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## Original Article

# Higher BMI Is Associated with Reduced Cognitive Performance in Division I Athletes

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## Key Words

Body mass index · Physical activity · Risk factors · Weight status

## Abstract

**Objective:** Poor cardiovascular fitness has been implicated as a possible mechanism for obesity-related cognitive decline, though no study has examined whether BMI is associated with poorer cognitive function in persons with excellent fitness levels. The current study examined the relationship between BMI and cognitive function by the Immediate Post Concussion and Cognitive Test (ImPACT) in Division I collegiate athletes. **Methods:** Participants had an average age of  $20.14 \pm 1.78$  years, were 31.3% female, and 53.9% football players. BMI ranged from 19.04 to 41.14 and averaged  $26.72 \pm 4.62$ . **Results:** Regression analyses revealed that BMI incrementally predicted performance on visual memory ( $R^2$  change = 0.015,  $p = 0.026$ ) beyond control variables. Follow-up partial correlation analyses revealed small but significant negative correlations between BMI and verbal memory ( $r = -0.17$ ), visual memory ( $r = -0.16$ ), and visual motor speed ( $r = -0.12$ ). **Conclusions:** These results suggest that higher BMI is associated with reduced cognitive function, even in a sample expected to have excellent levels of cardiovascular fitness. Further work is needed to better understand mechanisms for these associations.

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## Introduction

Despite increased awareness, the prevalence of obesity continues to rise in many countries. In 2008, an estimated 1.5 billion people worldwide were overweight (BMI  $\geq 25$ –29.9 kg/m<sup>2</sup>), with 500 million considered obese (BMI  $\geq 30$  kg/m<sup>2</sup>) [1]. Overweight and obese indi-

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viduals are at elevated risk for numerous health problems, including cardiovascular disease, type 2 diabetes, musculoskeletal disorders, and even some forms of cancer [1–3]. The cost of obesity and these comorbid conditions is substantial, totaling nearly USD 150 billion per year in the USA alone [4].

There is growing evidence that obesity is also associated with adverse neurocognitive outcomes including Alzheimer's disease [5], stroke, and vascular dementia [6]. Research also demonstrates an association between obesity and impaired cognitive functioning long prior to the onset of these conditions. Even after controlling for comorbid medical conditions, obese individuals exhibit deficits in multiple cognitive domains, including attention, executive function, and memory [7–16].

The mechanisms for obesity-related cognitive dysfunction remain poorly understood. Neuroimaging studies link obesity to structural and functional changes, including greater atrophy, development of white matter hyperintensities [5], reduced neural connectivity [17], and decreased blood flow in frontal brain regions [18]. Other work demonstrates aspects of glycemic controls, including altered insulin sensitivity and insulin resistance, as important contributors to obesity-related cognitive dysfunction [19–21].

Another likely contributor to obesity-related cognitive dysfunction is reduced cardiovascular fitness. Many obese individuals have poor cardiovascular fitness, perhaps attributable to low levels of physical activity found in this population [22, 23]. In turn, low levels of cardiovascular fitness are associated with reduced cognitive function in a variety of healthy and patient samples [24, 25], and improvements in cardiovascular fitness correspond to improved neuropsychological test performance [17, 24, 26, 27]. Similarly, a weight loss program combining diet and exercise was associated with improved neurocognitive functioning in obese adults [28].

Despite these findings, the contribution of physical fitness to obesity-related cognitive function remains unclear as risk factors often comingle. For example, American football players often have cardiovascular risk factors and type 2 diabetes [29], despite excellent fitness levels. No study to date has examined the association between body composition and cognitive function in a sample of persons expected to have better than average fitness levels. To do so, we examined BMI and cognitive function in a sample of Division I collegiate athletes. Based on the independent effect of obesity on cognition in past work, we expected that higher BMI would be associated with poorer cognitive function.

## Participants and Methods

### *Participants*

Data were collected from 323 (222 males; 101 females) college student athletes at a midsized Midwestern public university. Participants ranged in age from 18 to 24 years (mean  $\pm$  SD 20.14  $\pm$  1.78 years). Athletes were active in sports such as football, men's and women's basketball, gymnastics, field hockey, men's and women's track, cheerleading, wrestling, and women's soccer. Of note, the average number of concussions for the entire sample was 0.35  $\pm$  0.7).

### *Non-Football Sample*

Athletes who did not play football were grouped together for comparison against football players during data analysis. Participants in the non-football group ranged in age from 17 to 23 years (19.90  $\pm$  1.24 years). This group was composed of 48 males and 101 females. The number of athletes in each sport varied from a low of 4 (baseball) to a high of 21 (cheerleading).

## Measures

### *Immediate Post Concussion Assessment and Cognitive Testing (ImPACT)*

The ImPACT is a computerized neuropsychological test battery designed to assess attention, memory, and processing speed. After completion of the test, five composite scores as well as a total score are generated, including verbal memory, visual memory, visual motor speed, reaction time, and impulse control [30]. The ImPACT has high convergent validity [31] as well as excellent sensitivity and specificity [32] in college athlete populations.

### *BMI Calculation*

BMI was calculated from self-report of height and weight collected during the demographic section of the ImPACT.

## Procedures

Athletes completed testing in group format, though each was at an individual workstation and separated into different rooms. Testing was administered by faculty and graduate students in the psychology department, while athletic training staff provided supervision.

## Data Analysis

A series of regressions examined whether higher BMI was associated with reduced performance on composite scores of the ImPACT. Age, gender, sport, and number of past concussions were entered into Block 1 of the regression as control variables and BMI into Block 2. Change in predictive ability ( $R^2$  change) was examined to determine significance. To clarify these findings, partial correlations were also calculated between BMI and ImPACT composite scores separately for each gender and then within the subsample of football players. All data analyses were conducted on SPSS version 16 [33].

## Results

### *BMI Is Associated with ImPACT Test Performance*

Regressions were conducted between BMI and composite scores on the ImPACT. Analyses showed BMI provided incremental predictive ability over control variables (i.e. age, gender, sport, number of past concussions) for the visual memory ( $F(5, 317) = 2.79$ ,  $\Delta R^2 = 0.015$ ,  $p = 0.02$ ) composite score (table 1). No such prediction emerged for verbal memory ( $F(5, 317) = 3.07$ ,  $\Delta R^2 = 0.00$ ,  $p = 0.260$ ), visual motor speed ( $F(5, 317) = 1.57$ ,  $\Delta R^2 = 0.00$ ,  $p = 0.31$ ), reaction time ( $F(5, 317) = 0.76$ ,  $\Delta R^2 = 0.00$ ,  $p = 0.93$ ), or impulse control ( $F(5, 317) = 0.61$ ,  $\Delta R^2 = 0.00$ ,  $p = 0.68$ ).

In order to further assess the relationship between BMI and cognitive function, partial correlation analyses were conducted between BMI and the five ImPACT composite scores while controlling for number of concussions. For the entire sample, results revealed small but significant negative correlations between BMI and verbal memory ( $r = -0.17$ ,  $p < 0.01$ ), visual memory, ( $r = -0.16$ ,  $p < 0.01$ ), and visual motor speed ( $r = -0.12$ ,  $p < 0.05$ ) (table 2).

Semi-partial correlations were also conducted separately for each gender while controlling for number of concussions. For males, BMI was only significantly associated with visual memory ( $r = -0.14$ ,  $p < 0.05$ ). For females, BMI was not significantly associated with any composite scores. See tables 3 and 4 for complete correlations for males and females.

**Table 1.** Linear regressions between BMI and ImPACT composite scores<sup>a</sup>

	B	SE	$\beta$	t	p	$\Delta R^2$
<i>Verbal memory</i>						
Control variables	0.024	0.016	0.114	1.501	0.132	0.042
Full model	-0.002	0.001	-0.076	-1.129	0.260	0.004
<i>Visual memory</i>						
Control variables	0.012	0.022	0.042	0.551	0.582	0.027
Full model	-0.004	0.002	-0.152	-2.240	0.026	0.015
<i>Visual motor speed</i>						
Control variables	0.186	1.287	0.011	0.145	0.885	0.021
Full model	-0.117	0.116	-0.069	-1.008	0.314	0.003
<i>Reaction time</i>						
Control variables	-0.005	0.014	-0.029	-0.381	0.704	0.012
Full model	0.000	0.001	0.006	0.085	0.933	0.000
<i>Impulse control</i>						
Control variables	-0.270	0.292	-0.071	-0.924	0.356	0.009
Full model	0.086	0.206	0.029	0.419	0.675	0.001

<sup>a</sup>Control variables included gender, number of past concussions, age, and sport.

**Table 2.** Correlations between BMI and composite scores for entire sample

	BMI	Verbal memory	Visual memory	Visual motor speed	Reaction time	Impulse control
BMI	-	-0.17**	-0.16**	-0.12*	0.06	0.03
Verbal memory		-	0.47***	0.29***	-0.13*	-0.09
Visual memory			-	0.33***	-0.17**	-0.21***
Visual motor speed				-	-0.32***	-0.24***
Reaction time					-	-0.16**
Impulse control						-

\*Significant at  $p \leq 0.05$ .

\*\*Significant at  $p \leq 0.01$ .

\*\*\*Significant at  $p \leq 0.001$ .

**Table 3.** Correlations between BMI and composite scores for males

	BMI	Verbal memory	Visual memory	Visual motor speed	Reaction time	Impulse control
BMI	-	-0.11	-0.14*	-0.12	0.04	0.02
Verbal memory		-	0.47***	0.30***	-9.14*	-0.13
Visual memory			--	0.39***	-0.19**	-0.29***
Visual motor speed				-	-0.36***	-0.24***
Reaction time					-	-0.08
Impulse control						-

\*Significant at  $p \leq 0.05$ .

\*\*Significant at  $p \leq 0.01$ .

\*\*\*Significant at  $p \leq 0.001$ .

**Table 4.** Correlations between BMI and composite scores for females

	BMI	Verbal memory	Visual memory	Visual motor speed	Reaction time	Impulse control
BMI	–	0.02	–0.14	0.12	–0.04	0.12
Verbal memory		–	0.47***	0.22*	–0.04	–0.05
Visual memory			–	0.16	–0.12	–0.08
Visual motor speed				–	–0.18	–0.25*
Reaction time					–	–0.32***
Impulse control						–

\*Significant at  $p \leq 0.05$ .

\*\*Significant at  $p \leq 0.01$ .

\*\*\*Significant at  $p \leq 0.001$ .

**Table 5.** Correlations between BMI and composite scores for football players

	BMI	Verbal memory	Visual memory	Visual motor speed	Reaction time	Impulse control
BMI	–	–0.11	–0.19*	–0.10	0.01	0.00
Verbal memory		–	0.46***	0.33***	–0.13	–0.09
Visual memory			–	0.42***	–0.17*	–0.27***
Visual motor speed				–	–0.34***	–0.19*
Reaction time					–	–0.14
Impulse control						–

\*Significant at  $p \leq 0.05$ .

\*\*Significant at  $p \leq 0.01$ .

\*\*\*Significant at  $p \leq 0.001$ .

### *BMI and Cognitive Dysfunction in Football Players*

Semi-partial correlations, controlling for number of concussions, were also conducted separately for football players and other sport athletes. The characteristics of the other sports athlete sample has been discussed above. In football players, BMI was only significantly associated with visual memory ( $r = -0.19$ ,  $p < 0.05$ ). For other sport athletes, BMI was not significantly associated with any composite scores. See tables 5 and 6 for complete correlations for football players and other sport athletes.

## **Discussion**

The findings of the current study indicate that BMI is negatively associated with cognitive function in a sample expected to have better than average cardiovascular fitness. Several features of these findings necessitate further discussion.

BMI was found to be associated with reduced cognitive performance in Division I athletes, but only in specific areas of functioning. Notably, measures of memory had the greatest associations with BMI while no association was found on measures related to executive function and attention. One factor that may be responsible for these differential effects is cardiovas-

**Table 6.** Correlations between BMI and composite scores for other sport athletes

	BMI	Verbal memory	Visual memory	Visual motor speed	Reaction time	Impulse control
BMI	–	0.03	–0.12	0.06	0.06	0.06
Verbal memory		–	0.48***	0.23**	–0.12	–0.12
Visual memory			–	0.20*	–0.18*	–0.16*
Visual motor speed				–	–0.27**	–0.29***
Reaction time					–	–0.20*
Impulse control						–

\*Significant at  $p \leq 0.05$ .

\*\*Significant at  $p \leq 0.01$ .

\*\*\*Significant at  $p \leq 0.001$ .

cular fitness. Cardiovascular fitness is known to have a beneficial effect on cognitive functioning [34], including measures of executive function [35] and attention [36]. Such findings raise the possibility that fitness helps to moderate the effects of BMI on some aspects of cognitive function (i.e. memory) but not others (i.e. executive function). Furthermore, no association was found between BMI and ImpACT composite scores for females. The explanation for this pattern is unclear, but may involve the differential risk of concussion in male versus female athletes, underreporting of concussions, or a yet-to-be determined factor. Additional work in other populations is much needed.

The results of the current study indicate that BMI is related to poor cognitive function but the exact mechanisms for this association are unclear. It is possible that athletes with a high BMI who over exert themselves are more likely to exhibit impaired performance on testing. Other possibilities include the known physiological effects of higher BMI, including reduced glycemic control [37] and even reduced perfusion to the frontal brain regions [38]. Future prospective studies are needed to clarify the underlying mechanisms which may be at work, especially studies quantifying physical activity level.

The current study is limited in several ways. An important limitation for the current study involves the manner in which BMI was quantified. BMI is known to be limited in several ways, including poor adjustment for demographic factors (e.g. age, sex), concerns regarding the cut-points for BMI groups, and failure to directly measure body fat [39]. As a result, an individual can be lean with high muscle mass and may still be classified as obese according to BMI. This concern may be particularly relevant in a sample of athletes. However, it is noteworthy that greater BMI was still associated with poorer cognitive function in the current sample, despite these concerns. Future studies should consider alternate measures of obesity, including dual energy X-ray absorptiometry [40]. Another concern involves sample composition as groups were not balanced across gender or sport. The gender imbalance may be particularly important because men and women can be incorrectly identified as obese at different rates [39] and have different incidence rates of concussion [41]. The sport imbalance is also an important consideration as athletes from particular sports may be classified as obese and have very different body types. (i.e., offensive lineman in football vs. a men's basketball player).

In summary, the results of the present study indicate that higher BMI is associated with reduced verbal and visual memory in Division I athletes. Further work is needed to identify the mechanisms by which obesity adversely impacts cognitive function, particularly studies involving neuroimaging.

## Disclosure Statement

The authors have no conflicts of interest to declare.

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