the mandatory military conscript registry (INSARK) and linked to national quality registry SWEDEHEART/RIKS-HIA data on smoking, diabetes, hypertension, obesity (BMI > 30 kg/m^2) in 60 years or younger Swedish males with first MI. Patients were followed up in the Cause of Death registry. The 5659 complete cases (deceased = 106, still alive = 5553) were descriptively compared. Crude and adjusted associations were modelled with logistic regression.

Results: After multivariable adjustment, one SD increase in CA was associated with a decreased odds ratio of being a current smoker (0.63 [0.59, 0.67], $P < 0.001$), previous smoker (0.79 [0.73, 0.84], $P < 0.001$), having diabetes (0.82 [0.74, 0.90], $P < 0.001$), being obese (0.90 [0.84, 0.95], $P < 0.001$) at hospital admission, and an increased odds ratio of two-year survival (1.26 [1.02, 1.54], $P < 0.001$). CA was not associated with hypertension at hospital admission (1.03 [0.97, 1.10], $P = 0.283$).

Conclusions: This study found substantial inverse associations between young adulthood CA, and middle-age lifestyle risk factors smoking, diabetes, and obesity, and two-year survival in first MI male patients. CA assessment might benefit risk stratification and possibly aid further tailoring of secondary preventive strategy.

1. Introduction

Coronary Heart Disease (CHD) remains the leading cause of death globally and Myocardial Infarction (MI) its most common acute event, afflicting seven million individuals annually [1,2]. Acute MI and underlying CHD is a result of both genetic and lifestyle-related factors. The INTERHEART study found that nine modifiable risk factors, including smoking, unhealthy diet, diabetes, hypertension, physical inactivity, and psychological stress explained 90% of the population attributable risk of MI [3]. Patient *behaviour* is essential for reducing these modifiable risk factors, and underlying causes of such behaviour is therefore of great importance.

General cognitive ability (CA) denotes the distillate of an individual's mental capacities [4–6]. CA is evident in basic day-to-day cognitive functions such as information processing, problem solving, and memory [7,8]. Within an individual, CA is highly stable from age 18 to 65 [9]. Quantified as the full-scale Intelligence Quotient (IQ), the intra-individual stability of CA displays the highest test-retest reliability of all psychological constructs [8,10]. Across individuals, however, CA exhibits considerable variation [8], which in turn is strongly predictive of several health-related life outcomes, for example educational achievement [11,12], job status attainment, and work performance [8,13,14]. Genetic studies have shown that CA is strongly heritable, and its phenotypical expression is subject to physical trauma and ageing effects, yet from adolescence and onwards it is resilient to other environmental influences (e.g. education) [8,15,16].

With respect to MI risk factors and mortality, aggregate research shows that higher CA early-in-life is associated with a greater likelihood to (i) exercise [17], (ii) eat healthy [17], (iii) be health literate [13], (iv)

☆ Grant support: This work was supported by the Swedish Research Council for Health, Working Life, and Welfare [2014-4947], the Vårdal foundation [2014-0114], and U-CARE [2009-1093].

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[1] This author takes responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

http://dx.doi.org/10.1016/j.ijcard.2016.12.144

Please cite this article as: J. Wallert, et al., Cognitive ability, lifestyle risk factors, and two-year survival in first myocardial infarction men: A Swedish National Registry s..., Int J Cardiol (2016), http://dx.doi.org/10.1016/j.ijcard.2016.12.144

be less prone to psychological stress and pathology [18], (v) not smoke [19], (vi) have less hypertension [20], (vii) not develop obesity [21], (viii) not develop CHD [22], and (ix) live longer [23]. This indicates that CA constitutes a general MI/mortality risk indicator, particularly since CA seems to predispose individuals for a range of cardiovascular risk factors.

It is therefore interesting to note that consensus guidelines on primary and secondary MI prevention [24,25] do not mention individual differences in CA, especially when there is evidence that current rehabilitation programs leave room for improvement [25,26]. In the SWEDEHEART national quality registry on Secondary Prevention after Heart Intensive Care (SEPHIA), only 21% of post-MI patients reach the four most important rehabilitation targets; smoking cessation, systolic blood pressure (SBP) < 140 mmHg, LDL cholesterol <1.8 mmol/L, and maintaining adequate exercise [26]. Patient behaviour through lifestyle change is key in reaching these targets [25], and CA is in turn crucial for such target behaviour [13].

We related CA measured in young adulthood to four established lifestyle risk factors (smoking, diabetes, hypertension, and obesity) measured ~30 years later, and to two-year post-MI survival among first MI male patients ≤60 years. We hypothesized that higher CA was associated with: (1) lower prevalence of these four lifestyle risk factors at first MI hospital admission; (2) lower mortality within two years after the MI. We also hypothesized that (3) CA would be lower in the sample under study compared to simulated population data.

2. Methods

2.1. Data sources

The SWEDEHEART national quality Registry for Information and Knowledge about Swedish Heart Intensive Care Admissions (RIKS-HIA) contains data on >100 variables from patients admitted to a Cardiovascular Care Unit (CCU) in Sweden for acute coronary syndrome. RIKS-HIA is unselected and provides excellent coverage of the Swedish population (~90% of all MIs < 80 years). The local hospital decides on discharge diagnosis, for MI cases according to ICD codes I21–I23 [27] based on ECG, clinical symptoms, and other information [28]. The Swedish Cause of Death registry records the death date for patients that died during the study period. The Swedish National Archives (Riksarkivet) maintain the INSARK database which contains digitalized data from all Swedish men that performed mandatory military conscription at age 18–20 between years 1969–1997 [29]. Women were either not allowed or rarely conscripted, a limitation restricting our study to men [30]. Registries were linked by the National Board of Health and Welfare (Socialstyrelsen).

2.2. Ethical statement

These national registries aim to include all cases without discrimination, are sanctioned by Swedish law and monitored by designated registry organizations. All patients are informed of their inclusion and their right to have their data erased at any time at their own request. No one requested this during 2011 and 2013 and very few did before 2011. The present study was approved by the regional ethics committee in Uppsala (Dnr: 2013/478), and adheres to the 1975 Declaration of Helsinki.

2.3. Case selection and survival classification

We selected RIKS-HIA male patients that suffered a first MI in Sweden from 1st of January 2006 to 31st of December 2011. Each patient was classified as survivor or non-survivor depending on if the patient was alive 24 months after their MI admission date. Therefore, the maximal theoretical age of RIKS-HIA patients that also had INSARK data was 62 years (born 1949, conscript 1969 at age 20, and had a first MI in 2011 at age 62). Implementation delays of the conscript procedure and the scarcity of 20 year old conscripts rendered an effective sample ≤ 60 years of age at the time of hospital admission. Hence, CA was estimated when patients were between 18 and 20, lifestyle outcomes were measured at the time of hospital admission when these subjects were admitted for their first MI, i.e. 30–60 years old (mean age = 51.8), and mortality was assessed two years post-MI. The average age difference between the predictor (CA) and outcomes was therefore approximately 30 years. There were few incomplete cases with missing values, primarily for length (16.9%), weight (7.4%), SBP (5.9%), HR (4.2%), and smoking (3.1%). Removal of incomplete cases rendered a final sample of 5659 complete cases (106 deceased, 5553 still alive). For reference, we also calculated baseline characteristics for 34,849 cases constituting the whole first MI male population registered between 2006 and 2011 in RIKS-HIA with complete values on all but the CA variable.

2.4. Psychometric variables

We used the standardized nine (Stanine) scaled individual performance on the four psychometric tests (S1–4) from the Swedish Enlistment Battery (SEB). These tests estimate verbal ability (S1), logical reasoning (S2), spatial/non-verbal ability (S3), and technical understanding (S4) [30]. A principal component analysis revealed similar and substantial factor loadings from all subtests on the first principal component, taken to be the general CA factor (loadings range = −0.53 to −0.46). This first composite factor was the only one which eigenvalue was >1 and accounted for most of the variance in test scores (65.6%). Similar to [9], we therefore added the four standardized subtest scores and divided their sum by four to construct a unit weighted CA estimate. Because the psychometric scores on each subtest were standardized in relation to the total male conscript cohort with $\mu = 5$, $\sigma = 2$, and are normally distributed in this population [30], it was possible to simulate CA in the full conscript cohort. This required calculating the population standard deviation (σ) which was done by taking the ratio of the population mean (μ) and the sample mean (x) and multiplying this with the sample standard deviation (s)

$$\sigma = \left(\frac{\mu}{x}\right) * s$$

which resulted in $\sigma = 1.56$. We then simulated a Gaussian vector of length = 5659 with $\mu = 5$ and $\sigma = 1.56$ to represent CA in the full conscript cohort.

2.5. Lifestyle risk factors and covariates

We selected four established MI/mortality risk factors with clear behavioural components, also found to be CA-related in previous studies [5,19,21,31]: self-reported smoking (current smoker/previous i.e. quit >1 month ago/never), known comorbid diabetes (yes/no), hypertension defined as if previously or presently medicated for this condition (yes/no), and obesity defined as body mass index (BMI) > 30 kg/m^2 (yes/no). Additionally, we selected age (years), resting-state SBP (mmHg), resting-state heart rate (bpm), primary percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG) (yes/no), and discharge medicines: ACE-inhibitors and/or A2-blockers (yes/no), oral anticoagulants (yes/no), other antiplatelet (yes/no), beta blockers (yes/no), and statins (yes/no).

2.6. Statistical procedures and software

We present continuous variables as mean (SD) and categorical variables as count (%) unless specified otherwise. For group comparisons on categorical variables we used the Pearson's χ^2-test, and for continuous variables the Welch's t-test. Binomial and multinomial logit modelling was performed to estimate the adjusted influence of CA on the odds of lifestyle risk factor prevalence and survival. Odds ratios (OR) with 95% profile likelihood confidence intervals (CI) and z-tests for coefficient significance are reported. Given the patients relatively low age, we only assumed a log-linear association between age and survival. Statistical significance was set to 5% (two-tailed). Complete cases were analysed in R (version 3.2.3, R Development Core Team, Austria, Vienna) [32] using packages *AER, base, MASS, nnet, plyr, psych, stats,* and *rms*.

3. Results

Age ranges for complete cases at first MI admission in the full sample (30–60), the subsample deceased (38–60), subsample still alive (30–60), and the total first MI male RIKS-HIA population (11–99) are reported complementary to the mean (SD) ages represented in Table 1. Descriptive statistics in Table 1 shows that all four psychometric mean estimates and their aggregated mean CA were lower in non-survivors compared to survivors (comparison of CA means, $P = 0.003$). Non-survivors were also slightly older ($P < 0.001$), more likely to currently smoke, less likely to never have smoked ($P = 0.007$), more likely to have diabetes ($P < 0.001$) at hospital admission, and less likely to receive beta blockers ($P < 0.001$), statins ($P < 0.001$), and other antiplatelets ($P < 0.001$) at discharge. Heart rate was higher ($P < 0.001$) in non-survivors. Group comparisons for previous smoking, hypertension, and obesity prevalence, primary PCI and CABG, and for height, weight, SBP, and BMI were not statistically significant. CA in the full study sample was also lower compared to CA in the simulated full male conscript population ($P < 0.001$). Compared to the empirical norm, we see that our full sample represents a considerably younger portion of first MIs in Sweden ($P < 0.001$).

Logit modelling was then performed and odds ratios computed (OR). Table 2 shows that one SD increase in CA corresponds to an unadjusted (crude) decreased odds by 37% of being a current smoker, 20% of being a previous smoker, 18% of having diabetes, 13% of being obese,

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and a 1% increased odds of having hypertension at first MI hospital admission. Adding covariates did not significantly change the CA estimate on any lifestyle factors. Furthermore, one SD increase in CA corresponded to an unadjusted 34% increased odds of survival two years post-MI. Adjustment for age, lifestyle factors, cardiac variables, primary PCI, CABG, and discharge medication, rendered CA significantly associated with survival, with the full model showing a 26% odds increase for survival per one SD increase in CA.

4. Discussion

We evaluated CA measured during mandatory military conscription in young adulthood, to four major lifestyle risk factors assessed 30 years later at the time of an acute MI and to the two-year survival, in at the time middle-aged first MI male patients. Higher CA was consistently associated with lower risk of being a smoker, having diabetes, and being obese, but not with having hypertension. Higher CA was also consistently associated with lower post-MI mortality. Moreover, the first MI males under study had relatively lower CA than the expected military conscript population norm.

4.1. Clinical implications

Regarding lifestyle factors, our results confirm previous findings of lower youth CA associated with higher smoking prevalence at age 40 in similar patients [19], and findings of lower childhood CA in current smokers compared to never/past/ever smokers at age 50 [33]. To the extent of our knowledge, diabetes has not been studied as a comorbid diagnosis in first MI patients with respect to CA, and conflicting results found in general-population samples (e.g. [20,34].). We found a substantial negative association between CA and diabetes which extends the literature in this regard. This suggests further investigation since the typical age at first MI implies that ~90–95% of those with comorbid diabetes have type 2 diabetes for which behavioural change has considerable potential [35]. There was also an inverse association between CA and obesity, corroborating previous findings of a negative association between early-in-life CA and risk of obesity in middle-age [36]. Previous research also suggests that low CA predisposes for obesity and not the reverse [21]. Hypertension was not associated with CA in our study, which seems to deviate from previous findings of an inverse association [20]. Hence, there might not be a CA association with hypertension in this relatively young sample, although it may develop later. In line with this reasoning, hypertension was considerably more prevalent in the approximately 15 years older whole first MI male RIKS-HIA population norm. Research on CA associations with hypertension over the lifespan would clarify this. This negative finding may also be a result of regression dilution due to underdiagnosed hypertension in less healthcare compliant low CA patients.

Overall, the present findings add to previous research [5,6,13,17,18,22,23,34,37–39] showing that individuals with low early-in-life CA are less likely to lead a healthy life, with substantial differences in both lifestyle risk factor prevalence and lower survival rates as a result. CA might therefore play a key role for the aggregation of the general cardiovascular risk factor burden and higher post-MI mortality. Our findings suggest that low CA is a substantial risk indicator worthy of clinical attention for these patients. Those with low CA have a higher risk factor burden and lower survival rates which implies a greater need for lifestyle modifications.

Consensus guidelines recommend treatment and care tailored to specific risk-groups [24,25]. However, CA is not mentioned in these guidelines, and CA's well-established relationship with learning, understanding, and remembering facts and instructions is not optimally used in secondary prevention for these patients. On that note, the SPICI survey found that 60% of patients believed they "were cured" after Percutaneous Coronary Intervention (PCI), while doctors generally believed their patients had understood the information conveyed about their lifelong cardiovascular disease [40]. Not only will low CA individuals understand less of what the doctor tells them, but they may also give the impression that they understand to facilitate social interaction. Empirically, low CA is associated with a tendency to over-claim knowledge [41]. Perhaps the unsatisfactory present state of secondary prevention partly reflects a mismatch between standard post-MI care and individual differences in patient CA. Although it is unfeasible to intervene directly on CA, there are abundant examples from both the school system and geriatric medicine of successful interventions with tailored communication and support based on individual differences in CA.

Table 1
Sample and norm descriptive data.

	Full sample (n = 5659)	Non-survivors (n = 106)	Survivors (n = 5553)	Simulated norm[a] (n = 5659)	Empirical norm[b] (n = 34,849)
S-1	4.75 (1.88)	4.16 (1.82)	4.77 (1.88)	5.00 (2.00)	–
S-2	4.74 (1.86)	4.44 (1.89)	4.75 (1.86)	5.00 (2.00)	–
S-3	5.13 (1.89)	4.86 (1.91)	5.14 (1.89)	5.00 (2.00)	–
S-4	4.59 (1.82)	4.03 (1.84)	4.60 (1.82)	5.00 (2.00)	–
CA	4.81 (1.51)	4.37 (1.48)	4.81 (1.50)	5.00 (1.56)	–
Age	51.8 (5.4)	53.6 (4.6)	51.7 (5.4)	–	66.6 (11.8)
SBP (mm Hg)	149.5 (27.2)	143.8 (31.7)	149.6 (27.1)	–	147.8 (28.0)
Heart rate (bpm)	77.7 (18.9)	90.2 (25.7)	77.5 (18.7)	–	78.2 (21.2)
Height (cm)	179.0 (6.6)	179.0 (7.4)	179.0 (6.6)	–	176.7 (6.8)
Weight (kg)	90.8 (15.2)	90.8 (19.7)	90.9 (15.1)	–	84.4 (14.3)
BMI	28.3 (4.3)	28.0 (5.7)	28.3 (4.3)	–	27.0 (4.1)
Current smoker	2251 (40)	55 (52)	2196 (40)	–	9052 (26)
Previous smoker	1529 (27)	29 (27)	1500 (27)	–	13,107 (38)
Never smoker	1879 (33)	22 (21)	1857 (33)	–	12,690 (36)
Diabetes	559 (10)	25 (24)	534 (10)	–	5545 (16)
Hypertension	1651 (29)	33 (31)	1618 (29)	–	14,276 (41)
Obesity	1652 (29)	31 (29)	1621 (29)	–	6843 (20)
Primary PCI	2393 (42)	37 (35)	2356 (42)	–	11,864 (34)
CABG	13 (0)	0 (0)	13 (0)	–	56 (0)
ACE inhibitor	3824 (68)	66 (62)	3758 (68)	–	22,105 (63)
A2 blocker	453 (8)	4 (4)	449 (8)	–	3884 (11)
Other anticoagulant	179 (3)	6 (6)	173 (3)	–	2005 (6)
Other antiplatelet	5161 (91)	70 (66)	5091 (92)	–	28,874 (83)
Beta blocker	5229 (92)	83 (78)	5146 (93)	–	31,184 (89)
Statin	5458 (96)	83 (78)	5375 (97)	–	31,604 (91)

Data are decimal mean (SD) or integer count (%). [a] Total conscript population. [b] Total first MI male population with complete values in RIKS-HIA as registered from 2006 to 2011. A2, alfa-2 receptor; ACE, angiotensin converting enzyme; BMI, body mass index; CA, cognitive ability; CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention; S1–4, stanine standardized subtests; SBP, systolic blood pressure.

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Table 2
Full sample ($n = 5659$) crude and adjusted odds ratios (OR) with 95% CIs per one SD increase in young adulthood CA.

		Adjusted for			
	Crude	Age	Age, Lifestyle[a]	Age, Lifestyle[a], SBP, HR	Age, Lifestyle[a], SBP, HR, PCI/CABG, Discharge medications[b]
CA (Curr. smoker)[c]	0.63***	0.63***	0.62***	0.63***	–
	(0.59, 0.67)	(0.59, 0.67)	(0.58, 0.67)	(0.59, 0.67)	
CA (Prev. smoker)[c]	0.80***	0.78***	0.79***	0.79***	–
	(0.74, 0.86)	(0.73, 0.83)	(0.73, 0.84)	(0.73, 0.84)	
CA (Diabetes)	0.82***	0.81***	0.81***	0.82***	–
	(0.75, 0.89)	(0.74, 0.88)	(0.73, 0.89)	(0.74, 0.90)	
CA (Hypertension)	1.01	0.99	1.02	1.03	–
	(0.96, 1.07)	(0.94, 1.05)	(0.96, 1.09)	(0.97, 1.10)	
CA (Obesity)	0.87***	0.88***	0.89***	0.90***	–
	(0.82, 0.92)	(0.83, 0.94)	(0.83, 0.94)	(0.84, 0.95)	
CA (Survival)	1.34**	1.39***	1.29*	1.27*	1.26*
	(1.11, 1.62)	(1.14, 1.68)	(1.06, 1.57)	(1.04, 1.54)	(1.02, 1.54)

[a] Lifestyle factors are modelled with the sole exclusion of the lifestyle factor presently modelled as outcome. Survival is only modelled as outcome. [b] ACE/ARB, oral anticoagulants, other antiplatelets, beta blockers, statins. [c] Multinomial logistic regression with never smoker as reference. CA, cognitive ability; CABG, coronary artery bypass grafting; HR, heart rate; MI, myocardial infarction; PCI, primary percutaneous coronary intervention; SBP, systolic blood pressure. *** $P < 0.001$. ** $P < 0.01$. * $P < 0.05$.

This practice might also benefit cardiology—MI patients are required to perform complex behaviour changes on which their future survival often depends.

4.2. Limitations of the study

Survival and lifestyle risk factors were measured at discrete timepoints. This should be complemented with future time-to-event designs, more accurately assessing risk over time. Selection bias of patients that died before the RIKS-HIA registration is possible, yet our results harmonize fairly well with previous cohort studies [42]. The restricted sample also limits conclusions to relatively young, first MI males. Secondary PCI treatment information was missing. However, additional statistical adjustment for primary PCI, CABG and discharge medicines—very important factors for future mortality in these patients—did not change the association of CA on mortality. Another possible limitation is that SES variables, such as education, job status, and income were unavailable. Similar to CA, SES is substantially and negatively associated with morbidity/mortality—both all-cause and cardiovascular specific [6,11]. However, given the stability of CA and that only later-in-life SES moderates the CA—mortality association [6], statistical adjustment for adult behavioural proxies of underlying CA (e.g. educational attainment, job status, and income) is probably incorrect [38]. There is epidemiological consensus to not adjust for a covariate that is both (a) associated with the exposure and the outcome, and (b) lies in the investigated pathway [43].

4.3. Strengths of the study

Linkage of three high-quality national registries provided data on the largest cognitive epidemiology sample to date of young first MI male patients. This allowed for analysis of the rare first MI patients that also die within two years after their MI, and precise logit modelling. Risk of reverse causality is low because CA data was collected in young adulthood ~30 years before other variables. The standardized data collection, registration, and monitoring procedures by either the military or specialized healthcare also benefited data quality.

4.4. Conclusions

This study found substantial inverse associations between CA, and the lifestyle-related cardiovascular risk factors smoking, diabetes, and obesity later in life, and two-year mortality in young first MI male patients. CA assessment might benefit risk stratification and possibly aid further tailoring of secondary preventive strategy.

Author contributions

All authors contributed to (1) the conception and design of the study, the acquisition, analysis, or interpretation of data for the work, (2) critically revised the manuscript, and (3) gave final approval and agrees to be accountable for all aspects of work ensuring integrity and accuracy. JW drafted the manuscript.

Conflicts of interest

None.

Acknowledgements

We are deeply grateful to the SWEDEHEART/RIKS-HIA patients. We thank Malin Ander and Claudia Lissåker for valuable manuscript comments.

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Please cite this article as: J. Wallert, et al., Cognitive ability, lifestyle risk factors, and two-year survival in first myocardial infarction men: A Swedish National Registry s..., Int J Cardiol (2016), http://dx.doi.org/10.1016/j.ijcard.2016.12.144