

Cardiorespiratory Fitness, Health-Related Physical Fitness and Academic Performance in College Students

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How to cite this paper: Yang, C. B., & Tsao, T. H. (2020). Cardiorespiratory Fitness, Health-Related Physical Fitness and Academic Performance in College Students. *Advances in Physical Education*, 10, 42-53.

<https://doi.org/10.4236/ape.2020.101005>

Received: January 10, 2020

Accepted: February 11, 2020

Published: February 14, 2020

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Abstract

Whether cardiorespiratory fitness (CRF) and physical fitness affect academic performance in college first-year students is a concerning issue. Therefore, the goal of this study was to examine the relationship between academic performance and CRF and the components of physical fitness in college first-year students. A total of 98 college first-year students (female: 30, male: 68) participated in this study. The CRF was measured using a gas analyzer on a treadmill and physical fitness included body mass index, sit-up in one minute, standing long jump, sit-and-reach, 800 (female) and 1600-m (male) run/walk. The two assessments were scheduled by an interval of 7 - 10 days. The grade point average (GPA) in formal grade report was provided by each participant after the completion of the first academic year. The data were analyzed by an independent t-test and the relationships between variables were analyzed by Pearson *product-moment* correlation. The results displayed that males were significantly higher than females in CRF ($p < 0.05$). For physical fitness, the BMI, sit-up in one minute, standing long jump were significantly higher in males than in females. However, females were significantly higher than males in the number of sit-and-reach ($p < 0.05$). For academic performance, the GPA displayed similar between different genders. After regression analyses, the CRF was significantly related with academic performance and explained 56% of the variance for GPA in male college freshmen. However, neither CRF nor the components of physical fitness showed any significant relationship with academic performance in females. In conclusion, the CRF accounted for the variance of academic performance in male. However, a similar result was not found in the female part.

Keywords

Maximal Oxygen Consumption, Grade Point Average, Running Performance

1. Introduction

Many college students face physiological, psychological and environmental challenges during the first year in college because of the transition from adolescence to adulthood (Dyson & Renk, 2006). In addition, learning and study demanding during college were different from those during senior high school. Of the changes in physiology and physique, the alteration in body weight should be alert. The study (Butler, Black, Blue, & Gretebeck, 2004) indicated that although the changes in physical activity and food intake occurred during the period of the first year in college, a decrease in physical activity was the main factor for an increase in body weight. On the other hand, physical inactivity or sedentary lifestyle is one of important contributors to lower cardiorespiratory fitness (Armstrong et al., 2006), which is associated with many diseases, such as hypertension, insulin resistance, and stroke (Healy, Matthews, Dunstan, Winkler, & Owen, 2011; Wilmot et al., 2012). Therefore, the issues of cardiorespiratory fitness and physical activity are important for college students.

In general, cardiorespiratory fitness (CRF) is measured using individual's maximum rate of oxygen consumption (VO_2max) during incremental exercise. In addition to being in association with physical activity, CRF was also significantly positively related with cognition (Åberg et al., 2009; Voss et al., 2011). Furthermore, the improvement in cognitive capacity was related with the enhancement in CRF by physical activity or exercise intervention in healthy elders or those with mild cognitive impairment (Reiter et al., 2015; Smith et al., 2013; Voss et al., 2013). There were several possible factors for the improvement of cognition due to the intervention of exercise, such as an increase in cortical thickness (Reiter et al., 2015), maintenance or improvement of brain function and structure (Burzynska et al., 2014; Colcombe et al., 2006), and an increase in brain blood flow (Burdette et al., 2010) although further studies are warranted for precise mechanisms. Recent studies indicated (De Almeida Santana et al., 2017; García-Hermoso, Esteban-Cornejo, Olloquequi, & Ramírez-Vélez, 2017) that CRF was significantly related with academic performance in children and young teenagers.

One recent study (Hötting & Röder, 2013) indicated that low physical fitness might negatively affect academic learning in college-aged women. It was possible that poor academic learning resulted in lower academic performance. Currently, many studies have investigated the effect of health-related physical fitness on academic performance in children and adolescents. The results showed that the improvement in academic performance was associated with the elevation of physical fitness due to the intervention of exercise, in addition to a significant relationship between academic performance and physical fitness (Blom, Alvarez, Zhang, & Kolbo, 2011; De Greeff et al., 2014; Van Dusen, Kelder, Kohl, Ranjit, & Perry, 2011; Welk et al., 2010). Taken the above-mentioned studies collectively, although many studies have examined the association between CRF and academic performance and the effect of CRF via exercise intervention on academic performance of children and teenagers, there are few studies exploring college stu-

dents in similar aspects. As a result, the aim of this study was to examine the association between CRF and academic performance in college freshmen. Based on significant associations between academic performance and CRF and physical fitness in children and adolescents, the hypothesis of this study was that a significant relationship between CRF and academic performance existed in college freshmen.

2. Methods

2.1. Participants

This study was approved by the institutional review board of local hospital (An Tai Hospital, Pingtung). The information of inviting participants was announced in the bullet boards of campus activities. The criteria of inclusion were as follows: possible participants were enrolled in the first year of undergraduate college, but they were not the member of any college or club sport team. No cardiometabolic or musculoskeletal disease was diagnosed. In addition, those who smoke or have alcohol use habit were excluded in this study. There were 110 (37 females/73 males) expressing their interest in this research. The participants and their legal guardians provided their written consent before enrolling in this study.

2.2. Health-Related Physical Fitness

Body mass index

The height and body mass of all participants were measured using wall-mounted tape measures and electronic scales, respectively. All participants were barefoot and dressed in swimming suit during measurements. The body mass index (BMI) was calculated as body mass (kg) divided by height squared (m^2).

Sit-up in one minute

The number of sit-up in one-minute was used for assessing the muscular strength. Each participant lay on a mat with crossed their arms placing on their chest. In addition, the participant bent their knees with personal comfortable angle. When they conducted this test, one assistant maintained the participant's feet firmly on the ground. The standard sit-up was that the participant must touch their knees using their elbows and return his/her back on the ground. The assistant counted the number of sit-up the participant completed.

Standing long jump

The standing long jump was the representative of explosive strength of the lower body. Each participant stood behind the starting line with their feet approximately personal shoulder width and jumped horizontally as far as he/she could. When jumping, the participant must take off and land with two feet together. The jump distance was recorded by centimeter using a tape ruler.

Sit-and-reach

The sit-and-reach was assessed for the lower-extremity flexibility. Before measuring, each participant sat on the floor with their legs fully extended and the ruler was placed between the two legs. Next, the participant was asked to slowly

reach as far as they could on the ruler using the fingertip of overlapped palms for two seconds while measuring. Three trials were performed and the best result was recorded.

800 and 1600-m run/walk

The 800 and 1600-m run/walk were measured in female and male participants, respectively. All participants were instructed to complete as fast as they could. If they were unable to run in all procedure, they were allowed to walk. The measurement was performed in a standard 400-m running track of athletic field. The completion time was measured in minutes and seconds by a stopwatch (Seiko, Japan).

2.3. Cardiorespiratory Fitness

Maximal oxygen consumption (VO_{2max}) was the representative of cardiorespiratory fitness (CRF) in this study. All participants' VO_{2max} were measured using MasterScreen CPX (Carefusion, Hoechberg, Germany) on a treadmill (T8000, Johnson, Taiwan). Before the VO_{2max} measurement, the participant had a 3-min walk at 5.5 km per hour on the treadmill. The speed was 6 km/h at the beginning and increased to 12 km per by 1 km/hr each minute. And, the speed maintained at 12 km/hr, but the slope increased by 2% grade each minute from the 0% until the criteria of maximum oxygen consumption. The maximal oxygen consumption was considered to be achieved if two of the following criteria were met: 1) heart rate (HR): age-predicted maximal HR ($220 - \text{age}$) (Polar, Vantage XL Polar System, Port Washington, NY); 2) respiratory exchange ratio (RER, $RER = VCO_2/VO_2$) > 1.05 ; 3) rate perceived exhaustion > 17 (RPE, Borg, 1982).

2.4. Grade Point Average

The grade point average (GPA) of each college freshman student was displayed in his/her annual academic report. After the end of the first year, the participant provided his/her formal academic report issued by the university. The range of GPA was from 0 to 4.3.

2.5. Data Analysis

The data were collected and analyzed when the participant completed all assessments and the whole academic year. All data were expressed as mean \pm standard (SD) and evaluated the normality by Shapiro-Wilk. The variables between different genders were analyzed by an independent student's t-test. The association between GPA and CRF and the components of physical fitness were assessed separately for males and females by Pearson *product-moment* correlation. The significance was accepted at a level of $p < 0.05$.

3. Results

A total of 98 participants (female: 30, male: 68) completed all measurements and their first academic year in this study. Five male and seven female college stu-

dents did not complete CRF, physical fitness or whole academic year due to their personal reasons. **Table 1** shows the CRF and health-related physical fitness of male and female participants. Due to different distances (800/1600 m) between different genders, the time to complete the distance was significantly longer in male participants than in female participants. However, male participants were faster than female counterparts in terms of the average speed (2.90 ± 0.4 vs. 2.85 ± 0.3 m/s) despite no significant difference between them. For other physical fitness components, male participants were significantly higher than female participants in BMI, bent-leg sit-up in one minute, standing long jump; however, female participants showed significantly higher than male participants in sit-and-reach. Regarding CRF, the $VO_2\max$ was significantly higher in male than in female participants (**Table 1**). For GPA, male and female participants were 3.6 ± 0.3 and 3.7 ± 0.2 , respectively, without a significant difference between them.

For the association between academic performance and CRF, there was a significant relationship between GPA and CRF in male freshmen ($r = 0.77$, $p = 0.00$, **Figure 1**). In addition, the time to complete 1600 m of health-related physical fitness was also significantly related to the GPA in male participants ($r = -0.63$, $p = 0.00$). However, the other components, BMI, bent-leg sit-up in one minute, standing long jump or sit-and-reach, did not significantly relate with GPA in male. For female freshmen, GPA did not correlate with CRF or the components of health-related physical fitness.

After further regression analyses, the CRF accounted for 56% of the variance in GPA in male participants. The components of health-related physical fitness did not account for the variance of GPA in male or in female participants. Therefore, CRF was only one predictor for academic performance in male participants among all measured variables.

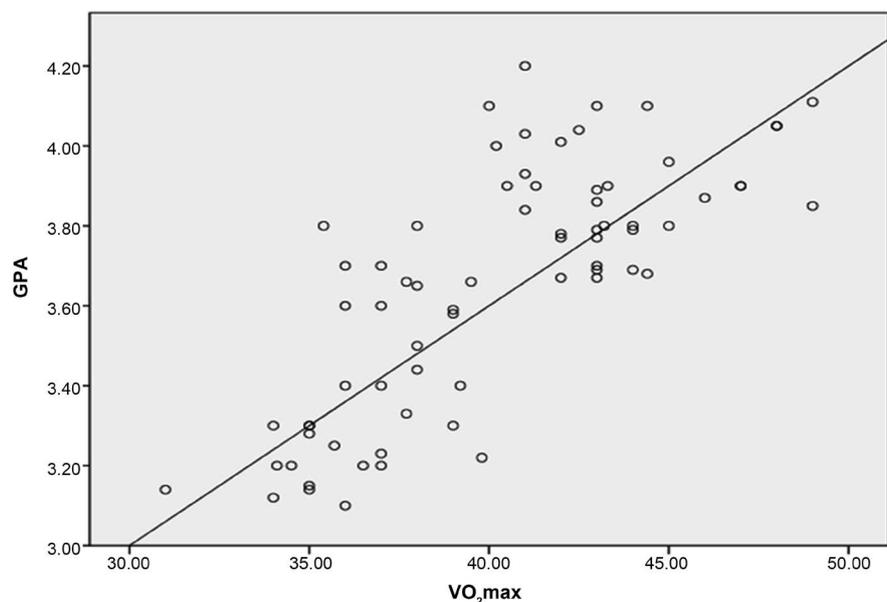


Figure 1. The relationship between academic performance (GPA) and cardiorespiratory fitness ($VO_2\max$) in male college first-year students.

Table 1. The participants' health-related physical fitness and cardiorespiratory fitness.

| | Male (n = 68) | Female (n = 30) | t value |
|---------------------------------------|---------------|-----------------|---------|
| Body mass index* (kg/m ²) | 22.2 ± 2.8 | 19.3 ± 2.7 | <0.05 |
| Sit-and-reach* (cm) | 26.8 ± 10.2 | 32.8 ± 10.5 | <0.05 |
| Standing long jump* (cm) | 205.7 ± 24.6 | 151.3 ± 18.6 | <0.05 |
| Sit-up* (times/min) | 40.9 ± 8.5 | 28.2 ± 9.2 | <0.05 |
| 1600/800 run/walk* (sec) | 513.4 ± 69.6 | 271.3 ± 27.7 | <0.05 |
| CRF* (ml/min/kg) | 41.2 ± 4.7 | 37.1 ± 3.6 | <0.05 |

*a significant difference between male and female; CRF: cardiorespiratory fitness.

4. Discussion

Many studies have examined the association between CRF and cognition in children and adolescents and a significant relationship was found between both of them. In the present study, the VO_{2max} is significantly correlated with academic performance in male college first-year students. For the components of physical fitness, the time to complete the 1600-m correlates with GPA in male part as well. Although academic performance significantly correlated with cardiorespiratory fitness and physical fitness in children and adolescents and the study suggested that CRF was in association with a neurocognitive process which was integral for academic performance (Chu, Chen, Pontifex, Sun, & Chang, 2016), similar issues concerning college students have been barely explored. Therefore, the result of this study adds the evidence to the relevant fields in terms of different participants.

The result regarding a significant association between CRF and academic performance in male college first-year students was the same as the other studies, which examined the same two variables in children (De Almeida Santana et al., 2017) and adolescents (García-Hermoso, Esteban-Cornejo, Olloquequi, & Ramírez-Vélez, 2017; Kwak et al., 2009). In addition, the CRF was the main explanatory factor for the GPA in male college participants after further regression. Although the mechanisms regarding CRF affecting academic performance have not been elucidated clearly, a few findings might account for the association between them. One study indicated that CRF was positively related with main neurocognitive process which was integral to academic performance (Chen, Fox, Ku, & Taun, 2013). Furthermore, the improvement in cognition due to exercise intervention might contribute to an enhancement in academic performance of children and young adolescents (Chaddock-Heyman, Hillman, Cohen, & Kramer, 2014; Hillman et al., 2014; Leckie et al., 2014). Cognition plays an important role in learning and academic performance. Based on the above-mentioned studies, this study inferred that cognition might be a bridge between CRF and academic performance. Therefore, further research on the mechanisms for CRF affecting academic performance via cognition is warranted. In spite of a significant association between CRF and academic performance similar to previous studies examining

the same two variables, several obvious differences in methodologies between this and previous studies worth noting such as using the developed formulas (PACER) to estimate cardiorespiratory fitness and mathematics and reading examinations given to students without prior notice to represent academic performance in previous studies.

For the relationship between academic performance and the components of physical fitness in the current study, the time to complete a 1600-m was significantly associated with academic performance in male participants. In the aspect of physical fitness and academic performance, there were fewer studies for college students compared with similar studies for children and adolescents; however, the time to complete a 1600-m in association with academic performance in this study was in line with the studies investigating the same variables in children (Chen, Fox, Ku, & Taun, 2013; Van Dusen, Kelder, Kohl, Ranjit, & Perry, 2011). Hillman, Castelli, & Buck (2005) suggested that increased cerebral blood flow with higher neurotransmitter and oxygen in faster finishers might be responsible for the time to complete a given distance as fast as possible associating with academic performance; however, these factors were not measured in this study. On the other hand, a significant association between the time to complete 1600 m and CRF was worth extra attention. The studies (Burns et al., 2015; Pober, Freedson, Kline, McInnis, & Rippe, 2002) indicated that the time to complete 1600 m was significantly negatively related with CRF. The studies indicated that higher-CRF individuals had higher neurocognitive function, shorter reaction time and more accurate response (Chaddock et al., 2010; Dupuy et al., 2015), which might benefit in elevating academic performance. In this study, a significant association between the time to complete a 1600-m and CRF was also found ($r = -0.84, p < 0.00$), which implied faster finisher, higher CRF. On the basis of the finding, CRF relating to the time to complete a 1600-m possibly indirectly led to a significant association between the time to complete a 1600-m and academic performance. Therefore, further studies explore whether the factors for the relationship between academic performance and CRF may influence the relationship between academic performance and the time to complete a given distance of physical fitness at the same time.

In this study, except the time to complete the 1600-m, the other physical fitness components were not related with academic performance in males. Previous studies for children and teenagers displayed that some of physical fitness components were associated with academic performance, some were not (Castelli, Hillman, Buck, & Erwin, 2007; Esteban-Cornejo et al., 2014; Eveland-Sayers et al., 2009; Kalantari & Esmaeilzadeh, 2016). For example, body mass index (BMI). The studies (Castelli, Hillman, Buck, & Erwin, 2007; Van Dusen, Kelder, Kohl, Ranjit, & Perry, 2011) showed that BMI correlated with academic performance in children and juveniles, but, the other studies did not (Du Toit, Pienaar, & Truter, 2011; London & Castrechini, 2011; Wittberg, Northrup, & Cottrel, 2009). In this study, there was no significant relationship between BMI and academic performance. On the other hand, academic performance was not related

with CRF or the components of physical fitness in female participants. A few studies (Baxter, Guinn, Tebbs, & Royer, 2013; Eveland-Sayers, Farley, Fuller, Morgan, & Caputo, 2009) displayed similar results, some components of physical fitness relating with academic performance in males, but, the same components not relating with academic performance in females. Although the 800-m and 1600-m were an obvious difference between male and female participants, to explain factors resulting in different results between the genders was beyond the scope of this study.

The study (Butler, Black, Blue, & Gretebeck, 2004) indicated that a decrease in physical activity led to an increase in body weight during the period of freshman. However, the engagement of physical activity and exercise can enhance cardiorespiratory fitness and shorten the time to complete a given distance at the same time (Eather, Morgan, & Lubans, 2013; Kettunen, Vuorimaa, & Vasankari, 2014; Singhal & Siddhu, 2014). As a result, this study encourages college first-year students to participate more in aerobic physical activities or exercises, such as hiking, running, cycling and swimming, so that not only CRF but also academic performance may be elevated based on the finding regarding the association between CRF and GPA in this study.

A few limitations should be acknowledged in this study. With respect to cardiorespiratory fitness and academic performance, the participants in the majority of studies were children and teenagers. The studies examining the same variables for college freshmen are few. As a result, we can't help but refer to the studies regarding the effect of cardiorespiratory fitness and the components of physical fitness on academic performance and cognition of children, adolescents and senior adults. On the other hand, using whole year academic performance was also an obvious characteristic in this study, considering that the assessment of academic performance was different from the other studies which evaluated reading, language and mathematics without prior notice during the experiment. Grade point average (GPA) was based on all subjects learned by the participants during the first academic year. Therefore, the type of academic performance in this study was a long-term type, which was different from an impromptu type in the above-mentioned studies. Third, the sample size was smaller and the number of females was fewer compared with that of males in this study. On the basis of these limitations, it should be cautious when researchers generalized the current results to other populations.

5. Conclusion

CRF ($VO_2\max$) and the time to complete the 1600-m of physical fitness components were significantly related to the GPA in male college freshmen. Furthermore, CRF was the main predictor for their academic performance during the first year in college. Therefore, future studies for the reasons regarding why the CRF affects academic performance and whether the changes in CRF and physical fitness by the intervention of aerobic exercise are in association with the change in academic performance are necessary for college students.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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