Transactions of the Illinois State Academy of Science
(2025) Volume 118, pp. 15-21

received 10/18/24
accepted 6/3/25

The Association between Physical Fitness and Academic Performance in College-Age Students

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ABSTRACT

The purpose of this study was to investigate the relationship between physical fitness measurements and the academic performance of college students. 78 students from two collegiate institutions in Illinois, collectively (19.9 +/1.3 years; range: 18-24 years) participated in this study. All participants self-reported their college grade point average. Body mass index, relative handgrip strength, and estimated maximal oxygen consumption (VO_{2max}) were measured to determine physical fitness. Participants also completed a questionnaire on their sociodemographic profile. Statistically significant correlations were observed between GPA and BMI (r =-.403), grip strength (r =.459), and $VO_{2\,max}$ (r =.416) while controlling for sex, race/ethnicity, and household income. Linear regression models indicated that measures of physical fitness were significant indicators of academic performance including VO_{2max} (.452, 95% CI .010, .035), relative muscular strength (.377, 95% CI .381, 1.618), and BMI (-.327, 95% CI -.040, -.006). Results of the present study indicate that academic performance and physical fitness in collegiate students are significantly related while controlling for potential confounding variables.

Keywords: *Academic performance; cardiorespiratory fitness; muscle strength*

INTRODUCTION

Cardiorespiratory fitness (CRF) and muscular strength have been identified as important markers for total body health, including the promotion of skeletal and lean body mass (Janz et al., 2021), as well as the prevention and mitigation of obesity, cardiovascular disease, and all-cause mortality (Blair et al., 1989; Ortega et al., 2008; Pandey et al., 2016; Stoner et al., 2020). Despite the health benefits of physical fitness, approximately one-quarter (24.2%) of the U.S. population meets the established Physical Activity Guidelines for Americans for both aerobic and muscle-strengthening activities (Elgaddal et al., 2022). This is concerning as low fitness levels and obesity rates remain public health concerns. Moreover, national obesity rates have risen in recent years due to a multitude of social factors such as sedentary behavior, isolation during COVID-19, poor diet, and sleep disturbances (Edwards et al., 2011; Marshall et al., 2023; Redondo-Flórez et al., 2021). Across all ages, higher body mass index (BMI) values and poor fitness levels have been associated with different pathological conditions including stress disorders, depression, anxiety, and a variety of physiological conditions (Donnelly et al., 2016; Redondo-Flórez et al., 2021; Sanyaolu et al., 2019). As such, it is important that adults continue to pursue healthy behaviors related to establishing or maintaining physical fitness levels.

In addition to physical health, physical fitness has been associated with improved cognitive function. CRF has been associated with increased vascularization which increases blood flow to the brain and results in neurogenesis and increased cognitive processing ability (Dubuc et al., 2017). Muscular strength has also been suggested to promote cognitive benefits through the association of strength training and synaptogenesis (Adelantado-Renau et al., 2018). These benefits are associated with the executive function hypothesis which suggests that physical activity can potentially increase neural growth which is in turn associated with higher-level cognitive processes (Kopp, 2012; Kramer et al., 1999).

While there is mounting evidence to suggest positive cognitive outcomes with higher levels of physical fitness, previous studies have established positive associations with aspects of health-related physical fitness and academic performance among youth populations (Bass et al., 2013; Coe et al., 2013; Donnely et al., 2016; Olivares & García-Rubio, 2016; Santana et al., 2017). This research presents the foundation for future research in older populations, such as college-age students, which remains under-investigated. Establishing or maintaining physical fitness during the transition from adolescence to adulthood is important as enrolling in college brings about additional stressors that often lead to reduced physical activity and increased weight gain (Wetter et al., 2013). Previous studies have suggested that college students are at high risk of increasing sedentary behaviors (Carballo-Frazanes et al., 2020; Felez-Nobrega et al., 2017). Additionally, the transitional stressors of college also increase levels of anxiety and physical stress, which can reduce information retention and cerebral blood flow (Dubuc et al., 2017).

Foundational research on the relationship between physical fitness and academic performance among college

students has found positive associations between CRF and academic performance (Dubuc et al., 2017; Redondo-Flórez et al., 2022). However, current literature fails to assess other components of physical fitness and their association with academic performance, such as muscular strength, which warrants future investigation. Therefore, the aim of the current study is to examine the associations between components of health-related physical fitness and academic performance among collegiate undergraduate students. It is hypothesized that that measures of CRF and muscular strength will be positively associated with academic performance, whereas BMI will be negatively associated with academic performance.

MATERIALS AND METHODS

Participants. A total of 78 undergraduate students enrolled in a general education biology or kinesiology course for all majors (age:19.9 ±1.3 years; 39.7% male and 60.3 % female) were recruited from a private and public post-secondary institution in central Illinois. All recruited participants were instructed ahead of their research appointment to wear comfortable exercise-type clothing, avoid tobacco and caffeine 3 hours prior, avoid alcohol and cannabis use 12 hours prior, avoid strenuous exercise 24 hours prior, consume plenty of fluids, and obtain an adequate amount of sleep the night before. Before participation occurred, all students were fully informed of the goal, procedures, and risks of the study and completed a written informed consent form. This study was approved by the Illinois College and Illinois State University Institutional Review Board.

Procedure. At the beginning of the study, all potential participants completed the Physical Activity Readiness Questionnaire (PAR-Q), which established exclusion criteria. Exclusion criteria were: (1) presenting with some types of pathology (cardiovascular condition, high blood pressure, cancer, arthritis, osteoporosis, history of back injury, or metabolic conditions such as diabetes); (2) taking some kinds of medication (steroids, cancer therapy, or beta-blocker medications); (3) lacking permission from a doctor to complete non-medically supervised physical activity. Other exclusion criteria established for the study include being outside the age range of 18-65. Following the PAR-Q, a self-report questionnaire was administered surveying demographic information and GPA. All subjects underwent anthropometric measurements, followed by physical fitness assessments.

Measures.

Anthropometrics. Height was measured using the Frankfort horizontal plane to the nearest 0.1 cm via a wall mounted stadiometer (SECA 216, Seca Corporation, Hanover, MD). Body mass was measured to the nearest 0.1 kg using a portable scale (Tanita BF-350 Bioimpedance scale, Tanita Corp, Tokyo, Japan). All subjects were measured barefoot and with minimal clothes. Height and mass were used to calculate BMI as mass in kg/height in m^2.

Cardiorespiratory Fitness Testing . Cardiorespiratory fitness was assessed using the Rockport one-mile walk test. This assessment has been previously validated for adult populations by Seneli et al. (2013). All participants completed a one mile walk as quickly as possible without running. Upon completion, time and heart rate were recorded in order to estimate VO_{2max}, using the following formula: VO_{2max} ($ml.kg.min^{-1}$) = 132.853 – (0.1692 * WT) – (0.3877 * age) + (6.315 * sex) – (3.2649 *time) – (0.1565 * HR). When considering participant's sex, the numerical value of one was used for males, whereas females received a numerical value of zero.

Musculoskeletal Fitness Testing. Isometric grip strength was measured using a handheld dynamometer (Takei Digital Grip Strength Dynamometer, Takei Scientific Instruments Co., Ltd). Sizing adjustments were made for each participant. Participants performed this assessment while standing upright with their arms straight at their sides. Each participant squeezed as hard as possible for the duration of three seconds to perform a maximal voluntary isometric contraction. A total of three trials were performed with each hand, alternating hands between trials. The highest value from each hand was summed and divided by two to quantify combined grip strength. This value was divided by body mass to calculate relative grip strength (kg grip/kg mass).

Academic Performance. Self-reported grade point average (GPA) of each participant was used to assess academic performance. While there is no standardized definition for academic performance (Castelli et al., 2014), it can be defined as the extent to which a student, teacher, or institution has achieved their education goals (Donnelly et al., 2016). GPA is a common assessment of academic performance and has been shown to be strongly associated with other measures of student achievement across curricula (Bacon and Bean, 2006), making it applicable within the context of college achievement.

Covariates. Participants completed a self-report survey on demographic information. The survey included the self-report of the participant's biological sex (male or female), current chronological age, and race and ethnicity. The socioeconomic status (SES) portion of the survey included the self-report of the highest level of education of both their biological mother and father, if applicable. The survey also included the reporting of annual household income (ranging at intervals from less than $35,000 to more than $200,000).

Statistical Analysis. Descriptive statistics were calculated for the total sample with mean and standard deviation utilized for scale variables and frequency and percentage (%) utilized for categorical variables. Partial Pearson correlations and multiple linear regression models were used to examine the associations between components of physical fitness and academic performance. All analyzes were adjusted for biological sex, SES, and racial/ethnic background. All statistical analyses

were conducted using IBM SPSS version 29 with 95% confidence intervals (Alpha of $p < .05$).

RESULTS

Descriptive statistics for all variables are reported in Table 1. Partial Pearson correlation coefficients were calculated from the relationships between BMI, relative grip strength, $VO_{2\ max}$, and GPA while adjusting for a series of covariates. Table 2 demonstrates a significant correlation between GPA and BMI (r =-.403, p =.002), VO_{2max} (r =.431, p = <.001), and relative grip strength (r =.458, p = <.001). The results of the linear regression models analyzed by the association of physical fitness and academic performance can be found in Table 3. The linear regression models indicate that VO_{2max} was a significant indicator of academic performance (.452, 95% CI .010, .035, p = <.001), as was relative muscular grip strength (.377, 95% CI .381, 1.618, p = .002), and BMI (-.327, 95% CI -.040, -.006, p = .008).

DISCUSSION

This study examined the association between components of health-related physical fitness and academic performance in a sample of undergraduate students. The main results of this study indicate that physical fitness is significantly associated with academic performance. It was observed that CRF and muscular strength were positively associated with academic performance, while BMI was negatively associated with academic performance, resulting in the rejection of the null hypothesis in support of the research hypothesis. These results remain consistent when controlling for biological sex, racial/ethnic background and SES. CRF and muscular strength were found to have the strongest associations with student achievement.

Regarding weight status, our results found that BMI has a moderate, negative association with GPA among college students. These results agree with previous studies. A similar study by Franz and Feresu (2013) found that BMI was significantly correlated with GPA and that students with normal BMI classifications had higher GPA values when compared to those who were classified as overweight. Anderson and Good (2016) found that BMI was significantly related to course grades. Aime et al. (2017) observed that overweight and obese female students had lower GPA values when compared to students with normal BMI values. It was also observed that those with higher BMI values had lower levels of academic self-efficacy, which partially mediated the relationship between BMI and academic performance.

Overall, our results indicate that higher BMI values are negatively associated with GPA in college students, when controlling for sex, SES, and racial/ethnic background. These results are significant as they indicate that physical health and fitness continue to be associated with academic performance in post-secondary education. Previous reports have indicated that BMI is negatively associated with academic performance in youth populations (Castelli et al., 2007; Gaydosh & McLanahan, 2021; He et al., 2019; Martin et al., 2017). While these associations remain mixed within the current literature (LeBlanc et al., 2012; Ryu et al., 2021; Torrijos-Niño et al., 2014), Martin et al. (2017) suggested that BMI became more strongly associated with academic performance as children age due to changes in executive function brought on by puberty. The current results suggest that these negative associations persist during the transition into post-secondary education.

Table 1. Descriptive statistics of study variables.

Variable, n = 78 participants	Count / M	% / SD
Age (years)	19.91	1.3
Sex		
Male	31	39.7
Female	47	60.3
Race/Ethnicity		
White non-Hispanic	51	65.4
Hispanic	6	7.7
Black non-Hispanic	15	19.2
Multiracial	3	3.8
Other	3	3.8
Household Income		
Greater than $200,000	5	6.4
$150,000-199,999	12	45.4
$100,000-149,999	11	14.1
$75,000-99,999	13	16.7
$50,000-74,999	8	10.3
$35,000-49,999	8	10.3
Less than $35,000	4	5.1
Missing	17	21.8
Body Mass Index (kg/m^2)	27.16	6.61
VO_{2max}	40.49	10.14
Relative Grip Strength	0.35	0.18
Grade Point Average	3.24	0.47

Note. M = Mean, SD = Standard Deviation

Table 2. Partial correlation coefficients between physical fitness and academic performance.

Measure	1	2	3	4
1. Grade Point Average	—			
2. Body Mass Index	-.403*	—		
3. VO2 max	.431**	-.756**	—	
4. Relative Grip Strength	.458**	-.262*	.420**	—

Note. All values adjusted for sex, race/ethnicity, and household income. *= p<.05. **= p<.01.

Table 3. Summary of multiple regression analysis for students academic achievement.

Effect	β	SE	95% CI		p-value
			LL	UL	
VO2 max	.452	.006	.010	.035	<.001**
Relative Grip Strength	.377	.308	.381	1.618	.002**
Body Mass Index	-.327	.008	-.040	-.006	.008**

Note. All values adjusted for sex, race/ethnicity, and household income. β = standardized beta coefficients; SE = standard error; CI = confidence interval; LL = lower limit; UL = upper limit. *= p<.05. **= p<.01.

The results of our study indicate that a higher CRF is associated with a higher GPA. This mirrors the finding of Redondo-Flórez et al. (2022) and are further supported by a female-only undergraduate sample by Dubuc et al. (2017) who both found positive associations between $VO_{2\,max}$ values and GPA. While the current study estimated $VO_{2\,max}$, using a submaximal assessment, a specific indicator of aerobic or cardiorespiratory fitness, other literature suggests increasing the amount of aerobic physical activity in college students is associated with higher measures of academic performance (Shantakumar et al., 2022). While there is no currently validated mechanism for how CRF influences academic performance strictly in undergraduate student populations, the connection between the two variables through increased cognitive function has been suggested (Dubuc et al., 2017). At higher $VO_{2\,max}$ values, there is increased oxygen availability to the brain, which promotes more executive function capabilities such as working memory, inhibition, and cognitive flexibility, all of which were seen in more aerobically active young adults (Shantakumar et al., 2022).

Our data suggests the importance of CRF in academic performance as an extension beyond adolescence. Higher CRF in children has been associated with more successfully meeting and exceeding math and reading benchmarks in middle school (Bass et al., 2013), as well as being correlated to higher academic performance in adolescents through the mediation of larger amounts of white brain matter (Esteban-Cornejo et al., 2019). Similar to literature on undergraduate populations, increased CRF in adolescents is associated with faster cognitive processing and reaction time (Hillman et al., 2005).

We found that higher muscular strength is strongly associated with higher college GPA. While there is currently limited literature on the association between muscular strength and academic performance in college students, Keating et al. (2013) found that students who strength train at least once a week had higher GPA values than students who did not strength train on a weekly basis. Additionally, Hashimoto et al. (2023) found that college students performed better on cognitive memory and recall tests two days following strength training and that the fMRIs of these students showed more connectivity throughout their hippocampi. These findings suggest there is a mechanism underlying the process through which muscular strength may promote cognitive activity and therefore academic performance, but more research is still needed on this subject.

Literature on muscular strength in adolescence shows that increased muscular strength and muscle endurance are correlated with meeting and exceeding academic standards (Bass et al., 2013), as well as with increased amounts of white matter in the brain (Esteban-Cornejo et al., 2019). However, a study by Cadenas-Sanches et al. (2020) found that muscular strength lost its significance after accounting for CRF and BMI in a sample of adolescence. Regardless, it has been observed that strength training in adolescence promotes neural synaptogenesis (Adelantado-Renau et al., 2018) and may still have cognitive benefits in adulthood (Hashimoto et al., 2023).

The current study found that these significant associations between physical fitness and GPA remained constant while controlling for sex, race/ethnicity, and household income. Current literature has called for additional studies which control for SES and race/ethnicity concurrently to better understand social factors that interact with the physical activity and academic performance relationship, as these variables have significant interactive effects (Bowser et al., 2016; Rogers et al., 2015; Williams et al., 2016). Due to the complex interaction of individuals' social, physical, and mental states, it is not unexpected for variables outside of physical fitness to influence academic performance. Previous literature notes that health behaviors and their associated outcomes are influenced by socioeconomic factors (Babeer et al., 2022). In terms of SES, increased parental education and increased household income have been found to be associated with better working memory in adolescence (Akhlaghipour & Assari, 2020). While working memory was negatively associated with racial minority status (Akhalghipour & Assari, 2020). However, it is important to note that these associations are not the product of these socially constructed factors but rather demonstrate inequalities within our current society. Previous studies have demonstrated that lower levels of executive function observed within lower SES households and racial/ethnic minority populations were partially mediated by cortisol levels (Blair et al., 2011), suggesting that chronic exposure to stress from an individual's built-in environment results in lower executive function development and as a result, academic performance (Mance et al., 2019; Nesbitt et al., 2013; Raver et al., 2013).

Additionally, Marshell et al. (2023), found that adolescents in low-income households reported higher BMIs, lower frequencies of meeting exercise guidelines, and lower sports participation than adolescents from higher-income households. This correlation is suggested to occur due to neighborhood disadvantages such as fewer sports participation opportunities, fewer parks and recreation facilities, and less access to healthy food distributors (Gordon-Larsen et al., 2006; Marshall et al., 2023). While the primary mechanism causing SES to have significance in the relationship between physical fitness and collegiate academic performance is unclear, these adolescent disadvantages may have a lasting impact throughout adulthood.

Physical outcomes must also be analyzed with consideration to biological sex as there are physiological differences between male and female adults and their respective physical fitness indicator values (Hunter et al., 2023). Females have higher healthy fat indexes in adulthood (Keating et al., 2013), which can cause differences in BMI and other body composition measures. Females also less frequently meet physical activity guidelines but

have more positive health habits and health awareness, the latter of which has been more strongly associated with academic performance than physical fitness (Ansari et al., 2014). Additionally, a common social norm is for males to strength train more frequently than females, which could cause lapses in some studies' findings (Keating et al., 2013).

There are limitations to the current study. The mean BMI (27.16 ± 6.61) of the sample population is classified as overweight, indicating a negatively skewed distribution of our dataset, and the inability to analyze data from individuals below the healthy BMI range. The overall study sample is small, which limits its statistical strength and generalizability. This study is of a cross-sectional design which prevents any conclusions to causal relationships between physical fitness and academic performance. While this study includes a sociodemographic analysis, it fails to include measures of one's psychological health, motivation, activity levels, and lifestyle choices. For example, previous studies have found that grit is independently correlated with physical activity, physical fitness, and academic achievement in both adolescents and college-aged students (Cosgrove et al., 2018; Daniels et al., 2023; de Bruijn et al., 2021; Dunston et al., 2022). Future studies examining these variables should include aspects of psychosocial determinants and their mediating influence.

However, the results of the study advance current known associations between academic performance and physical fitness with the inclusion of strength measurement through grip strength. The findings of the current study can be seen as foundational to further studies by analyzing more diverse student populations, analyzing physical fitness indicators through a wider variety of methods, and measuring more confounding variables that may impact physical fitness or academic performance.

SUMMARY

Overall, the results from the current study show that academic performance is significantly associated with measures of physical fitness when controlling for sociodemographic measures in undergraduate college students. While there may be other confounding variables influencing the relationship between physical fitness and academic performance, the preliminary results of this study can demonstrate the importance of physical health at collegiate levels. This information may guide universities towards developing programs and increased opportunities for students to learn about this information (e.g.: workshops on adopting healthy lifestyles and understanding how physical fitness is connected to cognitive performance) while also having more access to physical activity (e.g.: organized sport activities or longer fitness center hours) to promote their physical literacy and physical fitness, respectively. Inherently, more undergraduate access to physical fitness may improve academic performance at the university level, increasing the reputability of the university while also increasing the potential for undergraduate students to transition successfully into further education such as graduate study programs or highly competitive employment opportunities.

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