

Health Indices and Cognitive Performance in Emerging Adults

Darla M Castelli*, R. Matthew Brothers, Jungyun Hwang, Hildi M Nicksic, Elizabeth M. Glowacki, Michelle L. Harrison and Daniel Van Dongen

The University of Texas at Austin, USA

Abstract

The purpose of this study was to examine the relationship of health indices with cognition in emerging adults.

Methods: Methods included collecting measures of C-Reactive Protein (CRP), arterial stiffness, cardiorespiratory fitness, blood pressure, Body Mass Index (BMI), and cognitive performance from fourteen participants. Cognitive performance was assessed through the administration of Kaufman Brief Intelligence Test, Stroop Color-Word Test, and Trail Making Test A & B. CRP was commercially measured using the hsCRP Enzyme Immunoassay kit. Cardiorespiratory fitness was determined by the VO_2 maximal testing using incremental stages on a cycle ergometer, while arterial stiffness and pulse wave velocity were measured using two identical transcutaneous Doppler flowmeters.

Results: ANOVA calculations revealed gender differences in cardiorespiratory fitness and BMI. Pearson correlations disclosed significant relationships between CRP and all conditions of the Stroop test and the Trail Making A condition. Surprisingly, in this sample, CRP was not significantly related to BMI. Multiple regression analyses, using Stroop tests as the dependent variable while controlling for IQ and BMI, evidenced that CRP negatively and cardiorespiratory fitness positively contributed to cognitive performance for multiple conditions of the Stroop conditions. No single factor significantly predicted cognitive performance on the Trail Making test.

Conclusions: Despite being at the developmental peak, CRP and cardiorespiratory fitness were associated with cognitive performance in emerging adults. On the Stroop task, CRP level significantly predicted cognitive performance for both congruent and incongruent tasks, but this effect was not reproduced on all conditions of the Trail Making reaction time tasks. These findings are valuable because identifying how health risks are related to cognition at this stage of lifespan may help us to better understanding how to maintain cognitive health and minimize premature cognitive decline as we age.

Keywords: Cognition; C-Reactive Protein (CRP); Cardiorespiratory fitness; Arterial stiffness

Introduction

Although there is robust evidence supporting the relationship between physical activity and cognition [1-4], most research has focused on older adult [5-8] and child populations [9-12]. However, given that individuals within the emerging adult population have an increased prevalence of health risk factors [13], it is critical that attention be directed toward identifying the potential contributors to such early declines in overall health.

Emerging adulthood is classified as a developmental stage between adolescence and adulthood, including individuals in their late teens and mid-twenties [14]. Individuals in this age range typically exhibit the most efficient behavioral responses when presented with cognitive stimuli of any age range population as the brain is developmentally mature and age-related loss of cognition has not commenced [15]. Traditionally, cardiorespiratory fitness is high and health risk relatively low during the second and third decade of life; however, this status is changing, as incidence of morbidity is increasing among young people [16]. Because diseases previously common in older adults have become prevalent in younger populations, it is important to understand how cognitive health may be impacted.

Young adults with low fitness who were studied over a 15-year period were found to have developed diabetes, hypertension, and metabolic syndrome [17]. Furthermore, the emerging adults of today have high blood pressures, high cholesterol levels, high BMIs, and increased risks for artery calcification [18,19]. The prevalence of risk factors within emerging adults is especially troubling when one considers that individuals within this age group are thought to be at their peak cardiorespiratory and cognitive abilities. As such, the current study explores how health indices, such as levels of C-Reactive Protein

(CRP), relate to performance on congruent and incongruent cognitive tasks in an emerging adult population.

CRP is a protein produced by the liver and serves as an indicator of one's risk for developing coronary heart disease because of its rapid response to inflammation [20]. Elevated CRP levels are indicative of inflammation and often result from such factors as obesity and metabolic syndrome [21]. In addition to the health consequences associated with CRP, cognitive performance has also been linked to this protein such that a significant relationship was found to exist between cognitive dysfunction and elevated CRP levels, among overweight and obese individuals [22]. A systematic review of CRP and cognitive disorders found that six, cross-sectional- or cohort-designed studies among older adults, confirmed that high levels of CRP were associated with cognitive decline and risk for dementia [23].

Other health indices of consideration in populations at risk include, but are not limited to, arterial stiffness and blood pressure. Arterial stiffness, or a loss of elastic fibers within the arterial wall, is an indicator of risk for cardiovascular disease. Recently, arterial stiffness has been identified as an independent predictor of loss of cognitive function

*Corresponding author: Darla M Castelli, The University of Texas at Austin 1 University Station, Mail code D3700, Austin, TX 78712, USA, Tel:512-232-7636; E-mail: dcastelli@utexas.edu

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in older adults [24]. The age of onset of arterial stiffness is declining. Adiposity, body weight, and a clustering of risk factors culminating in metabolic syndrome have also been linked to a decline in cognitive function in later life [25]. During midlife or the ages of 25-74, the health of cardiorespiratory system has been associated with executive function and memory, while inflammation was only related to memory [26]. Accordingly, it was hypothesized that individuals with at least one of the health risk factors measured in this study (e.g., elevated CRP levels, elevated blood pressure, and poor cardiorespiratory fitness) would have slower and less accurate cognitive responses than emerging adults with fewer risk factors.

Methods

Participants

Upon receiving Institutional Review Board approval, fifteen emerging adults (n=8 females) with a mean age of 23.00 (SD=3.64) and a mean Body Mass Index (BMI) of 22.60 (SD=2.65) were recruited to participate in this study. The participants were solicited from various advertisements offered on a large university campus in the southern United States. All participants were involved in campus life as an employee or student.

Instruments and techniques

Three cognitive instruments, one blood assay, and various physiological techniques were used in this study. The cognitive measurements included the Kaufman Brief Intelligence Test (KBIT), Stroop Color-Word Test (Stroop), and Trail Making Test (Trail Making). The KBIT [27] provides an estimation of verbal (crystallized) and nonverbal (fluid) intelligence and has a reliability range from .88 to .94. The Stroop test [28] provides participants with 45 seconds to read words displayed on the page in columns. In the first task, Word, color names are written in black ink. In the second task, Color, "words" are composed of Xs in different colors of ink, requiring participants to identify ink color. For the final task, Color-Word, color names appear in contrasting colors of ink, requiring participants to identify ink color rather than reading the word. Trail Making A and B29 measures the time it takes for a participant to draw lines that connect ordered numbers as quickly as possible. The first test, Trail Making A, includes numbers, while the second test, Trail Making B, adds letters such that the connection is made from 1 to A to 2 to B. If an error was not immediately addressed by the participant (e.g., realizing that they had drawn a line to an incorrect number), the researchers prompted the participant to correct this action.

Using blood drawn through a venipuncture, serum levels of CRP were determined with an Enzyme-Linked Immunosorbent Assay (ELISA) method (High Sensitivity Enzyme Immunoassay, BioCheck, Inc., USA). According to the manufacturer's instructions (Schultz & Arnold, 1990), 96-well polystyrene microplates were coated with a mouse monoclonal-CRP antibody. After absorbance was read at 450 nm on a microplate reader and CRP concentrations were determined automatically according to the CRP standard curve.

Other techniques included in this research study centered on the collection of resting blood pressure, BMI as a measure of standing height and weight, and arterial stiffness. Arterial stiffness and pulse wave velocity were measured both manually and using an automatic device. The manual method consisted of using two identical transcutaneous Doppler flowmeters (810-A, Parks Medical, Aloha, OR) to obtain the velocity of pulse waves (PWV) between the following: the aortic arch

and the femoral artery (aortic PWV), the brachial and the radial artery (arm PWV), the femoral and the posterior tibial artery (leg PWV), the aortic arch and the posterior tibial artery (whole-body PWV), and between the brachial and the posterior tibial artery (baPWV) as previously described. Arterial pressure waves were digitized for off-line analysis with signal processing software (Biopac System, Santa Barbara, CA). Pulse wave velocity was calculated from distance divided by transit time. Transit time was determined from the time delay between the proximal and distal "foot" waveforms. The foot of the wave was identified as the commencement of the sharp systolic upstroke. Distance traveled by the pulse wave was assessed in duplicate with a random zero length measurement over the surface of the body with a non-elastic tape measure.

Procedures

After a twelve hour overnight fasting state, a resting blood draw was conducted to measure baseline CRP in the morning, which was analyzed using commercially available hsCRP Enzyme Immunoassay kit (BioCheck). Because one individual was not available for the blood draw, the corresponding analysis was conducted using fourteen subjects. If a CRP value was two standard deviations away from the group mean, an additional assay was run to confirm the accuracy of the level of risk. After the blood draw the participant was offered a snack, completed a health screening questionnaire, and height and weight were measured. Arterial stiffness measures and blood pressure measures were collected from the participant in a supine position, while resting comfortably. Participants were initially positioned on the cycle ergometer (Velotron Dynafit Pro, Seattle WA). Cardiorespiratory fitness was determined through four incremental five minute stages of submaximal cycling for the determination of oxygen consumption VO₂ versus work rate relationship followed by an ergometry test to determine maximal oxygen consumption (VO₂ max), using indirect calorimetry via continuous gas-exchange measurements, which also provided measurement of RER and METs (True-Max; ParvoMedics, Sandy, UT). On a second day of testing, participants completed baseline cognitive testing and an acute bout of physical activity. The cognitive test administration sequence was KBIT, Stroop, and Trail Making, which was followed post exercise by repeating the Stroop and Trail Making assessments. The results of the baseline cognitive assessments are described here, while the acute responses to physical activity are reported in another manuscript.

Variable	All (n=14)	Females (n=8)	Males (n=6)
Age (years)	23.00 (3.64)	22.88 (3.40)	23.17 (4.26)
KBIT (IQ)	107.64 (12.06)	108.58 (13.74)	106.91 (10.71)
BMI (Kg/m ²)	22.60 (2.65)	21.15 (2.20)*	24.53 (1.90)*
VO ₂ max (ml/Kg/min)	41.74 (10.58)	35.48 (8.68)*	49.03 (7.72)*
RER	1.07 (0.07)	1.08 (0.06)	1.06 (0.08)
METs	11.00 (4.32)	10.13 (2.46)	11.89 (5.71)
CRP (mg/L)	3.20 (2.76)	2.42 (1.41)	3.99 (3.95)
PWV (cm/sec)	533.73 (82.99)	525.99 (89.09)	541.46 (82.73)
Stroop Word (# words)	108.36 (13.41)	105.38 (15.24)	113.86 (20.27)
Stroop Color (# words)	80.93 (11.85)	78.38 (12.21)	84.86 (11.78)
Stroop Color-Word (# words)	51.79 (11.58)	54.50 (13.41)	53.86 (10.02)
TrailMaking A (secs)	13.87 (4.01)	13.46 (3.82)	15.37 (4.68)
TrailMaking B (secs)	2.14 (4.15)	34.11 (11.59)	36.29 (9.59)

Abbreviations: BMI: Body Mass Index; RER: Respiratory Exchange Ratio; METs: Metabolic Equivalent; CRP: C-reactive protein; PWV: Pulse Wave Velocity; BP: Blood Pressure. *p<.05

Table 1: Mean (SD) Values for Participant Demographics and Fitness Data by Gender.

Variable	1	2	3	4	5	6	7	8	9	10
Health Indices										
1. CRP (mg/L)	-									
2. PWC (cm/sec)	0.16	-								
3. BMI (kg/m ²)	0.01	0.25	-							
4. VO ₂ max (ml/kg/min)	0.14	0.14	0.04	-						
Cognitive Functions										
5. KBIT	0.08	0.13	-0.71**	0.09	-					
6. Word	-0.55*	-0.45	-0.07	0.39	0.21	-				
7. Color	-0.51*	-0.38	0.22	0.36	-0.03	0.88**	-			
8. Color-Word	-0.63**	-0.36	-0.37	0.26	0.17	0.78**	0.66**	-		
9. Trail Making A	0.48*	0.43	0.19	-0.16	0.00	-0.52*	-0.49*	-0.058*	-	
10. Trail Making B	0.27	-0.04	0.24	-0.57*	-0.34	-0.55*	-0.40	-0.48*	0.39	-

Abbreviations: CRP: C-reactive protein; PWC: Pulse Wave Velocity; BMI: Body Mass Index; VO₂ max: Maximal oxygen consumption, KBIT: Kaufman Brief Intelligence Test

* $p < .05$. ** $p < .01$.

Table 2: Internal Reliabilities and Correlations among Variables.

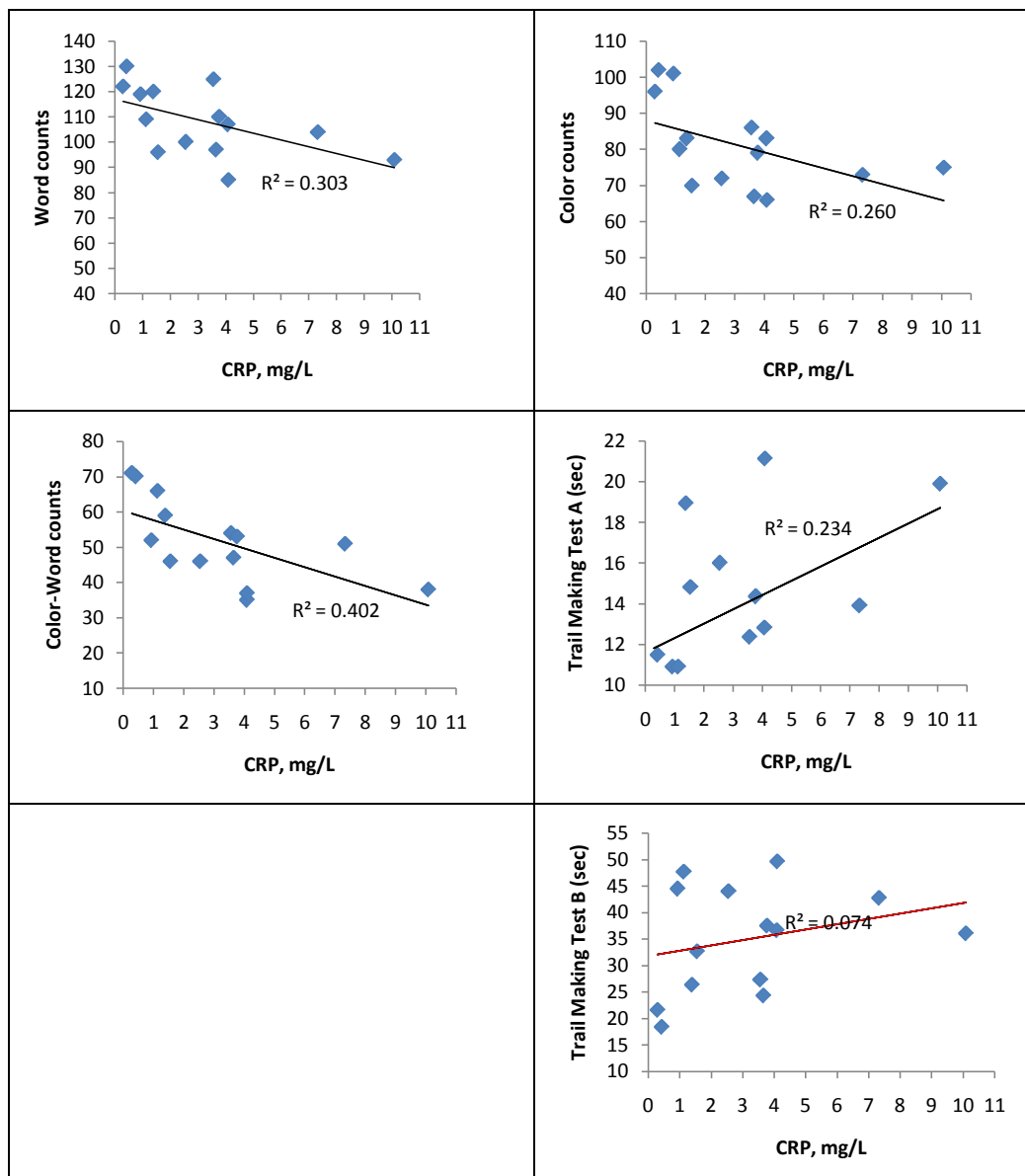


Figure 1: Association between Serum CRP Levels and Cognitive Performance.

Data analysis

All data were confirmed and reduced from a single database in IBM SPSS v19. Descriptive statistics and Pearson correlations were calculated to identify significant characteristics and associations between the variables in this database. Multiple Analysis of Variance (MANOVA) was calculated to determine differences in health indices, cognition and gender. Multiple regressions were calculated with the individual health indices of CRP, BMI, and cardiorespiratory fitness, and arterial stiffness, being regressed on to the dependent cognitive variables.

Results

Table 1 contains the fitness and demographic characteristics of this sample. An ANOVA revealed significant gender differences for BMI [$F(3, 11) 0.06; p=.01$] and cardiorespiratory fitness (ml/Kg/min) [$F(3, 11)=0.36; p=.01$]. There were no significant differences in age, KBIT (IQ), RER, systematic levels of CRP, arterial stiffness, blood pressure, and cognitive function tests by gender. Pearson correlations revealed that the only health marker that was significantly associated with all conditions of the Stroop cognitive assessments and the Trail Making A condition, was CRP (Table 2 and Figure 1). Among the other variables, BMI was not significantly correlated with other health indices and cognitive function tests, but was negatively correlated with KBIT ($r=-0.71, p<.01$). Age was significantly correlated with arterial stiffness ($r=0.67, p<.001$). Cardiorespiratory fitness has a significant, negative with Trail Making Test B ($r=-0.57, p=.027$). There were no significant correlations found between arterial stiffness, pulse wave velocity, and cognitive performance.

When IQ and BMI were controlled, CRP negatively predicted Word ($\beta=-0.69, p<.05$), Color ($\beta=-0.72, p<.02$), and Color-Word ($\beta=-0.83, p<.01$) and accounted for 59%, 73%, and 77% of the variance, respectively. CRP was not a significant predictor of performance on the Trail Making test of cognitive testing in either the congruent or non-congruent conditions ($\beta=0.58, p=.09$ and $\beta=0.41, p=0.33$, respectively). Arterial stiffness and pulse wave velocity did not significantly predict cognitive performance and did not contribute to the regression model. Cardiorespiratory fitness negatively predicted the condition of Trail Making B ($\beta=-0.62, p<.03$) and approached negative significance for Trail Making A ($\beta=-0.71, p<.09$).

Conclusions

Previous research suggests that the prevalence of negative health indices is increasing among emerging adults. The purpose of this study was to examine the relationship of health indices with cognitive performance on both congruent and non-congruent cognitive tasks. Although it was hypothesized that a clustering effect (the idea that multiple health indices would have a collective effect that was greater than any single health marker) would be significantly associated with and a predictor of cognitive performance, the findings in this study suggest that CRP was the only major contributor over other health markers. CRP exhibited predictive systematic levels on cognitive performance, under some, but not all task conditions, when controlling for BMI and IQ. Previous research has identified CRP as a direct neurotoxin resulting in immunoreactivity in the brains of individual's with Alzheimer's [31]. Because instances of highly elevated CRP create this neurotoxicity, it likely affects cognitive tasks under varied conditions; whereas, lower levels of CRP may be related to some cognitive tasks, but not others.

This finding is important among emerging adults, because it

supports the employment of preventive strategies, such as engagement in habitual physical activity within this population and may prioritize this health marker for preventive screening.

In accordance with previous research cardiorespiratory fitness was significantly related to cognitive performance on the Trail Making test [32]. However, surprisingly, in this population cardiorespiratory fitness was not a predictor of performance on the Stroop task. The strength of previously documented associations between aerobic fitness and cognition, in emerging adults, has been weak to moderate and accordingly, these findings could be impacted by the small size of this sample or could be an indicator of complex correlates that subserve cognitive function. These findings should be applied with caution.

Another surprise finding was that BMI was not significantly associated with CRP, as we had hypothesized. This was perhaps affected by the proportion of study participants who were considered to be at minimal risk for cardiorespiratory fitness, whereby some participants were considered "fit and fat". Possibly a larger, more targeted sample that classifies individuals into categories of fitness and risk (e.g., high fit and high risk) may help to further decompose this relationship between body composition, CRP, and cognitive function.

Future research should employ experimental designs to elucidate the potential clustering effects of metabolic syndrome risk factors as they relate to a decline in cognitive performance. Given the strength of the association and predictive qualities of CRP within this study, the effects of preventive strategies, such as regularly participating in physical activity and early screenings should be comprehensively examined.

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