DOES SEEKING THE BRAWNS IMPACT THE BRAIN?: AN INVESTIGATION OF MUSCULARITY-ORIENTED DISORDERED BEHAVIORS AND COGNITIVE FUNCTION

By

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Abstract: Brain health is impacted by body composition as well as associated health behaviors. The current shift in body-image ideals towards a more lean and muscular body has revealed new eating and exercise behaviors that may be related to cognitive function. The goal of this thesis is to investigate possible longitudinal relationships between a drive for muscularity and associated muscularity-oriented disordered behaviors (MODBs) with cognitive performance. Data were primarily drawn from Add Health – a national longitudinal database – Waves III and IV with supplemental results from Wave V. Drive for muscularity and MODB engagement were gathered during a home interview in emerging adulthood. Cognition variables included short-term verbal memory, long-term verbal memory, and working memory measured via immediate word recall, delayed-word recall, and number recall, respectively. Results of a one-way ANCOVA revealed that those with a drive for muscularity had significantly lower immediate word recall ($F(3, 12819) = 3.845$, $p = .009$), delayed word recall ($F(3, 12807) = 5.933$, $p < .001$), and composite cognition scores ($F(3, 12843) = 6.080$, $p < .001$) than the other weight goal groups after controlling for covariates. Next, hierarchical linear regressions were conducted to assess the association between composite MODB scores, as well as individual MODBs, and cognitive outcomes. Legal PES-use (βs = 0.06-0.07, $p < .05$) and exercise ($\beta = 0.06$, $p < .05$) were positively associated with some of the cognition scores after taking covariates into account. Conversely, lifting weights ($\beta = -0.06$, $p < .05$) and eating different foods than usual ($\beta = -0.05$, $p < .05$) exhibited negative associations with some of the cognitive outcomes. Composite MODB score was not related to cognitive variables. Future research should be conducted to examine other potential outcomes related to the drive for muscularity and associated MODBs.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Despite the fact that cognitive function previously has been shown to have established relationships with body composition (Anstey, Cherbuin, Budge, & Young, 2011; Gunstad, Lhotsky, Wendell, Ferrucci, & Zonderman, 2010; Veronese et al., 2017; Yang, Shields, Guo, & Liu, 2018), eating disorders (Galimberti, Martoni, Cavallini, Erzegovesi, & Bellodi, 2012; Green, Rogers, Elliman, & Gatenby, 1994; Nikendei et al., 2011), and weight stigma (Guardabassi & Tomasetto, 2018, 2020; Nikendei et al., 2011), few studies have examined the link between cognitive function and an emerging and related concept in the health literature: Muscularity-Oriented Disordered Behaviors (MODBs). MODBs are theorized to be the result of current trends toward a "muscular ideal." Specifically, the current ideal of physical attractiveness or the ideal body in men has become increasingly muscular over time (Leit, Pope Jr, & Gray, 2001; Pope Jr, Olivardia, Gruber, & Borowiecki, 1999). Similarly, in women the ideal body image has expanded towards an emphasis on a toned, "fit" physique, in addition to a thin-ideal (Homan, 2010).

A number of behaviors have been associated with the desire for increased muscularity. Nagata and colleagues propose that actively trying to gain weight may be a proxy by which one wishes to achieve increased muscularity (Nagata et al., 2019). To be clear – in this case, "gaining weight" refers to gaining muscle mass not fat mass. Alterations to one's diet may be used in order to gain lean muscle mass. About two-thirds of adolescents in the United States are currently estimated to engage in eating behaviors to increase muscle size or tone (Eisenberg, Wall, & Neumark-Sztainer, 2012).

Pathological eating behaviors that are aimed to increase muscle-mass, develop greater muscle leanness, or both have been characterized as “muscularity-oriented disordered eating” (MODE) (Murray et al., 2017; Pila, Mond, Griffiths, Mitchison, & Murray, 2017). Such dietary alterations include: over-regulation of protein consumption and restriction of other dietary macronutrients, consuming protein supplements, engaging in cheat meals, eating beyond the point of feeling full, and maintaining access to preplanned foods (Murray et al., 2017; Pila et al., 2017).

Other behaviors associated with the desire to increase muscularity include performance-enhancing substance (PES) use, both legal and illegal. Legal PESs include substances such as creatine and amino acids, and illegal include anabolic-androgenic steroids (AAS)(Smolak, Murnen, & Thompson, 2005). Creatine is considered one of the most used dietary supplements worldwide and has been shown to increase body mass by 2% (Branch & Williams, 2002). AAS’s, on the other hand, are one of the most popular substances used by adult males (Cafri et al., 2005). A national survey found that nearly 17 million adults reported steroids or other PESs. Compulsive exercise and overtraining to the point of injury have also been identified as maladaptive muscularity-oriented behaviors (Pritchard, Parker, & Nielsen, 2011). Along with injury, MODBs are linked to a number of adverse health outcomes, such as: more severe medical events, as well as cardiovascular, hematologic, psychiatric, hormonal, and metabolic effects (Pope Jr et al., 2014). Cognitive function, however, has remained underexplored in relation to MODBs, despite previously established relationships between cognitive function and related concepts such as weight status, eating disorders, and weight stigma (see Appendix A for a comprehensive review of each of these literatures). The available, if limited literature, on MODBs and cognition function is presented in the following section.

CHAPTER II

REVIEW OF THE LITERATURE

Muscularity-Oriented Disordered Behaviors and Cognitive Performance

While cognitive performance has not been directly investigated in those with body compositions consisting of increased muscle mass and low adiposity, certain muscularity-oriented disordered behaviors have been shown to be associated with cognitive function. These behaviors include use of creatine and steroids, excessive exercise or overtraining, and certain dietary habits. Evidence for each of these behaviors is presented below.

Creatine Use

Creatine is a natural compound that is created through a two-step process which involves a combination from the amino acids: arginine, glycine, and methionine (Andres, Ducray, Schlattner, Wallimann, & Widmer, 2008). Its purpose is to immediately supply energy to muscle and brain tissues with increased energy demands (Persky & Brazeau, 2001). Previous research suggests that higher resting creatine levels may improve cognitive performance on memory tasks (Ferrier et al., 2000). Avgerinos and colleagues (Avgerinos, Spyrou, Bougioukas, & Kapogiannis, 2018) conducted a systematic review to examine the effect of oral creatine supplements on cognitive function in healthy adults. Two of the studies suggest that creatine enhances short-term memory (McMorris, Mielcarz, Harris, Swain, & Howard, 2007; Rae, Digney, McEwan, & Bates, 2003), while short-term memory only improved in vegetarians after creatine supplementation in another study (Benton & Donohoe, 2011). However, in a study of young adults, creatine did not impact short-term memory (Rawson et al., 2008).

Additionally, one of the studies examined long-term memory and also improved in the creatine group (McMorris et al., 2007). In this same study, there were no differences in executive function between the placebo and creatine groups. Two studies examined the effect of creatine on sustained attention, but yielded mixed results (Benton & Donohoe, 2011; Ling, Kritikos, & Tiplady, 2009). Ling et al. also found that the creatine group had improved performance on response inhibition tasks (Ling et al., 2009). Different aspects of intelligence were assessed in three of the studies, in which two studies found improved performance (Rae et al., 2003; Rawson et al., 2008). However, the sample of young adults showed no change. Overall, these findings suggest that creatine supplements may improve short-term memory in healthy adults. However, the impact of creatine on other cognitive domains is uncertain. No negative effects of creatine on cognitive function have been found.

Anabolic-Androgenic Steroid (AAS) Use

AAS are characterized as a group of hormones that consist of testosterone and other synthetic relatives (Kanayama, Hudson, & Pope Jr, 2010). These substances were originally used by athletes and bodybuilders, beginning in the 1950's. It was not until the 1980's that the general population began using AAS (Kanayama, Hudson, & Pope Jr, 2008). AAS are utilized to promote rapid increases in muscle mass and enhance athletic performance. However, several adverse health effects have been associated with AAS-use, such as: increased risk of psychiatric effects, prolonged suppression of the hypothalamic-pituitary-testicular axis, premature death, cardiovascular disorders, and others (van Amsterdam, Opperhuizen, & Hartgens, 2010). Cardiovascular conditions related to AAS-use, including hypertension, lower LDL cholesterol level, cardiomyopathy and myocardial dysfunction may pose consequences to the brain and cognitive function (Gorelick et al., 2011). Specifically, cardiovascular diseases have previously been linked to effects on brain structure, cognitive decline, and dementia (Debette et al., 2011; Knopman et al., 2001; L. Li et al., 2012). AAS-use, in turn, may also impact these areas.

Kanayama et al., (Kanayama, Kean, Hudson, & Pope Jr, 2013) are among the first to probe the relationship between male AAS-users versus weightlifters that report no AAS use on various cognitive tasks. Their findings suggest that AAS-users exhibit cognitive deficits on two tasks of visuospatial memory. Additionally, within the AAS-user group total reported lifetime AAS-dose was correlated with deficits of both immediate and delayed Pattern Recognition Memory. However, long-term male AAS-users did not differ from non-using-weightlifting controls on measures of reaction time, alertness, or verbal memory. A more recent study investigated both cognitive performance and brain morphology in long-term AAS-users (Bjørnebekk et al., 2019). The results present evidence that those in the AAS group performed worse than the non-AAS group on tests assessing working memory, processing speed, problem solving, fine motor speed, and executive function. Working memory, processing speed, and problem-solving tasks yielded the greatest differences. Although an emerging topic, the preliminary evidence suggest that AAS-use has negative effects on cognitive function, particularly memory.

Excessive Exercise/Overtraining

In a recent study, 15.8% of young adult males and 2.5% of young adult females reported exercising to gain weight or build muscle (Nagata et al., 2019). Weightlifting to gain muscle, in particular, is a popular method of muscle-enhancement among both boys and girls (McVey, Tweed, & Blackmore, 2005). Dissatisfaction with muscularity has been shown to predict exercising to the point of injury (Karazsia & Crowther, 2010). Overuse injuries and osteoarthritis are risks of excessive exercise (Weinstein & Weinstein, 2014). While overtraining and excessive weightlifting may have negative physical consequences on the body, the relationship between excessive weightlifting and cognitive function is yet to be investigated.

Much of the current literature has explored aerobic, or cardiovascular, exercise and cognitive function. A recent systematic review examined the effect of both acute and chronic exercise on cognitive function in adolescents (J. W. Li, O'Connor, O'Dwyer, & Orr, 2017). All studies included (11) reported an effect of exercise on at least one domain of cognitive function. However, the overall findings are mixed with only 37% of the cognitive domains favoring exercise and the remaining majority favoring the resting/control condition. It is worth noting that memory was the most consistently improved domain across the included studies. The work that has focused on cognitive function and anaerobic, resistance, or strength training alone, is largely restricted to elderly samples. Cassilhas and colleagues (Cassilhas et al., 2007) investigated the impact of a six-month resistance training program at either moderate or high intensity compared to controls in elderly individuals. Both experimental conditions improved more than the control group on tasks assessing working memory, verbal reasoning, visuospatial short-term memory, and long-term episodic memory. Other research has demonstrated that in an elderly sample, higher levels of resistance produced greater improvements in working memory over six months compared to moderate levels of training (Lachman, Neupert, Bertrand, & Jette, 2006). This work may not depict a universal relationship between strength training and cognitive function, as elderly samples are subject to cognitive aging.

Few studies examining physical activity and cognitive function in younger samples have been conducted. One systematic review summarized the literature concentrated on physical activity and cognitive function in young to middle-aged adults (Cox et al., 2016). Of the 14 studies that met the review criteria, 12 found that higher levels of physical activity had a positive influence on domains of cognitive function. This relationship was very consistent across studies for executive function, but only moderately consistent for memory. Researchers have used self-report questionnaires to assess academic achievement and exercise participation in college students across several universities (Bellar, Judge, Petersen, Bellar, & Bryan, 2014). Participation in aerobic exercise, such as running, walking, biking, and aerobic classes, was related to higher reported grade point averages. Inversely, weightlifting participation was associated with lower grade point averages; however, this relationship was not significant. Further research is necessary to determine if excessive exercise and weightlifting, specifically, is associated with cognitive function.

Orthorexia Nervosa and Diet-Related Behaviors

Little work has been conducted in the realm of specific diet-related MODEs, such as engaging in cheat meals, over-regulation of protein consumption and restriction of other dietary macronutrients, and consuming protein supplements, and cognitive performance. Whey protein consumption has been shown to improve memory in elderly individuals 15 minutes and 60 minutes after protein shake intake (Kita et al., 2019). These findings, however, do not examine the longitudinal impact that protein supplements may have on cognitive function and may not reflect a relationship applicable to a sample of healthy young adults. Jakobsen and colleagues (Jakobsen, Kondrup, Zellner, Tetens, & Roth, 2011) investigated the effects of a high protein diet compared to a usual protein diet on reaction time in a group of healthy male young adults. After three weeks of the controlled protein diet, the high protein group had improved reaction times compared to the usual protein group. However, it is unknown if high protein consumption is related to executive function.

Implications may be drawn from the literature investigating ON and cognitive function, as such behaviors may be promoted as "healthy" by dietary theories. For example, compared to a healthy eating control group and a normal eating control group, more participants with ON reported using protein powder (Oberle, Klare, & Patyk, 2019). Participants with ON reported that they experience more difficulties in the areas of set shifting, working memory, planning, and task monitoring than a control group. However, this self-report measure only assesses participants' perception of their ability and does not reflect their true executive functioning. Few studies have explored ON using cognitive tasks. ON is associated with rigid eating and exercise patterns (Dunn & Bratman, 2016; Håman, Lindgren, & Prell, 2017). In relation to these strict behaviors and thoughts, scholars have examined cognitive flexibility in participants with ON. Studies have shown that while those with ON make more errors than participants without ON on a cognitive flexibility task (Hayatbini & Oberle, 2019; Koven & Senbonmatsu, 2013). However, overall performance on this task between participants with ON and controls was not significantly different. In addition, those with ON had fewer perseverative responses, which is the response-type related to cognitive inflexibility. Therefore, those with ON may evaluate themselves as having difficulties with executive function in daily life, however, they do not appear to exhibit deficits in these areas on tasks assessing such cognitive domains.

Only one study thus far has examined MODE and executive function (Griffiths, Murray, & Mond, 2016). In a sample of college men, MODE was positively related to set shifting difficulties. MODE is often rigid, strict, and those engaging in MODE may be reluctant to change these behaviors. These behavioral manifestations may be reflective of set shifting difficulties in those who engage in MODE. More research is needed to investigate whether MODE impacts other areas of cognitive function as well.

Current Study

Due to the gaps in the literature surrounding muscularity-oriented disordered behavior and its risk factors, consequences, and correlates, the proposed study seeks to advance the literature by examining the relationship between muscularity-oriented disordered behaviors and cognitive function. Specifically, the current study will be the first to investigate if those who endorse a drive for muscularity and any muscularity-oriented disordered behaviors show differential cognitive performance on a working memory task and two verbal memory tasks over time in a large nationally-representative sample of young adults. This research is important given the existing evidence that other weight statuses, related eating or body image pathology, and weight stigma have shown associations with cognitive function as well as emerging evidence that certain muscularity-oriented disordered behaviors are linked to performance on cognitive tasks. Examining these questions in young adults is warranted given that cognitive function deficits impacting health may emerge well in advance of overt neurocognitive disorders or clinically significant decline. Early detection could be critical to informing how to mitigate future cognitive injury or decline. Thus, the primary aims of this thesis are to identify those who endorse a drive for muscularity and then a) to examine if greater overall use of muscularity-oriented disordered behaviors (composite score) are related to poorer cognitive performance among individuals who endorse a drive for muscularity and b) to investigate if any specific muscularity-oriented disordered behaviors (individual items) are associated with differential cognitive performance among a sample of young adults who endorse a drive for muscularity. The seven specific behaviors will include: 1. eating different foods than usual, 2. eating more, 3. taking food supplements, 4. taking anabolic steroids or other illegal performance enhancing substances, 5. taking legal performance enhancing substances, 6. exercise, and 7. weightlifting.

CHAPTER III

METHODOLOGY

Study Design and Sample

Data used in the current study came from the National Longitudinal Study of Adolescent to Adult Health (Add Health). Add Health data is collected from a nationally representative cohort of youth that has been followed from adolescence into adulthood in the United States (Harris et al., 2016). The original cohort had 20,743 adolescents assessed when they were 11-18 years old. Systematic sampling methods and implicit stratification were utilized in the original sample (1994-1995, Wave I) to ensure that the schools included in the study were representative of U.S. schools with respect to region of the country, urbanicity, size, type, and ethnicity. Eighty high schools and 52 middle school were used in the original sample. Additional information regarding the Add Health study design are detailed by Harris et al., (Harris et al., 2016). All study procedures were reviewed and approved by the University of North Carolina Institutional Review Board.

The current study primarily uses data from the restricted-use Wave III (18-26 years, 2001-2002), Wave IV (24-32 years, 2008) and Wave V (34-43 years, 2016-2018) datasets. These waves contain the assessments that measure participation in muscularity-disordered behaviors and/or include evaluations of cognitive performance. For this study's purposes, Wave III serves as our "baseline assessment" and is referred to as baseline. Waves IV and V serve as 7 and 8-year and 15 and 17-year follow-up, respectively. We also include the Peabody Vocabulary Test from Wave I as an approximation of adolescent intellectual function/verbal ability and key covariate for future cognitive performance.

The original Wave IV and Wave V samples consisted of 15,701 and 12,272 respondents, respectively. We excluded participants who did not undergo cognitive testing. Of the samples from Waves IV and V that completed cognitive testing, participants who chose "trying to gain weight or bulk up" on the Drive for Muscularity measure were retained for analyses (see *Drive for Muscularity* in Measures section for more details). The final sample for Wave IV consisted of 1,976 participants who were 28.8 ± 1.8 years old, 81.9% male, and had a mean BMI of 25.3 ± 4.6 (see Figure 3 for how final Wave IV sample was selected). The final sample for Wave V consisted of 193 participants who were 37.9 ± 1.9, 85.0% male, and had a mean BMI of 26.7 ± 5.1 (See Figure 4 for how final Wave IV sample was selected). Males were overrepresented in both samples, as is expected in studies that assess a drive for muscularity. As is discussed further below, we focus our primary analyses on Wave IV, given its substantially higher sample size and, thus, greater power to test the proposed aims. Information on Wave V results are included in supplemental tables (Appendix B) given the limited sample available for analysis.

Measures

Baseline Measures: Emerging Adulthood (18-26 years)

We identified muscularity-oriented disordered eating behaviors using the procedures set forth by Nagata et al., (2019) in a previous analysis of muscularity-oriented disordered behaviors in the Add Health data. Participants were first categorized by whether they were attempting to gain weight (i.e., assumed muscle mass) and those endorsing a positive response were asked follow-up questions regarding specific behaviors. Item-level descriptions and response options are described below.

Drive for Muscularity

At baseline (young adult) participants were asked "What are you currently doing about your weight?" Response options included: "trying to lose weight" (1), "trying to gain weight or bulk up" (2), "trying to stay the same weight" (3), or "not trying to do anything about weight" (4). If participants chose the response "trying to gain weight or bulk up," it was coded as a weight gain or muscle-building attempt, which is indicative of a drive for muscularity. Only participants who selected this answer choice were included in our subsequent analyses.

Muscularity-oriented disordered behaviors

Those who reported weight gain or muscle-building attempt were then asked a follow-up question: "During the past seven days, which of the following things did you do in order to gain weight or build muscle? Check all that apply." Participant response options included: (a) ate different foods than usual, (b) exercised, (c) lifted weights, (d) took food supplements, or (e) ate more. Additionally, participants were asked, "In the past year, have you used anabolic steroids or other illegal performance enhancing substances for athletes?" (i.e., illegal PES use) and "In the past year, have you used a legal performance-enhancing substance for athletes (such as Creatine, Monohydrate, or Andro)?" (i.e., legal PES use). All response options were: 0 = no, 1 = yes. Together, these items represent seven different potential muscularity-oriented disordered behaviors (MODBs).

Follow-up Measures: 7-year follow-up (24-32 years) and 15-17-year follow-up (34-43 years)

Cognitive Function Variables

Working Memory

Working memory, an aspect of executive attention abilities, was assessed using a digit-span backwards task at Waves IV (7-year follow-up) and V (15-17 year follow-up). The digit-span backwards task is a standardized measure that is utilized to assess working memory in the Weschler Adult Intelligence Scale (WAIS-IV). The task involved an interviewer reading strings of numbers aloud, with 1-second intervals between each number. The participant was then asked to recall the string of numbers in reverse order. The task began with a two-number string and consisted of seven levels possible. At each level, the participant had two trials to recall the number string backwards correctly. If the correct response was given on the first trial, the second trial of that level was not administered and the interviewer would then move to the number string at the next level. If the participant was unable to accurately recall a number string in both trials, the task was concluded. The possible range of scores was from 0 to 7, where higher scores demonstrate better working memory (i.e., greater executive attention).

Verbal Memory: Short-term and Long-term

Verbal memory (i.e., word recall) scores were determined using the Rey Auditory-Verbal Learning Test at Waves IV (7-year follow-up) and V (15-17-year follow-up). To evaluate immediate word recall, the interviewer read a list of 15 common words aloud with 1-second intervals between each word. The participant was then instructed to recall as many of the 15 words as possible in a 90-second period, or until they indicated that they could not remember any other words. The participant received one point for each correct word recalled and higher scores indicate better short-term verbal memory.

Delayed word recall was assessed later in the home interview. Participants were asked to recall as many of the words from the previous list in the first recall task in a 60-second period. The participant received one point for each correct word recalled, with higher scores indicating better long-term verbal memory.

<u>Key Covariates</u>

General Verbal Ability

General verbal ability in adolescence was assessed using a modified version of the Peabody Picture Vocabulary Test at Wave I. In this task, the interviewer reads a word aloud and asks the participant to pick one of the four pictures in front of them that best fits this meaning. The task consisted of 87 items and raw scores were standardized by participant age. This measure was included in our analyses to control for general verbal ability in Wave I (adolescence) on verbal memory and working memory in Waves IV and V (adulthood).

Measured Body Mass Index

BMI was calculated by dividing weight (in kilograms) by height (in meters) squared in Waves IV and V. An interviewer measured weight and height using a digital scale.

Demographics

Demographics assessed include age, gender, and highest education achieved. Age was calculated by subtracting the participant's self-reported birthyear (Wave IV and V) from the year that the Wave IV and Wave V data were collected. Gender and education achieved collected via self-report measures in Waves IV and V.

Procedure

Wave III, Wave IV, and Wave V participants were drawn from the original Add Health Wave I participant pool. At Wave III, an interviewer traveled to participants' homes and administered an in-home interview. Additionally, sensitive items were asked using a self-report portion during the assessment. Wave IV consisted of a 90-minute computer-based self-report instrument and a 30-minute biomarker collection period in which anthropometric data was collected and cognitive assessments were performed. A computer-based self-report instrument was also administered at Wave V, along with a home visit for biomarker collection and cognitive assessment.

Data Cleaning

First, the subsample that underwent cognitive testing was extracted from the larger Add Health dataset. From this subsample, we selected all participants who endorsed the drive for muscularity (see Figures 3 and 4 for sample selection). The responses of these participants to the seven categorical muscularity-oriented disordered behaviors items were scored individually (1 point for yes or 0 points for no). Next, these variables were used to create a composite score of muscularity-oriented behaviors ranging from 0 to 7, with higher scores indicating greater use of behaviors. All data and variables were reviewed prior to scoring analysis to assure they were complete and met assumptions for bivariate correlation, as well as linear regression. Normality of the variables was analyzed through skewness and kurtosis. If skewness was less than 3.0 and kurtosis was less than 10.0, the data was considered normal (Kline, 2015). Outlier scores were characterized as any score with a standardized value greater than or equal to 3.3. Any outlier that influences the normality were removed and all other outliers retained.

Data Analysis

As an initial step, cognitive scores across the four weight groups ("trying to lose weight," "trying to gain weight or bulk up," "trying to stay the same weight," or "not trying to do anything about weight" were compared (see Figures 5 and 6) using an ANCOVA with BMI, age, gender, and education entered as covariates. Then participants who selected the answer choice "trying to gain weight or bulk up" on the measure of drive for muscularity were selected for subsequent analyses. Descriptive statistics and bivariate correlations were conducted among all variables to understand how many people in the "trying to gain weight or bulk up" sample were participating in different muscularity-oriented disorders behaviors and how these behaviors may be related to their cognitive function. Multiple independent t-tests were conducted to assess the relationship between individual muscularity-oriented disordered behaviors (ate different foods than usual, exercised, lifted weights, took food supplements, ate more, AAS-use/illegal PES use, and legal PES use) and cognitive scores (working memory task, short-term verbal memory task, and long-term verbal memory task). The two comparison groups for each behavior are those endorsing "yes" to the behavior vs. those endorsing "no" within our sample of individuals seeking to gain muscle.

Next, multiple stepwise linear regressions were performed to evaluate whether participating in more muscularity-oriented disordered behaviors overall was associated with cognitive performance at 7-year or 15-17-year follow-up. The independent variable was the composite score of muscularity-oriented disordered behaviors in young adulthood and the dependent variables were working memory task scores, short-term verbal memory scores, or long-term verbal memory scores at Waves IV or V. Covariates include gender, age, race, and BMI. These covariates were entered in Step 1 and the composite MODBs scores were entered in Step 2. The covariates would allow us to test whether the frequency of participation in MODBs overall is associated with cognitive performance over and above the demographics. Cognitive scores from previous waves were controlled for in the follow-up analysis as needed.

Multiple hierarchical linear regressions were also performed to examine the amount of variance accounted for in each of the three cognitive variables by individual muscularity-oriented behaviors. The independent variables were eating different foods than usual for weight gain, eating more, taking food supplements, taking legal PES, taking anabolic steroids or other illegal PES, exercise, and weight lifting; the dependent variables were working memory task score, short-term verbal memory scores, or long-term verbal memory scores at Waves IV and V. Covariates included gender, age, race, and BMI. These covariates were entered in Step 1 and the individual MODBs were entered simultaneously in Step 2. The covariates were to test whether participation in specific MODBs would be associated with cognitive performance over and above the demographics. Entering the MODBs simultaneously allow us to ascertain whether certain behaviors are unique predictors of cognitive function variables compared to others. However, simultaneous entry of related items can lead to multicollinearity. Thus, multicollinearity was assessed by examining the variance inflation factors (VIF). No VIF values were greater than 10; therefore, the simultaneous models were retained (Bowerman & O'Connell, 1990). As an exploratory measure, the data were also stratified by gender and separate linear regressions of cognitive performance at 7-year and 15-17-year follow-up on muscularity-oriented behaviors were conducted separately for both men and women.

CHAPTER IV

FINDINGS

Descriptives

When examining differences in cognitive function variables across the four weight groups ("trying to lose weight," "trying to gain weight or bulk up," "trying to stay the same weight," or "not trying to do anything about weight), it was found that those who were in the gain weight/bulk up group had significantly lower Wave IV standardized cognitive composite scores, $F(3, 12843) = 6.080$, $p < .001$, immediate word recall scores, $F(3, 12819) = 3.845$, $p = .009$, and delayed word recall scores, $F(3, 12807) = 5.933$, $p < .001$, than the other weight groups after adjusting for the covariates (see Figure 5 for means). Wave IV number recall scores were not significantly different across groups. Similar trends were observed across groups for Wave V standardized cognitive composite scores, $F(3, 1216) = 0.825$, $p = .480$, immediate word recall scores, $F(3, 1213) = 0.528$, $p = .663$, and delayed word recall scores, $F(3, 1211) = 2.012$, $p = .110$ (see Figure 6 for means).

Detailed demographic and descriptive data for the "trying to gain weight or bulk up" subsample can be found in Table 5. Bivariate correlations between MODBs and Wave IV and V cognitive scores in this subsample can be found in Table 6. Multiple independent *t*–tests were performed for each specific MODB (e.g., lift weights, legal PES-use, etc.) to compare cognitive scores at both waves in those who endorsed each MODB versus those who did not (see Tables 7 and 8for Waves IV and V, respectively).

For Wave IV, those who reported exercising to gain weight or bulk up had higher cognitive composite scores than those who did not, $t(1972) = -2.95$, $p < .01$. Similarly, those who reported using creatine to gain weight had significantly higher composite scores than those who did not, $t(1943) = -3.87$, $p < .001$. Other MODBs did not yield significant differences in cognitive composite scores (Table 7). These patterns for the composite score were likely driven by the relationships between exercise/legal PES-use and immediate word recall scores and number recall scores. Specifically, those who exercised to gain weight $t(1967) = -2.31$, $p < .05$, as well as those who used legal-PES to gain weight, $t(1938) = -3.55$, $p < .001$, had significantly higher immediate word recall scores than those who did not (Table 7). Likewise, those who endorsed exercising, $t(1970) = -3.59$, $p < .001$, and legal PES-use to gain weight, $t(1941) = -4.12$, $p < .001$, also had significantly higher number recall scores than those who did not (Table 7). There were no significant differences in delayed word recall scores at Wave IV for any MODB groups.

For Wave V, those who reported using legal PESs to gain weight or bulk up continued to exhibit significantly higher cognitive composite scores than those who did not, $t(191) = -2.24$, $p < .05$ (Table 8). In contrast to Wave IV, this effect appeared to be driven by the differences in delayed word recall scores at Wave V, as those who used legal PESs exhibited significantly higher delayed word recall scores compared to those who did not, $t(191) = -2.46$, $p < .05$. No other significant differences in Wave V cognitive composite scores were detected between those who endorsed other MODBs versus those who did not. Similarly, there were no significant differences in Wave V immediate word recall scores across any MODB groups. Also in contrast to Wave IV, those who ate different foods in order to gain weight ($t(114.56) = -2.48$, $p < .05$) and those who took food supplements ($t(191) = -2.17$, $p < .05$) scored higher on Wave-V number recall measures than those who did not (Table 8).

Primary Results – Wave IV

To follow-up initial descriptive analyses, the primary study analyses consisted of a series of hierarchical linear regressions to evaluate the relationship of MODBs in young adulthood (Wave III) on different measures of cognitive function later in adulthood (Wave IV) adjusting for key covariates. The following results and discussion focus primarily on Wave IV because it is better powered to test effects (Max N = 1,976*;* see Figure 3), whereas Wave V had a limited sample size (Max N = 193*;* see Figure 4). Regression results for Wave V are included in Appendix B. For Wave IV analyses, covariates were entered in Step 1 and included age, gender, BMI, highest education level, and Wave I general verbal ability. MODB composite scores were then entered in Step 2. Additional regression models were conducted with covariates entered in Step 1 and individual MODBs entered simultaneously. Associations between all covariates and Wave IV cognitive outcomes are displayed in Table 9, and associations between MODBs and Wave IV cognitive outcomes can be found in Table 10. In the next section, we describe the specific results across the different cognitive variables.

Standardized Composite Cognitive Scores. Hierarchical linear regression results showed that composite MODB scores did not account for a significant amount of the variance in standardized composite cognitive scores, p = 0.876, above and beyond the covariates (see Table 10). The overall regression model was significant, $F(6, 1818) = 48.640$, $p < .001$, and the covariates accounted for 13.8% of the variances in composite cognition scores at Wave IV – with older age, male sex, lower education level, and lower verbal ability consistently predicting lower cognitive composite scores (Table 9). BMI was not a significant covariate. Results of the hierarchical linear regression of composite cognitive scores on specific MODBs suggested that lifting weights to gain weight, $\beta = -0.064$, p = 0.013, was negatively associated with composite cognition scores (Table 10). Conversely, legal PES-use was positively associated with composite cognition scores, $\beta = 0.060$, p = 0.016 (Table 10). Other individual MODBs did not account for a significant amount in the variance of composite cognition scores. The overall regression model was significant, $F(12, 1812) = 25.594$, $p < .001$, and specific MODBs explained 0.7% of the variance in standardized Wave IV composite cognition scores overall.

Immediate Word Recall. Hierarchical linear regression results demonstrated that composite MODB scores did not account for a significant amount of the variance in Wave IV immediate word recall scores, $p = 0.442$, above and beyond the covariates (see Table 10). The regression model was significant, $F(6, 1813) = 25.875$, $p < .001$, suggesting that the covariates (older age, male sex, lower education, and lower verbal ability) explain a significant portion of variance in the lower cognitive scores. BMI was not significant. Results of the hierarchical linear regression of immediate word recall scores on specific MODBs revealed that both eating different foods than usual, $\beta = -0.046$, $p = 0.043$, and lifting weights to gain weight $\beta = -0.057$, $p = 0.033$, were negatively associated with Wave IV immediate word recall scores (Table 10). Additionally, legal PES-use positively predicted immediate word recall scores, $\beta = 0.063$, $p = 0.015$. Other individual MODBs did not account for a significant amount in the variance of immediate word recall scores. The overall regression model was significant, $F(12, 1807) = 14.188$, $p < .001$, and specific MODBs explained 0.8% of the variance.

Delayed Word Recall. Hierarchical linear regression results demonstrated that composite MODB scores did not account for a significant amount of the variance in Wave IV delayed word recall scores, $p = 0.356$, above and beyond the covariates (see Table 10). The regression model was significant, $F(6, 1810) = 27.197$, $p < .001$ – with older age, male sex, and lower education and verbal ability continuing as significant covariates, and BMI continuing to be unrelated. When specific MODBs were entered simultaneously, results of the hierarchical linear regression revealed that no specific MODBs were significantly associated with delayed word recall scores (Table 10). The regression model was significant, $F(12, 1804) = 13.03$, $p < .001$, but specific MODBs explained 0.0% of the variance.

Number Recall. Hierarchical linear regression results revealed that composite MODB scores did not account for a significant amount of the variance in number recall scores, $p = 0.260$, above and beyond the covariates (see Table 10). The regression model was significant, $F(6, 1816) = 33.160$, $p < .001$ - with lower education level, and lower verbal ability consistently predicting lower cognitive composite scores (Table 9). Results of the hierarchical linear regression of number recall scores on specific MODBs demonstrated that both exercising, $\beta = 0.062$, $p = 0.014$, and using legal PESs $\beta = 0.061$, $p = 0.017$, were positively associated with number recall scores (Table 10). Lifting weights negatively predicted immediate word recall scores, β = 0.-059, $p = 0.025$ (Table 10). Other individual MODBs did not account for a significant amount in the variance of number recall scores. The overall regression model was significant, $F(12, 1810) = 17.828$, $p < .001$, and specific MODBs explained 0.8% of the variance.

Summary. In sum, poorer Wave IV cognitive performance in the sample with a drive for muscularity was generally predicted by older age, male gender, and lower education and verbal ability scores but not by BMI. Adjusting for these covariates, the most consistent relationships between specific MODBs and Wave IV cognitive function indicators emerged for lifting weights (lower cognitive scores) and legal PES-use (higher cognitive scores). These patterns were driven by immediate word recall and number recall and not by delayed word recall. Potential relationships also emerged between exercise and higher number recall as well as between eating different foods and lower immediate word recall.

Exploratory Analyses – Wave IV Gender

The above analyses were repeated with Wave IV participants split by gender to explore whether differences in the relationships between MODBs and cognitive scores differed between men and women. In men, the above relationships described for the total sample remained – with similar directional associations and magnitudes (see Table 12). The only difference in the male subsample was that the lifting weights-lower number recall score relationship was reduced to trend levels: $p = 0.065$. In the sub-sample of women, none of the relationships from the above total sample analyses were significant (see Table 14). However, the magnitude and direction of the associations between MODBs and cognition scores were similar to that of men. Accordingly, the sample of women may have been under-powered.

Supplemental Results – Wave V

As mentioned above, hierarchical linear regression analyses were also conducted between MODBs and Wave V cognition scores although less emphasis was put on these results given the limited sample size at Wave V. Similar to Wave IV analyses, MODB composite scores did not account for a significant amount of the variance in Wave V composite cognition, immediate word recall, delayed word recall, or number recall scores (see Table 16 in Appendix B). Conversely, no individual MODBs contributed to the variance in composite cognitive scores, immediate word recall scores, or delayed word recall scores (Table 16 in Appendix B). Lifting weights was the only significant predictor of Wave V number recall scores, $\beta = -0.204$, $p = 0.012$, above and beyond the covariates. Although not reaching significance, the relationships between MODBs and Wave V cognitive scores revealed similar directions and magnitudes as the Wave IV analyses. Given the significantly smaller sample size in Wave V, these analyses may be under-powered compared to Wave IV analyses, especially for women who are already under-represented in both waves compared to men.

CHAPTER V

CONCLUSIONS

The purpose of this study was to determine if there is a relationship between the drive for muscularity and associated muscularity-oriented disordered behaviors, and cognitive function later in adulthood. No *a priori* hypotheses were made, given the lack and heterogeneity of the previous literature in this area. Descriptive data revealed that – as a group – those with a drive for muscularity had lower scores on composite cognition scores, short-term verbal memory scores, and long-term verbal memory scores than those with other weight change goals when taking age, gender, BMI, and education into account. Working memory scores, however, were similar across all groups. This pattern broadly suggests that individuals with a drive for muscularity do exhibit a unique cognitive profile of relative deficits after adjusting for age, gender, BMI, and education. When examining cognitive function within that subsample with a drive for muscularity – engaging in more MODBs overall (i.e., a higher MODB composite score) was not related to cognition when adjusting for age, sex, education, and BMI. However, relationships were observed between specific MODBs (e.g., legal PES-use and weight-lifting) and particular cognitive functions later in life.

Specifically, those who reported using legal PESs scored higher on tasks assessing short-term verbal memory, working memory, and overall composite cognition scores than those who did not at the 7-year follow-up in the total sample. However, long-term verbal memory was not impacted by legal PES-use. Conversely, short-term verbal memory, working memory, and composite cognition scores were lower for those who reported lifting weights to bulk up compared to those who did not. Eating different foods than usual was also negatively associated with short-term verbal memory scores at the 7-year follow-up, and exercise was positively associated with working memory scores. When conducting gender-stratified analyses, the same patterns emerged in men and women with regards to the direction and magnitude of the relationships; however, the relationships did not reach significance in our sample of women only. A lack of power may be responsible for the null findings in our female sample. Additionally, the drive for muscularity was assessed twenty years prior, at a time when fewer women may have been striving for a lean and toned figure as compared to a thin figure. Thus, the smaller sample size for women may be a direct result of selecting for individuals with a drive for muscularity at a time when that behavior was not as desirable for women as it may be today. Discussion of results below focus on the combined total sample of men and women.

Taken together, our results could suggest that short-term verbal memory and working memory might be more sensitive or vulnerable to the effects of specific MODBs, such as legal PES-use and/or lifting weights. Importantly, both of these cognitive functions are more related to speeded or executive attention abilities. In contrast, long-term verbal memory does not appear to be consistently impacted in our total sample. Such findings could reflect previous patterns in which certain cognitive functions (particularly semantic or autobiographical memory encoding and retrieval) are among the last cognitive domains to show decline in response to stress- and/or disease-related processes (O'Brien, 2006). This pattern is expected given how preserved these abilities are in normal cognitive aging (Glisky, 2007). These preserved memory abilities contrast with the documented deficits in speeded or executive functions task performance that emerge earlier in age-related decline and seem to be more sensitive to stress and vascular, metabolic, or inflammatory disease states, such as heart failure or obesity. Thus, our findings are consistent with the pattern described by the “frontal aging hypothesis,” in which deficits in speeded and executive control abilities decline at a faster rate than memory for words or general knowledge due to the greater vulnerability of the frontal lobe and its neural circuitry to age, stress, and disease (Greenwood, 2000; West, 1996). These earlier declines typically lead to greater variability in frontally-dominant cognitive tasks, allowing us to better detect both beneficial and harmful predictors of these functions in younger-aged samples.

With the regards to the findings on better cognitive performance, they are consistent with some of the previous literature that has examined the effects of creatine, a popular legal PES, on cognition. For instance, four previous studies have found beneficial effects of creatine on short-term memory (Benton & Donohoe, 2011; Ferrier et al., 2000; McMorris et al., 2007; Rae et al., 2003). Studies examining creatine use and working memory have also produced mixed results. Our findings support those that have demonstrated a positive effect of creatine on working memory (Rae et al., 2003). In contrast to our results, one study also described a positive effect of creatine-use on long-term memory (McMorris et al., 2007). Other work has demonstrated no impact of creatine on cognition in young adults, suggesting that creatine supplementation may only be beneficial for aging populations (Rawson et al., 2008). However, smaller amounts of creatine were administered in this study compared to others. Creatine may have several impacts on the brain, and in turn, cognition. For example, genetic creatine disorders are characterized by neurological impairments which may result in developmental delays or intellectual disability (Curt et al., 2015). Possible mechanisms of creatine supplementation, such as creatine’s ability to create a more regular regeneration of ATP (i.e., an energy-molecule) may also yield advantageous effects on cognitive performance (Dolan, Gualano, & Rawson, 2019).

Similar legal PESs, such as dehydroepiandrosterone (DHEA; an Andro supplement), have also been shown to produce mixed effects on cognitive function. In young, healthy adults, DHEA supplementation over a short period of time (e.g., one week) resulted in improved episodic memory (Alhaj, Massey, & McAllister-Williams, 2006). Previous work suggests that DHEA impacts the development of cortico-hippocampal structural covariance, which in turn is associated with higher scores of working memory (Nguyen et al., 2017). Conversely, DHEA supplementation in the elderly has not led to improvements in cognition (Maggio et al., 2015; Merritt, Stangl, Hirshman, & Verbalis, 2012; Wolf et al., 1997). Other psychosocial factors not measured in the current study may also contribute to the observed relationship between endorsement of legal PES use and better cognitive performance. Specifically, creatine-use, as well as other legal-PESs, may be more easily available and accessible to those with more socioeconomic resources. For example, income has been positively associated with levels of legal-PES (Ganson, Mitchison, Murray, & Nagata, 2020). Given the positive correlation between education and income, it is possible that those who are using legal PESs may already have higher baseline cognitive scores (Cagney & Lauderdale, 2002). However, we did control for education level and baseline verbal ability (a proxy for early cognitive function) in our analyses to reduce this possibility. It is also possible that those with greater socioeconomic standing benefit not only from being to afford PES purchases but also other higher quality nutrition, housing, and other socioeconomic determinants of health that would promote better brain health and cognitive performance (Coley, Leventhal, Lynch, & Kull, 2013; Féart, Samieri, & Barberger-Gateau, 2010; Simning, Conwell, & van Wijngaarden, 2014; van de Rest, Berendsen, Haveman-Nies, & de Groot, 2015). Notably, although our study detected a signal between legal PES use and cognition, no association was found for illegal PES use, despite some previous evidence showing that long-term steroid use is associated with poorer cognitive performance, particularly deficits in working memory (Bjørnebekk et al., 2019). The present study was not designed to test long-term use of illegal PES which may explain the lack of association. Additionally, under-reporting of illegal substance use may have led to under-reporting for this variable.

Similar to legal PES use, increased cognitive performance on the working memory task was observed in those in our sample who exercised to gain weight or bulk up. While it is unclear which forms of exercised are being engaged in by our participants, there is a substantial body of literature linking higher physical activity levels with cognitive benefits across a wide array of populations. For instance, increased exercise has been shown to be related to improved cognition scores in healthy older adults, as well as those with dementia (Kemoun et al., 2010; Tseng, Gau, & Lou, 2011). In samples of children, adolescents, and young adults, acute physical exercise has also been shown to improve scores of executive function, such as working memory (Donnelly et al., 2016). Thus, our finding that exercise showed protective relationships with working memory scores is expected. It is important to note that given the lack of nuance in the exercise item prompt (e.g., no information about whether the exercise was compulsive or excessive), the exercise item may not actually qualify as a MODB, thereby potentially limiting its usefulness as a MODB predictor of cognitive function.

With regards to the findings on poorer cognitive function and weight lifting, our study contributes to the current literature as most studies on this topic have been conducted in elderly samples participating in resistance-based training and not in samples of young adults. However, the previous results in older sample are not supported by the current findings. Specifically, resistance training has been shown to improve working memory, short-term memory, and long-term memory in older adults (Cassilhas et al., 2007; Lachman et al., 2006). Our study differs in population and the form of strength training assessed (i.e., weight lifting vs. resistance training), and our findings suggest that lifting weights to gain muscle or weight may actually lead to negative consequences in young to early adult cognition, particularly in working and short-term verbal memory. It is possible that those who reported weight lifting to gain muscle may have done so excessively, as a drive for muscularity has been shown to be positively predictive of exercising to the point of injury (e.g., lifting extremely heavy amounts of weight, lifting weights for a long period of time, or both) (Karazsia & Crowther, 2010). Short-term verbal memory has been shown to be impaired immediately following high-intensity exercise in both adults and children (Covassin, Weiss, Powell, & Womack, 2007; Samuel et al., 2017). Excessive weight lifting, in particular, has been shown to be detrimental to cognition scores. In a study on U.S. Marines, increases in weight carried over a two-hour period produced acute decreases in cognitive performance after the weight carrying task (Kobus, Brown, Wu, Robusto, & Bartlett, 2010). The negative impacts of high-intensity exercise and weight lifting may be due to various physiological mechanisms. Increased heart rate and decreased cerebral oxygenation following vigorous exercise, for example, may play a significant role (Nishihira et al., 1999; Shibuya, Tanaka, Kuboyama, & Ogaki, 2004).

The current findings with regards to weight lifting may also support recent research on eating disorder symptoms, particularly among men. Forrest and colleagues present research that highlights the centrality of muscularity-oriented concerns, such as feelings of guilt after missing a weight lifting session, in men's eating disorder symptoms (Forrest, Perkins, Lavender, & Smith, 2019). Such emotional responses may also correspond with rigidity and preoccupation toward exercise and eating behaviors among individuals with a drive for muscularity, similar to the presentation for orthorexia as mentioned in the introduction. For instance, our finding that the "eating different foods" item was linked to reduced working memory could reflect the cognitive load of pathological food preoccupation or dietary restriction, although it is difficult to ascertain from this vaguely-worded item whether these features actually play a role. Interestingly, the "eating more" and "taking food supplements" items were not associated with any cognitive variables suggesting that the addition to foods or supplements to the diet does not explain unique variance in cognitive function.

Though not directly assessed in the current study, other potential factors may be relevant in the link between drive for muscularity/weight lifting behavior and reduced cognitive scores and are, thus, discussed below as variables of interest. For example, cognitive features common in eating disorders such as perfectionism have been shown to predict a drive for muscularity among samples of men, as well as eating disorders in samples of women and men (Buzzichelli, Marzola, Amianto, Fassino, & Abbate-Daga, 2018; Goddard, Carral-Fernández, Denneny, Campbell, & Treasure, 2014; Lennon & Johnson, 2021). In relation to cognitive function, previous research suggests that different forms of perfectionism may impact attention and working memory. Specifically, high negative perfectionism, or perfectionism geared towards avoiding negative consequences, leads to cognitive impairment in attention and working memory compared to positive perfectionism (Slade, Coppel, & Townes, 2009). Other work presents data that directly links cognitive deficits to a drive for muscularity and MODBs: increased set shifting difficulties were associated with higher drive for muscularity and MODB scores, particularly with regards to muscularity-oriented disordered eating behaviors (Griffiths, Murray, & Touyz, 2013). Lastly, a parallel literature highlights weight stigma as a cognitively burdensome phenomenon. While generally examined in the context of excess weight, it is plausible that individuals with a drive for muscularity are also subject to internalized and externalized stigma processes that drive both weight lifting behaviors and impact cognitive processing. In brief sum, possible mechanisms of cognitive impairment in those with a drive for muscularity could involve the negative cognitions regarding one's muscularity or leanness and associated rigid, preoccupied, and/or compulsive eating or weight lifting behaviors.

Implications

Our findings have several clinical implications when considering a drive for muscularity and associated behaviors. First, when examining the potential benefits or adverse consequences of MODBs, we should do so individually. Our study suggests that when combining potential MODBs as measured in the Add Health dataset into a composite score, the effects of specific MODBs on cognition are obscured, as can often occur when aggregating items. For example, specific potential MODBs had opposite directional relationships with cognitive outcomes according to our results (i.e., positive for PES use and exercise vs. negative for weight lifting and eating behaviors) while many others exhibited null relationships with cognition. Therefore, these items should certainly be considered individually when assessing for relationships between them and other cognitive and psychosocial outcomes. Such a pattern also calls for the development of psychometrically-validated measures of MODBs for future investigations.

Second, creatine, or other legal PESs, warrants further study as a valuable predictor of cognitive function preservation and improvement. Creatine has been used to enhance physical well-being in populations with a lower BMI to increase skeletal muscle (Arazi, Eghbali, & Karimifard, 2019; Moon, Heywood, Rutherford, & Cobbold, 2013). Additionally, vulnerable populations (e.g., the elderly, those with dementia, or those with a BMI in the overweight or obese categories) may benefit from supplementation of creatine and/or other legal PESs to prevent cognitive decline(McMorris et al., 2007). Previous work has suggested that creatine has been advantageous to cognitive performance in elderly adults (McMorris et al., 2007; Rawson & Venezia, 2011). Based on our findings, the longitudinal effects of creatine supplementation should be examined in populations susceptible to cognitive decline and those with increased body and/or muscle dissatisfaction.

Additionally, rather than being protective against the development of eating disorders and low-weight conditions, the drive for muscularity may contribute to these conditions and other negative cognitions and behaviors. Currently, the DSM only considers harmful eating patterns in terms of eating disorders. Additionally, Body Dysmorphic Disorder is limited in that it excludes body fat concerns and is focused on specific areas of the body. Negative cognitions about one’s body weight and shape may be psychologically and cognitively detrimental. Our results suggest that there are other maladaptive behaviors associated with body dissatisfaction aside from eating, and that these behaviors may contribute to consequences later in life (e.g., cognitive deficits). It would be beneficial to consider other behaviors when updating diagnostic categories in the DSM. For instance, obligatory exercise (e.g., cardiovascular exercise or weight/strength training) in response to a drive for thinness, leanness, or muscularity should be considered. Lifting weights, or exercise in general, to gain weight, bulk up, or tone muscle, as well as associated negative thoughts related to self-loathing and lower body-esteem, may inhibit cognitive function later in life. Perhaps a more appropriate diagnostic category would encompass all body-image related disorders and associated behaviors (e.g., eating patterns, exercise, supplement use, and related distressing thoughts and emotions). A different diagnostic category may be more useful and encompassing when researching various related factors and consequences, and ultimately creating more effective treatments body-image focused disorders.

Limitations

Various limitations should be considered when interpreting the findings of the current study. First, as previously discussed, the sample was majority men. Thus, the null findings in the female sample may be due to a lack of power. Additionally, measures assessing participation in MODBs were gathered via self-report and may vulnerable to reporting bias. In particular, AAS-use is illegal in the United States and is associated with various negative attitudes, which may lead to under-reporting (Griffiths et al., 2016; Pope, Khalsa, & Bhasin, 2017).

Other limitations include those related to restrictions when using a national longitudinal study. Questions regarding taking food supplements or legal PES-use did not specify the type of product used (e.g., protein shakes, pre-workout, creatine, aminos). Thus, it is not clear if there is a specific product that may be more related to cognitive performance than others or whether a third variable related to ability to access these products is driving cognitive improvement. Similarly, other details regarding the severity (frequency and degree) of MODB participation, such as exercise and weight lifting, were not measured. Future research should investigate the specific types and amount of supplements and food consumed to gain weight, as well as the amount and intensity of exercise engaged in to assess for a dose-response relationship between specific MODBs and cognitive performance as well as probe critical features such as level of preoccupation and compulsivity.

Next, the Add Health survey did not include questions regarding body image related concerns and drives, or MODB behavior participation in later waves. This information may be important given the shift in body image ideals in recent years towards a more muscular, lean, and toned body in both men and women (Homan, 2010; Leit et al., 2001; Pope Jr et al., 1999). Therefore, it is unknown whether participants continued or began engaging in these behaviors into adulthood, prohibiting causal conclusions to be drawn.

In addition, cognitive testing was also not administered in earlier waves, such as Wave III. While the current study controlled for general verbal ability at Wave I, participants' cognitive ability was not assessed at the same time as their endorsed MODB engagement. Consequently, we are unable to determine changes in cognition from young adulthood into older adulthood. The cognitive testing administered by Add Health also only included a small number of tests (three) that do not evaluate a diverse range of cognitive abilities. As such, we are unable to examine the potential longitudinal relationships between MODB participation and other various cognitive abilities (e.g., inhibitory control, processing speed, verbal learning, or cognitive flexibility). Future research should include a more diverse cognitive battery. In addition, follow-up investigations would benefit from evaluating cognitive performance and body image concerns/behaviors at all time points in order to assess for cross-sectional and longitudinal effects of varying levels of different drives and their associated behaviors at multiple levels (i.e., length of use, frequency of use) on cognitive function.

Conclusions

Overall, the current study revealed that – at the group level – individuals with a drive for muscularity scored lower on multiple domains of cognitive function compared to groups with other weight goals (e.g., stay the same weight). Further investigation in this subsample showed no associations between a composite MODB score and cognitive outcomes. However, specific MODBs (i.e., legal PES-use and weight lifting) were shown to be related to working memory and short-term verbal memory later in life. While previous findings regarding the effects of legal PES-use and weight lifting on cognitive performance have been mixed, our study provides longitudinal associations that support potential benefits of legal PESs, such as creatine, and potential negative consequences of lifting weights on cognitive function. Various body-image related behaviors, specifically related to a drive for muscularity, may have longitudinal cognitive, emotion, and physical impacts that warrant future investigation. Future investigations will benefit from more precise and detailed measurement of muscularity-disordered behaviors and cognition over time in order to better elucidate these relationships.

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TABLES

Table 1. Major Cognitive Domains with Descriptions and Example Tests

Cognitive Domain	Description	Example Tests
Attention	Ability to focus awareness on a given stimulus or task, to concentrate on that stimulus or task long enough to accomplish a goal	-Flanker Inhibitory Control and Attention Test; Trail Making Test Part A
Memory	Cognitive processes involved in the acquisition, storage, and retrieval of new or retained information; can be auditory or visual	-Picture Sequence Memory -Rey Auditory Verbal Learning Test
Language	Language skills of various types are included. Includes measures of receptive vocabulary, reading decoding skills, and crystallized abilities	-Picture Vocabulary Test -Oral Reading Recognition -Boston Naming Test -Controlled Oral Word Association Test
Processing Speed	Assesses the amount of information that can be processed within a certain unit of time	-Pattern Comparison Processing Speed Test
Executive Function	Higher cognitive processes that enable forethought and goal-directed action	
Inhibition	Ability to choose a more complex and effortful solution to be correct	-Stroop Task -Go/No-Go Task -Hayling Sentence Completion Task
Cognitive Flexibility	Ability to shift between two concepts, tasks, or response rules	-Trail Making Test Part B -Wisconsin Card Sorting Task
Working Memory	Ability to hold information for a brief period and to manipulate it	-List Sorting Memory – Digit Span
Planning	Ability to find the exit to a maze; interpret a sequential picture or object arrangement	
Decision Making	Performance of tasks that assess process of deciding in the face of competing alternatives	-Iowa Gambling Task

Table. 2 Eating Disorders with Description and Associated Behaviors

Eating Disorder	Description	Associated Behaviors
Anorexia Nervosa	Obsessive fear of weight gain, refusal to maintain a healthy body weight, and an unrealistic perception of body image	-Persistent energy intake restriction
Bulimia Nervosa	Repeated binge eating followed by behaviors that compensate for overeating and prevent weight gain, self-evaluation is unduly influenced by body shape and weight	-Episodes of binge eating -Compensatory behaviors: misuse of laxatives, diuretics, or other medications; fasting; excessive exercise
Binge-Eating Disorder	Recurrent episodes of binge eating in which the individual loses control over eating and eats a large among in a discrete period of time	-Episodes of binge eating

Note. Adapted from the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; American Psychiatric Association, 2013) and Eating Disorder Hope (2018).

Table 3. Body Dysmorphic Disorder Diagnostic Criteria

A.) Preoccupation with one or more perceived defects or flaws in physical appearance that are not observable or appear slight to others.

B.) At some point during the course of the disorder, the individual has performed repetitive behaviors (e.g., mirror checking, excessive grooming, skin picking, reassurance seeking) or mental acts (e.g., comparing his or her appearance with that of others) in response to the appearance concerns.

C.) The preoccupation causes clinically significant distress or impairment in social, occupational, or other important areas of functioning.

D.) The appearance preoccupation is not better explained by concerns with body fat or weight in an individual whose symptoms meet diagnostic criteria for an eating disorder.

Note. Criteria from the *Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition* (DSM-5; American Psychiatric Association, 2013, pp. 242-243).

Table 4. Orthorexia Nervosa Proposed Diagnostic Criteria

Criterion A:
Obsessive focus on “healthy” eating, defined by dietary theory or set of beliefs whose specific details may vary; marked by exaggerated emotional distress in relationship to food choices perceived as unhealthy; weight loss may ensue as a result of dietary choices, but this is not the primary goal. As evidenced by the following:

1. Compulsive behaviors and/or mental preoccupation regarding affirmative and restrictive dietary practices believed by the individual to promote optimum health.

2. Violation of self-imposed dietary rules causes exaggerated fear of disease, sense of personal impurity and/or negative physical sensations, accompanied by anxiety and shame.

3. Dietary restrictions escalate over time, and may come to include elimination of entire food groups and involve progressively more frequent and/or severe “cleanses” (partial fasts) regarded as purifying or detoxifying. This escalation commonly leads to weight loss, but the desire to lose weight is absent, hidden or subordinated to ideation about healthy eating.

Criterion B:
The compulsive behavior and mental preoccupation becomes clinically impairing by any of the following:

1. Malnutrition, severe weight loss, or other medical complications from restricted diet.

2. Intrapersonal distress or impairment of social, academic, or vocational functioning secondary to beliefs or behaviors about healthy diet.

3. Positive body image, self-worth, identity and/or satisfaction excessively dependent on compliance with self-defined “healthy” eating behavior.

Note. Retrieved from pp.16 (Dunn & Bratman, 2016).

Table 5. *Characteristics of Participants*

	Total Sample (Max N=1976)	Males (Max N=1620)	Females (Max N=356)
Demographic Factors/Covariates			
Age (Wave IV)	28.8 ± 1.8	28.8 ± 1.8	28.4 ± 1.7*
Age (Wave V)	37.9 ± 1.9	37.9 ± 1.9	37.6 ± 1.8*
BMI (Wave IV)	25.3 ± 4.6	25.9 ± 4.6	22.5 ± 4.1*
BMI (Wave V)	26.7 ± 5.1	27.1 ± 5.1	24.8 ± 5.1*
Picture Vocabulary Test (Wave I)	99.7 ± 13.9	102.0 ± 13.8	96.2 ± 13.5*
Highest Education Level (Wave IV)			
Less than High School Diploma	190 (0.1)	157 (9.7)	33 (9.3)
High School Diploma/GED	420 (21.3)	375 (23.1)	63 (17.7)
Some College/Vocational Training	1,323 (66.9)	1,072 (66.2)	251 (70.5)
Bachelor's Degree and Beyond	43 (0.0)	34 (2.1)	9 (2.5)
Highest Education Level (Wave V)			
Less than High School Diploma	64 (0.1)	47 (4.8)	17 (6.5)
High School Diploma/GED	214 (17.1)	174 (17.6)	37 (14.2)
Some College/Vocational Training	522 (41.8)	408 (41.3)	114 (43.8)
Bachelor's Degree and Beyond	448 (35.9)	356 (36)	92 (35.4)
MODBs (Wave III)			
MODB Composite	2.3 ± 1.4	2.5 ± 1.4	1.6 ± 0.9*
Eat Different Foods (% yes)	563 (28.5)	435 (27.0)	128 (36.5)*
Exercise (% yes)	1014 (51.3)	930 (57.4)	84 (23.7)*
Lift Weights (% yes)	1029 (52.1)	965 (59.6)	64 (18.1)*
Take Food Supplements (% yes)	433 (21.9)	383 (23.6)	50 (14.1)*
Eat More (% yes)	1042 (52.7)	816 (50.4)	226 (63.8)*
Use Creatine (past 12 mo.; % yes)	439 (22.2)	427 (26.8)	12 (3.4)*
Use AAS (past 12 mo.; % yes)	62 (3.1)	56 (3.5)	6 (1.7)
Cognitive Factors			
Cognitive Composite (Wave IV)	5.1 ± 1.6	5.1 ± 1.4	5.3 ± 1.4
Cognitive Composite *z*-score	-0.1 ± 0.8	-0.1 ± 0.8	0.0 ± 0.8*
Immediate Word Recall	6.4 ± 1.4	6.3 ± 1.9	6.6 ± 1.9*
Delayed Word Recall	4.9 ± 2.0	4.8 ± 2.0	5.2 ± 2.1*
Number Recall	4.2 ± 1.5	4.2 ± 1.6	4.2 ± 1.5
Cognitive Composite (Wave V)	4.9 ± 1.6	4.9 ± 1.6	4.9 ± 1.6
Cognitive Composite *z*-score	-0.1 ± 0.8	-0.1 ± 0.8	-0.1 ± 0.9
Immediate Word Recall	6.1 ± 2.1	6.0 ± 2.0	6.5 ± 2.5
Delayed Word Recall	4.3 ± 2.2	4.3 ± 2.2	4.3 ± 2.3
Number Recall	4.2 ± 1.6	4.3 ± 1.6	3.9 ± 1.3

Note. Wave I = 1994-1995. Wave III = 2001-2002. Wave IV = 2008. Wave V = 2016-2018. BMI = body mass index. MODEBS = Muscularity-oriented disordered eating behaviors.
Continuous variables represented with mean ± SD. Categorical variables represented with N (%).
**p* < .05 for independent t-test or chi-square test comparing males and female.

Table 6. *Bivariate Correlations between MODBs and Cognition Scores*

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MODBs (Wave III)																
1. Composite	--															
2. Eat Different Foods	.34**	--														
3. Exercise	.55**	-.01	--													
4. Lift Weights	.55**	-.10**	.41**	--												
5. Take Food Supplements	.59**	.07**	.15**	.21**	--											
6. Eat More	.24**	.08**	-.17**	-.22**	.04	--										
7. Creatine-Use	.59**	-.01	.17**	.26**	.35**	-.04	--									
8. AAS-Use	.26**	-.01	.03	.06**	.12**	-.03	.26**	--								
Cognitive Function																
Wave IV																
9. Cognitive Composite *z*-score	.05*	-.03	.07**	.01	.02	-.01	.09**	-.02	--							
10. Immediate Recall	.02	-.04	.05*	.00	.01	-.03	.08**	-.01	.82**	--						
11. Delayed Recall	.00	-.02	.02	-.01	.02	-.00	.02	-.04	.83**	.65**	--					
12. Number Recall	.08**	-.01	.08**	.01	.02	.02	.09**	-.00	.67**	.26**	.28**	--				
Wave V																
13. Cognitive Composite *z*-score	.17*	.11	.04	-.00	.12	.07	.16*	.04	.48**	.84**	.84**	.66**	--			
14. Immediate Recall	.13	.05	.01	.01	.09	.10	.11	.04	.37**	.39**	.31**	.18*	.84**	--		
15. Delayed Recall	.14	.04	.01	.07	.05	.03	.18*	.09	.84**	.29**	.31**	.23**	.84**	.69**	--	
16. Number Recall	.13	.16*	.06	-.08	.16*	.03	.09	-.05	.38**	.28**	.19**	.48**	.29**	.29**	.27**	--

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves III, IV, & V. Light grey and * $p < .05$, and dark grey and ** $p < .01$.

Table 7.

MODB group differences in Wave IV standardized cognitive outcomes in adults 24-32 years of age (Max N = 1,976).

	Cognitive Composite Score $M \pm SD$		Immediate word recall (short-term memory) $M \pm SD$		Delayed word recall (long-term memory) $M \pm SD$		Number recall (working memory) $M \pm SD$	
MODB Endorsed	Yes	No	Yes	No	Yes	No	Yes	No
Eat Different Foods	-0.13 ± 0.72	-0.08 ± 0.79	6.25 ± 1.90	6.43 ± 1.96	4.80 ± 1.98	4.90 ± 2.06	4.16 ± 1.52	4.18 ± 1.56
Exercise	-0.04 ± 0.76*	-0.14 ± 0.78*	6.48 ± 1.92*	6.27 ± 1.97*	4.91 ± 2.03	4.84 ± 2.05	4.30 ± 1.56*	4.05 ± 1.51*
Lift Weights	-0.89 ± 0.77	-0.10 ± 0.78	6.38 ± 1.94	6.37 ± 1.95	4.87 ± 1.99	4.88 ± 2.09	4.19 ± 1.55	4.16 ± 1.53
Take Food Supplements	-0.06 ± 0.75	-0.10 ± 0.78	6.42 ± 1.85	6.37 ± 1.97	4.93 ± 2.04	4.86 ± 2.04	4.23 ± 1.56	4.16 ± 1.54
Eat More	-0.10 ± 0.75	-0.08 ± 0.79	6.31 ± 1.90	6.45 ± 1.99	4.86 ± 2.03	4.90 ± 2.05	4.21 ± 1.52	4.14 ± 1.57
Creatine-Use	0.04 ± 0.77*	-0.13 ± 0.77*	6.67 ± 1.96*	6.30 ± 1.93*	4.97 ± 2.07	4.85 ± 2.03	4.45 ± 1.54*	4.10 ± 1.54*
AAS-Use	-0.17 ± 0.77	-0.09 ± 0.77	6.27 ± 1.97	6.39 ± 1.95	4.47 ± 2.03	4.89 ± 3.04	4.18 ± 1.61	4.18 ± 1.54

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves III & IV.

*$p < .05$ for independent t-test comparing cognitive scores for groups who endorsed each MODEB time (yes or no).

Table 8.

MODB group differences in Wave V standardized cognitive outcomes in adults 33-45 years of age (Max N = 193).

	Cognitive Composite Score $M \pm SD$		Immediate word recall (short-term memory) $M \pm SD$		Delayed word recall (long-term memory) $M \pm SD$		Number recall (working memory) $M \pm SD$	
MODB Endorsed	Yes	No	Yes	No	Yes	No	Yes	No
Eat Different Foods	0.08 ± 0.87	-0.13 ± 0.80	6.25 ± 2.04	6.00 ± 2.10	4.46 ± 2.62	4.24 ± 2.01	4.65 ± 1.33*	4.08 ± 1.68*
Exercise	-0.03 ± 0.92	-0.10 ± 0.71	6.11 ± 2.21	6.06 ± 1.95	4.35 ± 2.56	4.29 ± 1.72	4.34 ± 1.74	4.13 ± 1.45
Lift Weights	-0.07 ± 0.91	-0.06 ± 0.71	6.10 ± 2.23	6.06 ± 1.89	4.45 ± 2.42	4.16 ± 1.88	4.13 ± 1.78	4.40 ± 1.34
Take Food Supplements	0.13 ± 0.70	-0.12 ± 0.85	6.43 ± 1.58	5.99 ± 2.20	4.52 ± 2.23	4.26 ± 2.20	4.71 ± 1.58*	4.11 ± 1.59*
Eat More	-0.00 ± 0.82	-0.12 ± 0.82	6.29 ± 2.11	5.88 ± 2.02	4.40 ± 2.31	4.26 ± 2.07	4.30 ± 1.45	4.19 ± 1.78
Creatine-Use	0.16 ± 0.70*	-0.14 ± 0.85*	6.47 ± 1.69	5.95 ± 2.19	4.98 ± 2.02*	4.10 ± 2.22*	4.49 ± 1.69	4.16 ± 1.58
AAS-Use	0.08 ± 0.99	-0.07 ± 0.82	6.50 ± 1.85	6.06 ± 2.10	5.25 ± 2.49	4.28 ± 2.19	3.88 ± 2.17	4.26 ± 1.58

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves III & V.

*$p < .05$ for independent t-test comparing cognitive scores for groups who endorsed each MODEB time (yes or no).

Table 9.

Prospective associations between covariates and Wave IV standardized cognitive outcomes in adults 24-32 years of age.

	Cognitive Composite *Z*-Score	Immediate word recall (short-term memory)	Delayed word recall (long-term memory)	Number recall (working memory)
	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)
Age (Wave IV)	-0.07 (-0.05 - -0.01)**	-0.05 (-0.11 - -0.01)*	-0.06 (-0.12 – -0.02)**	-0.04 (-0.07 – 0.01)
Biological Sex (Wave IV)	0.07 (0.05 – 0.23)**	0.07 (0.12 - 0.59)**	0.09 (0.23 – 0.72)***	-0.00 (-0.19 – 0.18)
Body Mass Index (BMI; Wave IV)	-0.03 (-0.01 – 0.00)	0.01 (-0.02 – 0.02)	-0.04 (-0.04 – 0.00)	-0.04 (-0.03 – 0.00)
Highest Education (Wave IV)	0.20 (0.06 – 0.09)***	0.17 (0.11 – 0.20)***	0.15 (0.10- 0.19)***	0.15 (0.08 – 0.15)***
Peabody Picture Vocabulary Test (Wave I)	0.24 (0.01 – 0.02)***	0.16 (0.02 – 0.03)***	0.17 (0.02 – 0.03)***	0.22 (0.02 – 0.03)***

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves I & IV.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 10.

Prospective associations between MODBs and Wave IV standardized cognitive outcomes in adults 24-32 years of age.

	Cognitive Composite *Z*-Score	Immediate word recall (short-term memory)	Delayed word recall (long-term memory)	Number recall (working memory)
	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)
MODB Composite	-0.00 (-0.03 – 0.02)	-0.02 (-0.09 – 0.04)	-0.02 (-0.10 – 0.04)	0.03(-0.02 – 0.08)
1. Eat Different Foods	-0.03 (-0.13 – 0.02)	-0.05 (-0.39 - -0.01)*	-0.03 (-0.32 – 0.08)	-0.00 (-0.16– 0.14)
2. Exercise	0.05 (-0.01 – 0.15)	0.03 (-0.06 – 0.33)	0.01 (-0.18 – 0.22)	0.06 (0.04– 0.34)*
3. Lift Weights	-0.06 (-0.18 - -0.02)*	-0.06 (-.043 - -0.02)*	-0.03 (-0.33 – 0.10)	-0.06 (-0.34 – -0.02)*
4. Take Food Supplements	-0.01 (-0.11 – 0.36)	-0.02 (-0.31 – 0.14)	0.01 (-0.19 – 0.28)	-0.03 (-0.27 – 0.08)
5. Eat More	-0.01 (-0.09 – 0.06)	-0.03 (-0.29 – 0.08)	-0.02 (-0.26 – 0.13)	0.02 (-0.07 – 0.22)
6. Creatine-Use	0.06 (0.02 – 0.20)*	0.06 (0.06 – 0.53)*	0.01 (-0.20 – 0.30)	0.06 (0.04 - 0.41)*
7. AAS-Use	-0.02 (-0.26 – 0.12)	-0.02 (-0.68 – 0.33)	-0.02 (-0.78 - 0.27)	0.00 (-0.37 - 0.41)

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves III & IV. Covariates included age, biological sex, BMI, education, and Wave I cognition.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 11.

Prospective associations between covariates and Wave IV standardized cognitive outcomes in adult men 24-32 years of age.

	Cognitive Composite *Z*-Score	Immediate word recall (short-term memory)	Delayed word recall (long-term memory)	Number recall (working memory)
	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)
Age (Wave IV)	-0.06 (-0.05 - -0.01)*	-0.06 (-0.12 - -0.01)*	-0.05 (-0.11 – 0.00)	-0.04 (-0.08 – 0.01)
Body Mass Index (BMI; Wave IV)	-0.03 (-0.01 – 0.00)	-0.00 (-0.02 – 0.02)	-0.04 (-0.04 – 0.00)	-0.03 (-0.3 – 0.01)
Highest Education (Wave IV)	0.18 (0.05 – 0.09)***	0.16 (0.10 – 0.20)***	0.14 (0.09 - 0.19)***	0.14 (0.07 – 0.14)***
Peabody Picture Vocabulary Test (Wave I)	0.24 (0.01 – 0.02)***	0.17 (0.02 – 0.03)***	0.16 (0.02 – 0.03)***	0.22 (0.02 – 0.03)***

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves I & IV.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 12.

Prospective associations between MODBs and Wave IV standardized cognitive outcomes in adult men 24-32 years of age.

	Cognitive Composite *Z*-Score	Immediate word recall (short-term memory)	Delayed word recall (long-term memory)	Number recall (working memory)
	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)
MODB Composite	-0.003 (-0.03 – 0.03)	-0.02 (-0.10 – 0.04)	-0.02 (-0.10 – 0.05)	0.03 (-0.03 – 0.09)
1. Eat Different Foods	-0.04 (-0.15 – 0.02)	-0.05 (-0.44 – 0.01)*	-0.03 (-0.37 – 0.08)	-0.01 (-0.21– 0.13)
2. Exercise	0.04 (-0.02 – 0.14)	0.03 (-0.09 – 0.32)	0.00 (-0.21 – 0.23)	0.06 (0.01– 0.34)*
3. Lift Weights	-0.06 (-0.18 - -0.01)*	-0.06 (-0.46 - -0.03)*	-0.03 (-0.34 – 0.12)	-0.06 (-0.34 – 0.01)
4. Take Food Supplements	-0.02 (-0.12 – 0.07)	-0.02 (-0.33 – 0.17)	0.02 (-0.17 – 0.34)	-0.04 (-0.34 – 0.06)
5. Eat More	0.01 (-0.07 – 0.09)	-0.20 (-0.27 – 0.13)	-0.02 (-0.27 – 0.15)	0.05 (-0.01 – 0.31)
6. Creatine-Use	0.07 (-0.02 – 0.20)*	0.06 (0.04 – 0.52)*	0.01 (-0.22 – 0.29)	0.07 (0.04 - 0.43)*
7. AAS-Use	-0.02 (-0.28 – 0.13)	-0.01 (-0.65 – 0.40)	-0.02 (-0.77 - 0.32)	-0.01 (-0.48 - 0.36)

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves III, & IV. Covariates included age, BMI, education, and Wave I cognition.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 13.

Prospective associations between covariates and Wave IV standardized cognitive outcomes in adult women 24-32 years of age.

	Cognitive Composite *Z*-Score	Immediate word recall (short-term memory)	Delayed word recall (long-term memory)	Number recall (working memory)
	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)
Age (Wave IV)	-0.10 (-0.02 - 0.002)	-0.04 (-0.16 - -0.08)	-0.13 (-0.28 – -0.03)*	-0.09 (-0.12 – 0.05)
Body Mass Index (BMI; Wave IV)	-0.001 (-0.01 – 0.02)	0.07 (-0.02 – 0.08)	0.01 (-0.05 – 0.06)	-0.09 (-0.07 – 0.01)
Highest Education (Wave IV)	0.26 (0.06 – 0.13)***	0.18 (0.07 – 0.28)**	0.19 (0.09 - 0.30)***	0.21 (0.08 – 0.22)***
Peabody Picture Vocabulary Test (Wave I)	0.24 (0.01 – 0.02)***	0.13 (0.00 – 0.04)*	0.19 (0.01 – 0.05)**	0.22 (0.01 – 0.03)***

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves I & IV.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 14.

Prospective associations between MODBs and Wave IV standardized cognitive outcomes in adult women 24-32 years of age.

	Cognitive Composite *Z*-Score	Immediate word recall (short-term memory)	Delayed word recall (long-term memory)	Number recall (working memory)
	βa (95% CI)	βa (95% CI)	βa (95% CI)	βa (95% CI)
MODB Composite	0.01 (-0.07 – 0.09)	0.01 (-0.21 – 0.44)	-0.02 (-0.27 – 0.18)	0.03 (-0.10 – 0.21)
1. Eat Different Foods	-0.02 (-0.19 – 0.13)	-0.03 (-0.57 – 0.31)	-0.02 (-0.55 – 0.36)	0.02 (-0.24– 0.37)
2. Exercise	0.06 (-0.12 – 0.31)	0.04 (-0.42 – 0.78)	0.01 (-0.57 – 0.38)	0.08 (-0.15– 0.69)
3. Lift Weights	-0.06 (-0.34 - 0.12)	-0.01 (-.67 - 0.60)	-0.03 (-0.81 – 0.51)	-0.10 (-0.81 – 0.07)
4. Take Food Supplements	0.01 (-0.21 – 0.23)	-0.01 (-0.65 – 0.55)	-0.01 (-0.70 – 0.54)	0.03 (-0.28 – 0.55)
5. Eat More	-0.06 (-0.28 – 0.07)	-0.06 (-0.73 – 0.24)	-0.02 (-0.59 – 0.41)	-0.07 (-0.53 – 0.14)
6. Creatine-Use	0.07 (-0.16 – 0.79)	0.10 (-0.24 – 2.37)	0.04 (-0.86 – 1.84)	0.03 (-0.66 - 1.15)
7. AAS-Use	-0.02 (-0.80 – 0.53)	-0.08 (-3.09 – 0.58)	-0.04 (-2.56 - 1.22)	0.08 (-0.44 - 2.10)

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves III, & IV. Covariates included age, BMI, education, and Wave I cognition.

* $p < .05$, ** $p < .01$, *** $p < .001$

FIGURES

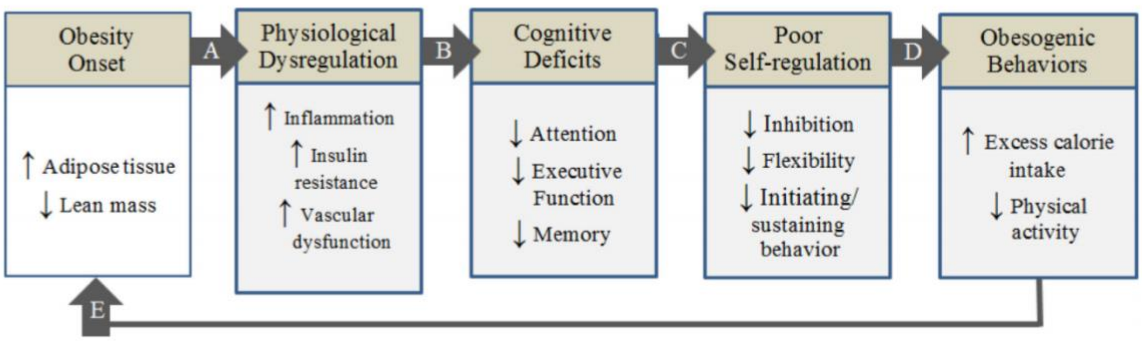


Figure 1. Cyclical model of obesity and cognition (Hawkins & Gunstad, 2017).

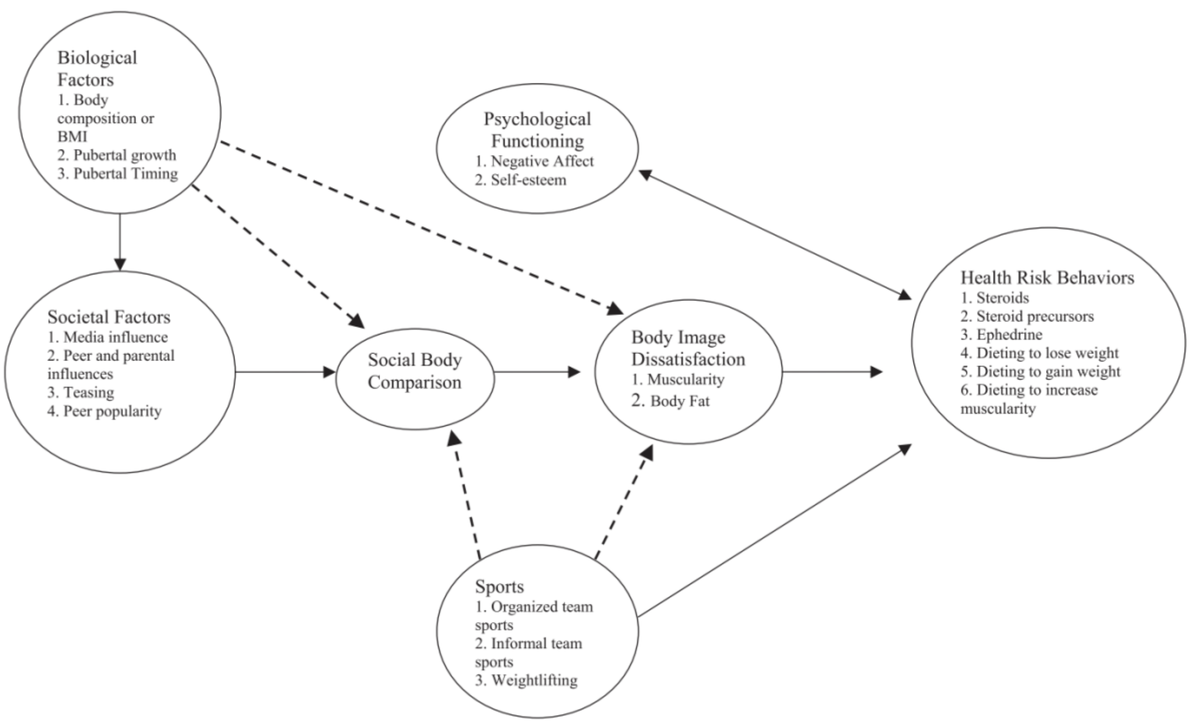


Figure 2. Model of factors that influence the pursuit of the muscular ideal (Cafri et al., 2005).

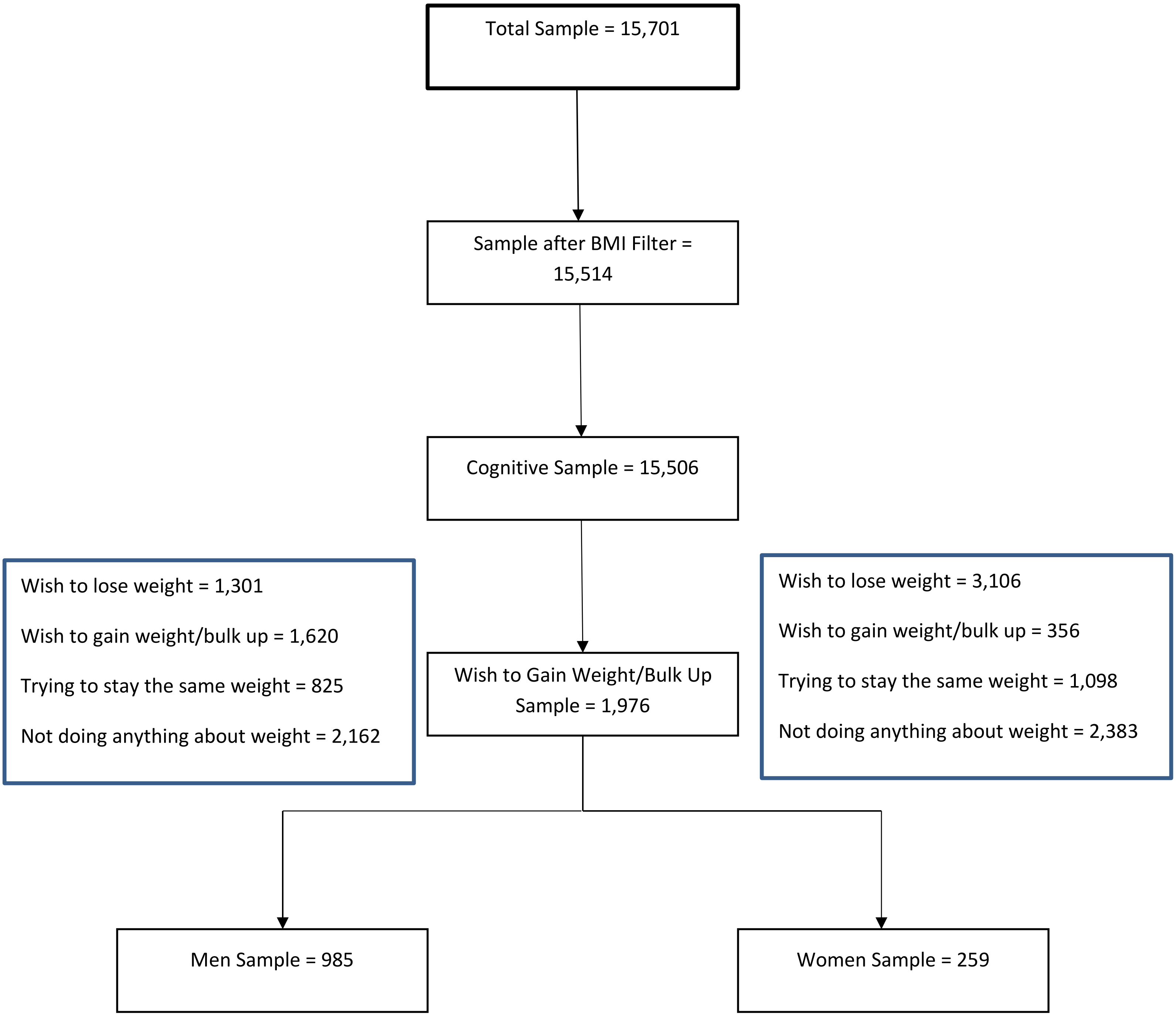


Figure 3. Participant flow chart of Wave IV participants who endorse a drive for muscularity and received cognitive testing.

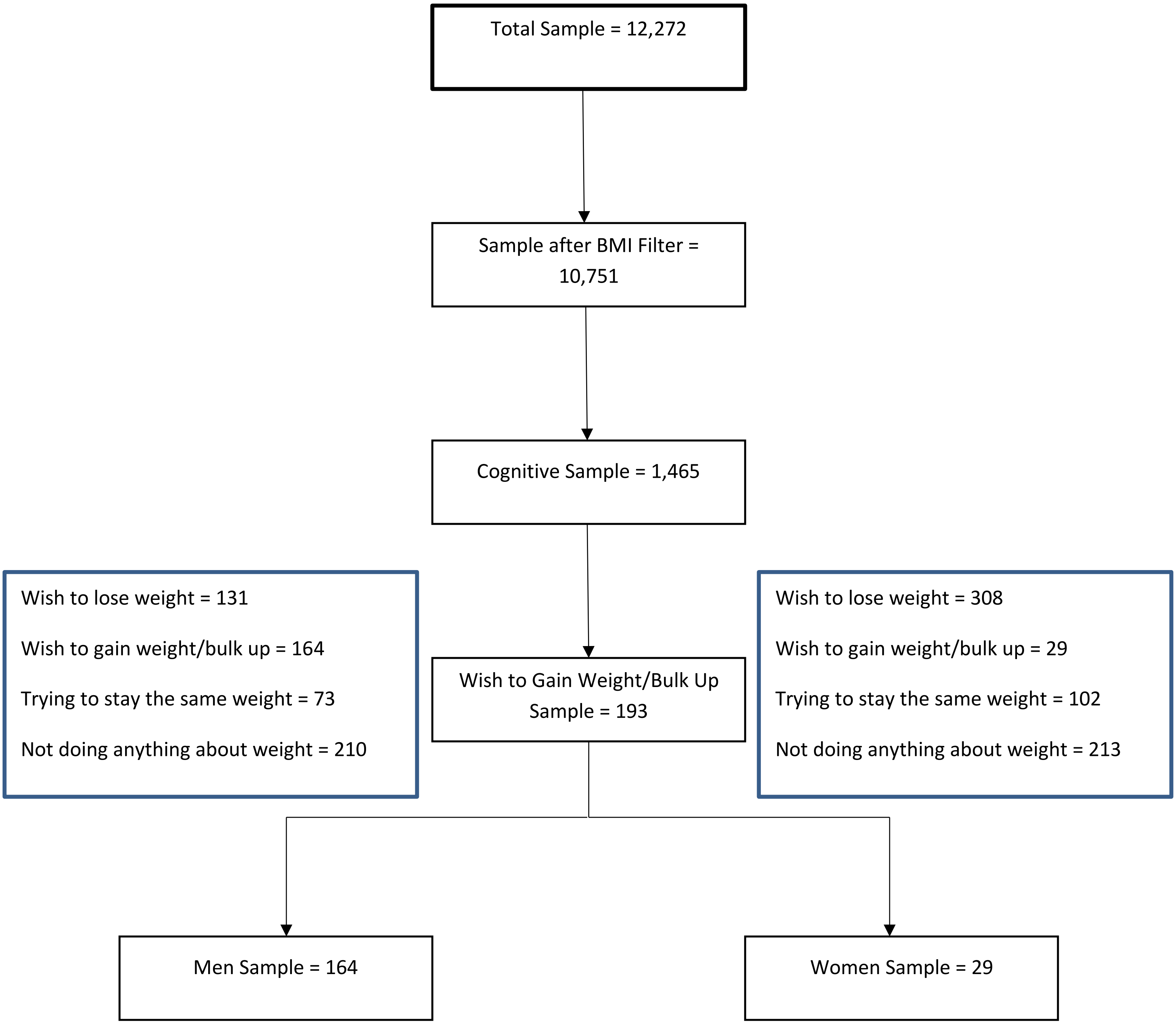
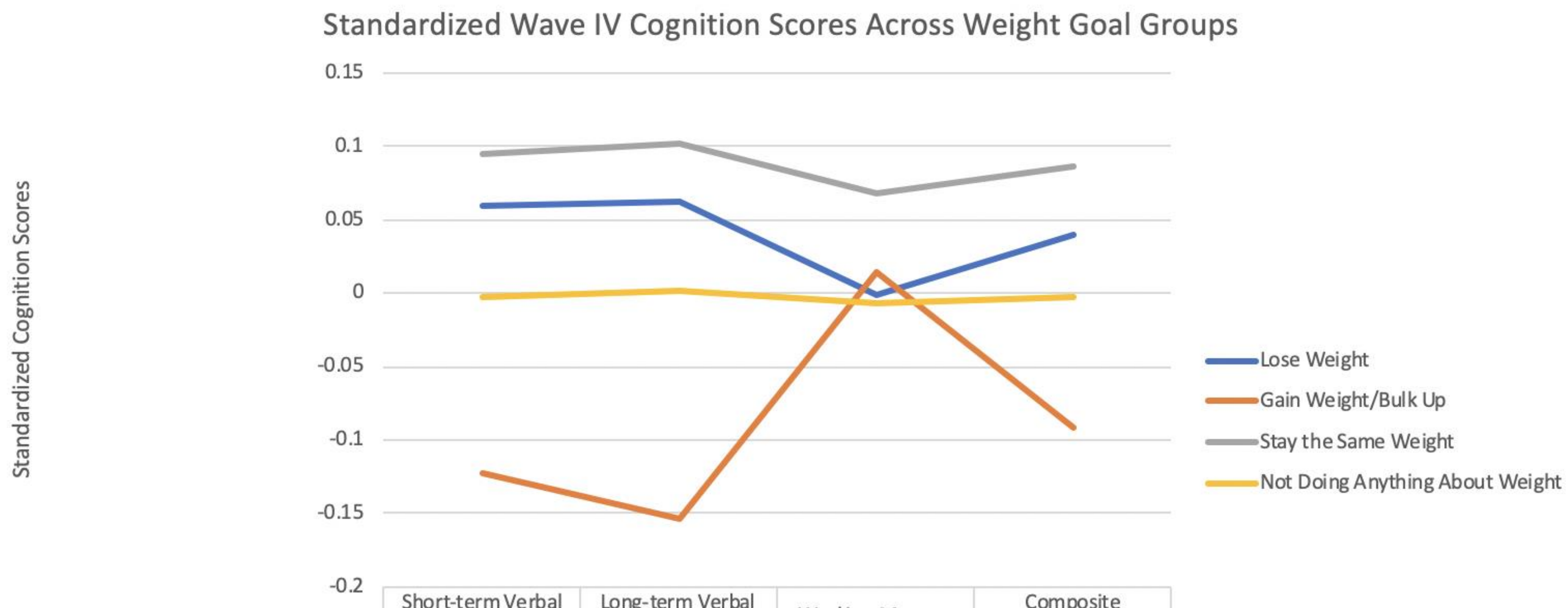
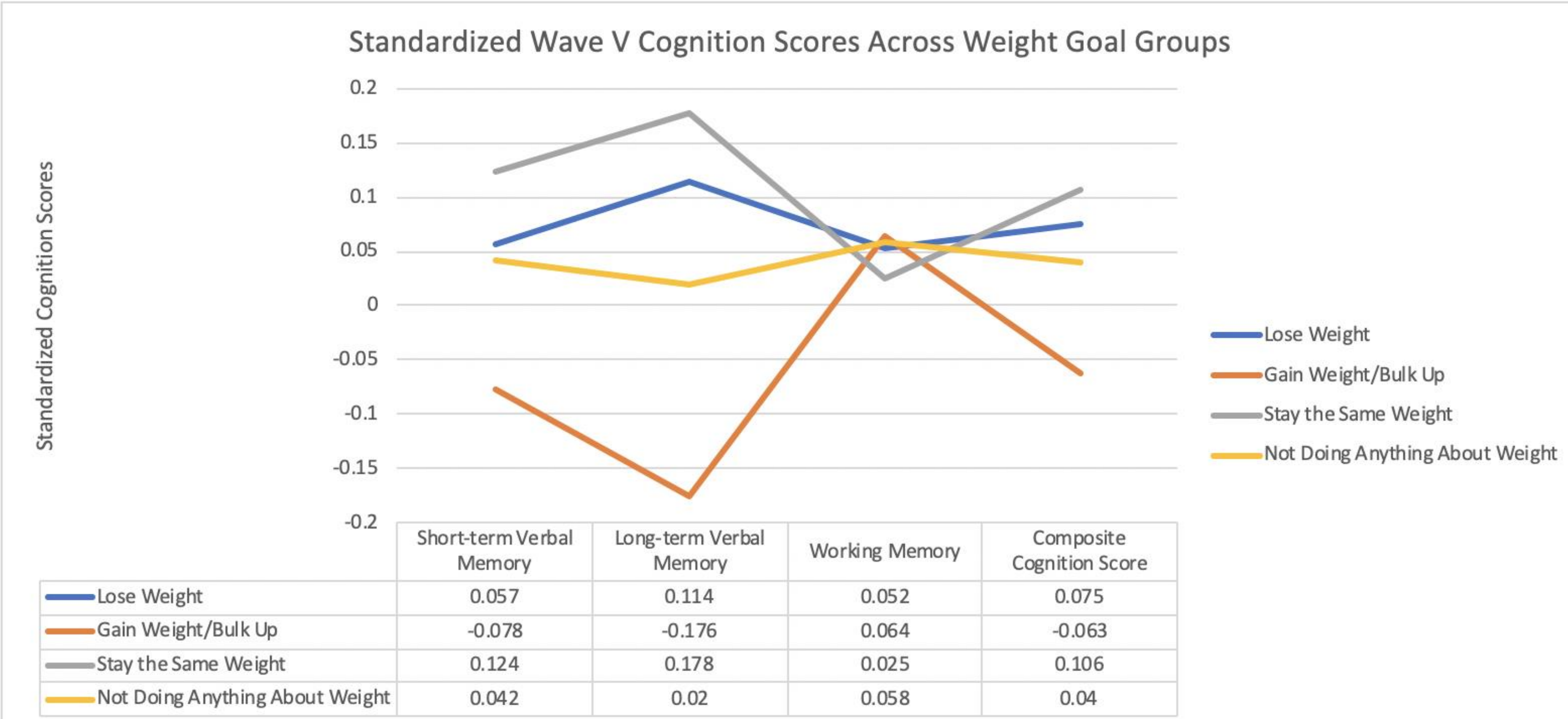


Figure 4. Participant flow chart of Wave V participants who endorse a drive for muscularity and received cognitive testing.



	Short-term Verbal Memory	Long-term Verbal Memory	Working Memory	Composite Cognition Score
Lose Weight	0.059	0.062	-0.001	0.039
Gain Weight/Bulk Up	-0.123	-0.154	0.014	-0.091
Stay the Same Weight	0.094	0.102	0.068	0.086
Not Doing Anything About Weight	-0.002	0.002	-0.007	-0.003

Figure 5. Mean Wave IV cognition scores across Wave III weight goal groups. Covariates included age, sex, BMI, and education.



	Short-term Verbal Memory	Long-term Verbal Memory	Working Memory	Composite Cognition Score
Lose Weight	0.057	0.114	0.052	0.075
Gain Weight/Bulk Up	-0.078	-0.176	0.064	-0.063
Stay the Same Weight	0.124	0.178	0.025	0.106
Not Doing Anything About Weight	0.042	0.02	0.058	0.04

Figure 6. Mean Wave V cognition scores across Wave III weight goal groups. Covariates included age, sex, BMI, and education.

APPENDICES

Appendix A. Review of the Literature

Obesity, defined as a body mass index (BMI) of 30 kg/m^2 or greater, has remained a prominent focus in the health literature due to high prevalence rates among adults in the United States and increased risk of numerous comorbidities that result from excess body weight due to elevated adiposity (Hales, Carroll, Fryar, & Ogden, 2020; Seidell & Halberstadt, 2015). At the other end of the weight spectrum, eating disorders like anorexia nervosa are associated with low or insufficient body weight or adiposity and have also been heavily investigated, as they have the highest mortality rate of any mental illness (Smink, Van Hoeken, & Hoek, 2012). Both obesity and insufficient weight have been associated with cognitive deficits across different domains, suggesting potential relationships between a person's body composition and their brain function.

Relationships between BMI and Cognitive Function: Different Ends of the Spectrum

Excess Body Weight and Cognitive Function

Hawkins and Gunstad (Hawkins & Gustand, 2017) propose a cyclical model of obesity and cognitive function in which excess adiposity leads to physiological alterations, such as glucoregulation, inflammation, or vascular dysfunction (See Figure 1). These physiological changes then contribute to cognitive impairment, particularly in attention, executive function, and memory. In turn, these deficits lead to poor self-regulation abilities which induces unhealthy, obesogenic behavior.

Many studies that have examined the relationship between obesity and cognitive function utilize BMI as the only measure of obesity (Gunstad et al., 2010). However, other obesity indices have been identified, such as waist circumference and waist-to-hip ratio (WHR). These indices have been shown to be more closely related to negative health outcomes than BMI, and therefore, have also been used in research assessing obesity and cognitive function (Dagenais et al., 2005; Lindqvist et al., 2006). Gunstad and colleagues present findings that suggest multiple obesity indices showed similar negative associations with global cognitive function, memory, and verbal fluency. Additionally, higher body mass has been shown to be related to more rapid decline on measures of global cognitive function, memory, and executive function overtime. An abundance of research has specifically focused on the relationship between executive function and overweight and obesity. A recent quantitative meta-analysis including 72 studies examined executive functioning in overweight and obese individuals compared to normal weight controls (Yang et al., 2018). Compared to normal weight controls, participants with obesity demonstrated poorer executive functioning across all domains. In contrast, participants who are overweight only exhibited deficits in inhibition and working memory as compared to controls.

Cognitive function has also been shown to contribute to obesity, suggesting a possible bi-directional relationship. In a systematic review, studies that examined the effects of treatments aimed to decrease body weight showed an improvement in executive function tasks (Favieri, Forte, & Casagrande, 2019). Additionally, studies that assessed cognitive interventions to improve executive function also resulted in improved executive function and lower body weight. Areas of executive function, such as working memory and inhibitory control contribute to participation in unhealthy eating behaviors (Keller, Hartmann, & Siegrist, 2016). For example, poorer working memory is associated with more consumption of fatty foods (Wyckoff, Evans, Manasse, Butryn, & Forman, 2017) and less consumption of fruits and vegetables (Allom & Mullan, 2014).

Weight Loss. In addition to the above work that links obesity to cognitive deficits observationally, some of the most important studies in the obesity-cognitive literature are those showing that cognitive function may improve following weight loss. Such studies show that changes in weight status are linked to changes in cognitive function, which provides stronger evidence that these constructs may be causally linked. Much of this work has used bariatric surgery as the mode of weight loss. In addition to significant weight loss following surgery, cognitive performance on measures of attention, executive function, and memory has also been shown to improve in bariatric surgery patients (Alosco et al., 2015). Other non-surgical weight loss interventions (e.g., behavioral) may yield similar effects on cognitive performance. A recent meta-analysis consisting of twenty studies, both randomized control trials and longitudinal studies, evaluated the impact of different behavioral and surgical weight loss interventions on multiple cognitive domains (Veronese et al., 2017). Weight loss interventions included dieting, physical activity, and bariatric surgery. Voluntary weight loss improved attention, executive function, and memory in longitudinal studies. In addition to these cognitive domains, language also improved after weight loss in randomized control trials. Together, these studies provide stronger evidence that an individual's body composition and/or weight status may linked to cognitive function in a causal manner. The next section describes how weight statuses at the other end of the weight spectrum have been linked to cognitive function.

Low or Insufficient Body Weight & Cognitive Function

Insufficient body weight typically includes individuals with eating disorders (anorexia nervosa), very low-birth-weight (VLBW) infants, failure to thrive children, and older adults who experience unintentional weight loss. A BMI of 18.4 kg/m^2 or lower in adults is considered underweight while VLBW is less than 1500 grams. Eating disorders and insufficient weight may be associated with cognitive function. Malnutrition, in particular, might have deleterious effects on cognitive functioning.

Very Low Birth Weight and Premature Babies. Birthweight has been shown to be positively related to cognitive function in childhood (Shenkin, Starr, & Deary, 2004). Children born preterm (less than 33 weeks' gestation) and children with VLBW (less than 1500 grams) may experience poorer academic achievement, more behavioral issues, and increased deficits in cognitive function compared to their normal weight and/or full-term peers later in life (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009). Poorer verbal fluency, working memory, and cognitive flexibility scores have been observed in preterm and very low birth weight children. Importantly, these findings present evidence that such cognitive “lags” persist into young adulthood for preterm and very low birth weight children.

Eating Disorders. Eating disorders may have a detrimental effect on the body as they have been shown to have the highest mortality rate of any mental illness (Smink et al., 2012). Similarly, the brain and cognitive function may be negatively impacted in those with eating disorders and maladaptive eating behaviors. Different disordered eating behaviors are related to specific eating disorders (See Table 2).

Anorexia nervosa (AN), especially, has been associated with a number of cognitive deficits. Memory deficits, both immediate and delayed, have been observed in patients with AN (Nikendei et al., 2011). Dieting and restricted eating have also been associated with poorer cognitive performance on memory tasks, suggesting that maladaptive eating patterns, even without an eating disorder diagnosis, may impact cognitive function (Green et al., 1994). The restriction of food associated with dieting and eating disorders are hypothesized to be one of the contributing factors to cognitive deficits observed in these populations. However, scholars also posit that the intense preoccupation with food and weight-related thoughts that accompany many eating disorders may impair cognitive performance, which has particular implications for the present study and its focus on drive for muscularity and associated behaviors.

Few studies have assessed cognitive function across the range of BMI. Antsey and colleagues used meta-analytic procedures to probe the relationship between BMI in both midlife and late-life and dementia (Anstey et al., 2011). Underweight BMI, overweight BMI, and obese BMI in midlife were all associated with increased risk of dementia. Such findings may imply cognitive deficits related to both underweight BMI and overweight/obese BMI in midlife. Other research compared executive function in participants with AN, participants with obesity, and healthy controls (Fagundo et al., 2012). Those with AN and participants with obesity performed worse than healthy controls on cognitive flexibility and decision-making measures. Additionally, participants with obesity also exhibited worse performance on an inhibition task than participants with AN and healthy controls. Overall, these findings provide support to the hypothesis that extreme weight conditions (underweight BMI to overweight and obese BMI) may contribute to cognitive dysfunction.

Weight Stigma

Importantly, weight status itself may not be the only weight-related factor associated with cognitive function. Recent work has turned towards investigating how weight stigma may influence other health factors, such as cognition. In a study that utilized a manipulated weight-base discrimination task, participants in the manipulation group with higher perceived weight stigma performed worse on an inhibitory control task. However, this relationship was not observed in the control group. These findings suggest that weight discrimination make invoke a sense of threat in overweight individuals, which may impair executive functioning. Similar work exploring the relationship between stereotype threat and executive function has supported these results (Guardabassi & Tomasetto, 2018, 2020). Specifically, in tasks that were labeled as tests of intelligence or cognitive function, BMI was negatively related to working memory in a sample of adults with obesity. Therefore, in addition to actual weight status, weight stigma may play a role in impaired cognitive performance. Such findings that sociocultural factors are important in the weight status-cognition relationship provide important context to the proposed study because drive for muscularity may not only result in changes to body composition that impact cognitive function but this drive may also be linked to social pressures regarding the ideal body that may also be important.

Current Trends in Body Ideal and Body Image

Traditionally, the ideal female body ideal has been focused on thinness, depicting an ideal with a small waist and low body fat (Grogan, 2016). In contrast, the male body ideal has been characterized by a dual-focus on high muscularity and low body fat (i.e., leanness) (Thompson & Cafri, 2007). However, the male and female ideal has shifted in recent years to reflect an image that appears "worked out" or having defined muscle tone. The current ideal of physical attractiveness or the ideal body in men has become increasingly muscular over time (Leit et al., 2001; Pope Jr et al., 1999). Similarly, in women the ideal body image has expanded towards an emphasis on a toned, "fit" physique, in addition to a thin-ideal (Homan, 2010).This body ideal has been coined the "muscular ideal." Biological, societal, psychological, and other factors have been shown to influence the desire to achieve the muscular ideal (See Figure 2)(Cafri et al., 2005).

The shifts in the ideal body have led to muscularity-oriented body image dissatisfaction in both men and women, such that 90% of college-aged men and 57% of women reported being dissatisfied with their muscle tone (Frederick et al., 2007; Garner, 1997). Body dissatisfaction has been shown to predict a number of maladaptive dietary and other behaviors, such as restricting, binging, excessive exercise, and performance-enhancing substance-use (Karazsia, Crowther, & Galioto, 2013; Neumark-Sztainer, 2005; Tylka, 2011).

The pursuit of the muscular and toned ideal, and particularly muscularity-oriented body dissatisfaction, may become pathological and could potentially lead to muscle dysmorphia (MD), a subtype of body dysmorphic disorder (BDD). Pope and colleagues suggest MD may develop from participation in various body-change behaviors that are aimed to improve the appearance of one's muscularity (Pope Jr, Gruber, Choi, Olivardia, & Phillips, 1997)(Pope et al., 1997). Such body change behaviors may include excessive weight lifting and rigid diet regimens (Olivardia, Pope Jr, & Hudson, 2000).

While not recognized as a clinical disorder by the DSM-5, Orthorexia Nervosa (ON) is another form of pathology that has been linked to the muscularity-oriented goals (White, Berry, & Rodgers, 2020). Bratman, the founder of the term, describes ON as a pathological obsession with the pursuit of healthy eating (Bratman, 1997). Proposed diagnostic criteria for ON can be found in Table 4. In a sample of college men, White and colleagues presented novel findings that ON and both attitudinal and behavioral components of a drive for muscularity are positively correlated. They suggest that such results are indicative of a co-occurrence between concerns surrounding healthy eating and concerns related to increasing muscularity. Together, these types of pathological thinking patterns and behaviors share a lot in common with other eating disorders in which preoccupation with food and corresponding behaviors begin to impair function, despite the fact that the original intent may appear to be "healthy" or "fitness-focused." Such work highlights drive for muscularity and associated behaviors as an emerging research area that warrants further study. Although the extant research is limited, available studies on muscularity-oriented eating pathology are described below.

Muscularity-Oriented Disordered Behaviors (MODBs)

A number of behaviors have been associated with the desire for increased muscularity. Nagata and colleagues propose that actively trying to gain weight may be a proxy by which one wishes to achieve increased muscularity (Nagata et al., 2019). To be clear – in this case, "gaining weight" refers to gaining muscle mass not fat mass. Alterations to one's diet may be used in order to gain lean muscle mass. In a survey of adolescents in the United States, about two-thirds of boys and girls reported changing their eating behaviors to increase muscle size or tone (Eisenberg et al., 2012). Pathological eating behaviors that are aimed to increase muscle-mass, develop greater muscle leanness, or both have been characterized as "muscularity-oriented disordered eating" (MODE). Such dietary alterations include: over-regulation of protein consumption and restriction of other dietary macronutrients, consuming protein supplements, engaging in cheat meals, eating beyond the point of feeling full, and maintaining access to preplanned foods (Murray et al., 2017; Pila et al., 2017).

Other behaviors associated with the desire to increase muscularity include performance-enhancing substance (PES) use, both legal and illegal. Legal PESs include substances such as creatine and amino acids, and illegal include anabolic-androgenic steroids (AAS)(Smolak et al., 2005). Creatine is considered one of the most used dietary supplements worldwide and has been shown to increase body mass by 2% (Branch & Williams, 2002). AAS's, on the other hand, are one of the most popular substances used by adult males (Cafri et al., 2005). A national survey found that nearly 17 million adults reported steroids or other PESs. Compulsive exercise and overtraining to the point of injury have also been identified as maladaptive muscularity-oriented behaviors (Pritchard et al., 2011). Along with injury, MODBs are linked to a number of adverse health outcomes, such as: more severe medical events, as well as cardiovascular, hematologic, psychiatric, hormonal, and metabolic effects (Pope Jr et al., 2014). Cognitive function, however, has remained underexplored in relation to MODBs, despite the previously established relationships between weight status, eating disorders, and weight stigma with cognitive function.

Appendix B. Wave V Supplemental Results Tables

Table 15.

Prospective associations between covariates and Wave V standardized cognitive outcomes in adults 33-45 years of age.

	Cognitive Composite *Z-Score*	Immediate word recall (short-term memory)	Delayed word recall (long-term memory)	Number recall (working memory)
	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)
Age (Wave V)	-0.10 (-0.10 – 0.02)	-0.97 (-0.26 - 0.05)	-0.09 (-0.27 – 0.07)	-0.06 (-0.17 – 0.07)
Biological Sex (Wave V)	-0.01 (-0.34 – 0.29)	0.05(-0.51 - 1.11)	-0.00 (-0.93 – 0.88)	-0.07 (-0.97 – 0.31)
Body Mass Index (BMI; Wave V)	-0.01 (-0.02 – 0.02)	-0.02 (-0.06 – 0.05)	-0.00 (-0.07 – 0.06)	-0.00 (-0.05 – 0.04)
Highest Education (Wave V)	0.33 (0.05 – 0.11)***	0.29 (0.09 – 0.26)***	0.23 (0.05- 0.25)**	0.25 (0.05 – 0.19)**
Peabody Picture Vocabulary Test (Wave I)	0.20 (0.00 – 0.02)**	0.16 (0.00 – 0.04)*	0.10 (-0.01 – 0.04)	0.21 (0.01 – 0.04)**

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves I & V.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 16.

Prospective associations between MODBs and Wave V standardized cognitive outcomes in adults 33-45 years of age.

	Cognitive Composite *Z*-Score	Immediate word recall (short-term memory)	Delayed word recall (long-term memory)	Number recall (working memory)
	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)
MODB Composite	0.02 (-0.07 – 0.10)	0.02 (-0.19 – 0.24)	0.05 (-0.16 – 0.32)	-0.02 (-0.19 – 0.15)
1. Eat Different Foods	-0.02 (-0.30 – 0.24)	-0.05 (-0.94 – 0.44)	-0.02 (-0.89 – 0.65)	0.04 (-0.39– 0.68)
2. Exercise	0.05 (-0.17 – 0.33)	0.05 (-0.42 – 0.86)	0.03 (-0.60 – 0.83)	0.04 (-0.37– 0.62)
3. Lift Weights	-0.12 (-0.47 – 0.05)	-0.89 (-1.04 – 0.31)	-0.00 (-0.76 – 0.74)	-0.20 (-1.19 – -0.15)*
4. Take Food Supplements	-0.00 (-0.30 – 0.29)	-0.00 (-.79 – 0.75)	-0.06 (-01.20 – 0.52)	0.07 (-0.34 – 0.85)
5. Eat More	0.07 (-0.12 – 0.37)	0.09 (-0.27 – 0.99)	0.05 (-0.49 – 0.92)	0.04 (-0.36 – 0.62)
6. Creatine-Use	0.07 (-0.16 – 0.43)	0.04 (-0.56 – 0.97)	0.12 (-0.23 - 1.48)	0.002 (-0.58 - 0.60)
7. AAS-Use	-0.01 (-0.62 – 0.52)	0.01 (-1.33 – 1.62)	0.05 (-1.14 - 2.15)	-0.09 (-1.85 - 0.42)

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves III, & V. Covariates included age, biological sex, BMI, education, and Wave I cognition.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 17.

Prospective associations between covariates and Wave V standardized cognitive outcomes in adult men 33-45 years of age.

	Cognitive Composite *Z*-Score	Immediate word recall (short-term memory)	Delayed word recall (long-term memory)	Number recall (working memory)
	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)
Age (Wave V)	-0.15 (-0.13 – -0.001)*	-0.13 (-0.30 - 0.02)	-0.13 (-0.33 – 0.03)	-0.08 (-0.20 – 0.56)
Body Mass Index (BMI; Wave V)	-0.03 (-0.03 – 0.02)	-0.03 (-0.07 – 0.05)	-0.01 (-0.07 – 0.06)	-0.04 (-0.06 – 0.04)
Highest Education (Wave V)	0.33 (0.04 – 0.12)***	0.29 (0.08 – 0.26)***	0.21 (0.03 - 0.24)	0.27 (0.06 – 0.21)**
Peabody Picture Vocabulary Test (Wave I)	0.19 (0.002 – 0.02)*	0.12 (-0.004 – 0.04)	0.09 (-0.0 – 0.04)	0.24 (0.01 – 0.04)**

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves I & V.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 18.

Prospective associations between MODBs and Wave V standardized cognitive outcomes in adult men 33-45 years of age.

	Cognitive Composite *Z*-Score	Immediate word recall (short-term memory)	Delayed word recall (long-term memory)	Number recall (working memory)
	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)
MODB Composite	0.04 (-0.07 – 0.11)	0.05 (-0.16 – 0.29)	0.04 (-0.20 – 0.31)	0.01 (-0.17 – 0.19)
1. Eat Different Foods	0.04 (-0.22 – 0.36)	-0.01 (-0.67 – -0.78)	0.00 (-0.82 – 0.82)	0.08 (-0.29– 0.86)
2. Exercise	0.06 (-0.17 – 0.36)	0.06 (-0.42 – 0.91)	0.03 (-0.62 – 0.89)	0.05 (-0.37 – 0.69)
3. Lift Weights	-0.11 (-0.46 – 0.08)	-0.09 (-1.04 – 0.33)	-0.02 (-0.85 – 0.71)	-0.16 (-1.10 – -0.01)*
4. Take Food Supplements	-0.02 (-0.36 – 0.27)	-0.4 (-0.98 – 0.62)	-0.11 (-1.48 – 0.33)	0.10 (-0.24 – 1.02)
5. Eat More	0.03 (-0.20 – 0.31)	0.09 (-0.31 – 1.00)	0.04 (-0.57 – 0.91)	-0.04 (-0.65 – 0.39)
6. Creatine-Use	0.10 (-0.12 – 0.48)	0.07 (-0.46 – 1.08)	0.14 (-0.21 - 1.53)	0.03 (-0.52 - 0.70)
7. AAS-Use	-0.02 (-0.65 – 0.50)	0.01 (-1.34 – 1.56)	0.06 (-1.10 – 2.18)	-0.12 (-2.00 – 0.30)

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves III, & V. Covariates included age, biological sex, BMI, education, and Wave I cognition.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 19.

Prospective associations between covariates and Wave V standardized cognitive outcomes in adult women 33-45 years of age.

	Cognitive Composite *Z*-Score	Immediate word recall (short-term memory)	Delayed word recall (long-term memory)	Number recall (working memory)
	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)
Age (Wave V)	0.22 (-0.10 – 0.37)	0.07 (-0.55 - 0.82)	0.22 (-0.31 – 1.10)	0.22 (-0.21 – 0.66)
Body Mass Index (BMI; Wave V)	0.03 (-0.06 – 0.07)	0.04 (-0.17 – 0.21)	-0.04 (-0.21 – 0.17)	0.07 (-0.10 – 0.14)
Highest Education (Wave V)	0.35 (-0.01 – 0.17)	0.27 (-0.08 – 0.43)	0.31 (0.06- 0.47)	0.20 (-0.09 – 0.24)
Peabody Picture Vocabulary Test (Wave I)	0.18 (-0.01 – 0.03)	0.35 (-0.01 – 0.13)	0.13 (-0.05 – 0.09)	-0.14 (-0.06 – 0.03)

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves I & V.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 20.

Prospective associations between MODBs and Wave V standardized cognitive outcomes in adult women 33-45 years of age.

	Cognitive Composite *Z*-Score	Immediate word recall (short-term memory)	Delayed word recall (long-term memory)	Number recall (working memory)
	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)	β[a] (95% CI)
MODB Composite	-0.06 (-0.33 – 0.24)	-0.17 (-1.12 – 0.48)	0.20 (-0.45 – 1.21)	-0.22 (-0.75 – 0.26)
1. Eat Different Foods	-0.39 (-1.51 – 0.18)	-0.52 (-4.99 – -0.16)*	-0.30 (-4.07 – 1.10)	0.02 (-1.13– 1.21)
2. Exercise	0.21 (-0.59 – 1.34)	0.17 (-1.88 – 3.65)	0.15 (-2.17 – 3.74)	0.16 (-0.88 – 1.80)
3. Lift Weights	-0.28 (-1.58 – 0.55)	-0.12 (-3.69 – 2.43)	0.004 (-3.25 – 3.29)	-0.62 (-3.40 – -0.43)*
4. Take Food Supplements	0.18 (-0.60 – 1.44)	0.17 (-1.81 –4.07)	0.34 (-0.93 – 5.34)	-0.16 (-2.03 – 0.81)
5. Eat More	0.27 (-0.39 – 1.46)	0.17 (-1.69 – 3.61)	0.20 (-1.69 – 3.97)	0.27 (-0.40 – 2.16)
6. Creatine-Use	0.11 (-1.07 – 1.75)	0.01 (-3.83 – 4.26)	0.24 (-2.15 - 6.49)	-0.05 (-2.20 - 1.72)
7. AAS-Use	--	--	--	--

Note. Data is from the National Longitudinal Study of Adolescent to Adult Health (Add Health) Waves III, & V. Covariates included age, BMI, education, and Wave I cognition.

* $p < .05$, ** $p < .01$, *** $p < .001$. Data for AAS-Use is unavailable given insufficient sample size endorsing this MODB.

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