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Quantitative Physical Fitness Measures Inversely Associated With Myopia Severity in Military Males: The CHIEF Study

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Abstract

Myopia has been linked to body weight and sedentary status, but the association with quantitatively measured physical fitness in adults has not been examined. Cross-sectional analyses were performed to investigate the association between physical fitness and myopia in 3,669 military men (aged 29.4 years) in Taiwan. The severity of myopia obtained from the left eye was classified as mild (−0.5 to −3.0 diopters; $n = 544$), moderate −3.1 to −6.0 diopters; $n = 563$), and high (<−6.0 diopters; n =150); others were defined as nonmyopia ($n = 2{,}412$). Aerobic fitness was evaluated by time for a 3000-meter run test, and muscular endurance was evaluated by numbers of 2-min sit-ups and 2-min push-ups. A value of $p < .0125$ was considered significant. A multiple linear regression analysis was used to determine the relationship. Individuals who were less physically fit had higher risk of myopia. The associations were dose-dependently significant with mild, moderate, and high myopia for 3000-meter running time ($\beta = 9.64$; 95% confidence intervals [3.22, 16.05], $\beta = 12.41$; 95% CI [6.05, 18.76], and $\beta = 20.87$; 95% CI [9.22, 32.51], respectively) after controlling for the potential covariates. There tended to be an inverse association with moderate and high myopia for numbers of 2-min push-ups ($\beta = -1.38$; 95% CI [−2.43, −0.34] and $\beta = -2.10$; 95% CI [− 3.97, −0.22], respectively) and 2-min sit-ups ($\beta = -0.83$; 95% CI [−1.54, −0.12] and $\beta = -1.29$; 95% CI [−2.56, −0.02], respectively), respectively. This study suggested that physical fitness, particularly aerobic fitness of the military males who received regular training, is inversely associated with myopia severity, independent of service specialty, body mass index, and educational level.

Keywords

aerobic fitness, anaerobic fitness, military population, myopia, physical activity, young male adults

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Myopia is the most common type of refractive errors in which light rays focus at a point in front of the retina, leading to a blurred vision (Smith, Hung, & Arumugam, 2014). Myopia is the consequence of decompensated incoordination of the four ocular components involving the cornea, aqueous humor, lens, and vitreous humor. Incidence of myopia increases with age due to progressive elongation of the axial length of eyes during early childhood (Benjamin, Davey, Sheridan, Sorsby, & Tanner, 1957) and reaches the peak in adolescence (He et al., 2004, 2007). Myopia is a global pandemic eyesight-threatening disease, particularly in East and South Asia (Xu et al., 2005). Among those who are older than 30 years of age, the prevalence is similar between East and West countries, which is around 20%–50% (Kleinstein et al., 2003; Saw et al., 2008).

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Several risk factors of myopia including both genetic and environmental factors have been identified. For instance, the paired box gene (PAX-6) has been suggestive with an association with high and extreme myopia (Tang et al., 2014). Environmental risk factors such as increased amounts of near work (e.g., reading, frequent use of handheld devices and screens computers), higher degree of urbanization that can reflect lower levels of outdoor activity, and increased educational stress are risk factors for myopia (Lee, Lo, Sheu, & Lin, 2013). On the contrary, increased outdoor activity implying a lower chance of near work and increased times of outdoor light exposure could reduce the risk of myopia incidence in children (Ho, Wu, & Liou, 2019; Lee et al., 2013). The relationship of physical activity and myopia is less well studied (Jones et al., 2007). Lower physical activity may result in not only myopia but also obesity in children and adolescents. In a vicious cycle, obesity, which leads to an increase of insulin resistance and inflammation, may in turn cause development of myopia (Cordain, Eaton, Brand Miller, Lindeberg, & Jensen, 2002; Galvis et al., 2016).

A previous study in Taiwan reported that the prevalence of myopia was up to 86% in the military recruits aged between 18 and 24 years in 2010–2011 (Lee et al., 2013). Although young adults with myopia might have lower physical activity levels at baseline than those without myopia prior to enlistment (Guggenheim et al., 2012), all enlisted military personnel in Taiwan are required to maintain their superior physical fitness by regular training to pass the annual three basic exercise tests, the same as the U.S. Army Physical Fitness Test (O'Connor, Bahrke, & Tetu, 1990), for military rank promotions and award. We hypothesized that the maximal exercise capacity might be related to the status of myopia in the military personnel after training. The aim of the study was to examine the association of quantitative measured physical fitness with the severity of myopia in a military population in Taiwan.

Method

Study Population

The study used a voluntary military population of 4,080 adults, aged 18–50 years from the cardiorespiratory fitness and hospitalization events in armed forces study (CHIEF) carried out in eastern Taiwan during 2014 (Lin et al., 2016; Tsai et al., 2019). All participants carried out a formal health examination in the Hualien Armed Forces General Hospital. Self-reported questionnaires were filled for their habits of toxic substance usage, such as cigarette smoking and alcohol intake status (current vs. former or never), and exercise frequency in leisure times in the past 6 months. The participants underwent at least one of the three basic exercise tests including a 2-min sit-ups test, a 2-min push-ups test, and a 3,000-meter run test, separately at the Military Physical Training and Testing Center of eastern Taiwan. The study design of the CHIEF study has been described in detail previously (Chen et al., 2017; Lin et al., 2016; Tsai et al., 2018).

Laboratory Assessment

Anthropometric parameters of height and weight were assessed in a standing position for each participant. Body mass index was defined as body weight (kg) divided by square of height (m^2), and waist size was measured at the midpoint between the top of the iliac crest and the last palpable rib (Ma et al., 2013). Hemodynamic data of pulse rate and blood pressure were measured once over right upper arm by an automated blood pressure monitor (FT-201, Parama-Tech Co Ltd, Fukuoka, Japan) in a sitting position after rest for 15 min or more (Sala, Santin, Rescaldani, & Magrini, 2006). Laboratory data of blood routine and biochemical tests for serum total cholesterol, triglycerides, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, and fasting plasma glucose were obtained after a 12-h fast (Bachorik and Ross, 1995).

Ophthalmic Examination

Noncycloplegic autorefraction of both eyes was measured once using the TOPCON KR8100P Auto Kerato-Refractometer (Topcon Corporation, Tokyo, Japan). Best corrected visual acuity was also assessed using a Snellen chart. At prescreen of the enlistment, those with extreme myopia (≤ -10.0 diopters) or significant ocular problems including strabismus, amblyopia, pathology affecting clarity of the ocular media, and previous ocular surgery were not qualified to serve in the military. Women were further excluded due to fewer case number ($n = 411$) and lower physical capacity, leaving a sample of 3,669 men for the analysis. The severity of myopia was classified as mild (−0.5 to −3.0 diopters), moderate (−3.1 to −6.0 diopters), and high (< -6.0 diopters). Others were defined as nonmyopia (> -0.5 diopters). Analyses were carried out on the left eye only since there was a high correlation of refractive errors between the left and right eyes ($r = 0.96$).

Physical Fitness Assessment

Physical fitness including aerobic fitness and muscular endurance was separately assessed in the afternoon of the same day. Aerobic fitness was evaluated by 3,000-meter running time (Grant, Craig, Wilson, & Aitchison, 1997; Siddall et al., 2017). All runs were held at 4:00 PM and performed only when the risk coefficient of heat stroke (the product of outdoor temperature [°C] and relative humidity [%] × 0.1) was less than 40 (Havenith & Fiala, 2015) and there was no rain. Muscular endurance was evaluated by numbers of push-ups and sit-ups done within 2 min, respectively (Vezina, Der Ananian, Campbell, Meckes, & Ainsworth, 2015). Each examinee performed push-ups and sit-ups on the sponge pads and obtained scores if the body position on the movement return to the initial set points was sensed by red infrared lights of the computer system. All courses were monitored and recorded by video. Since the exercise tests are linked to rank promotion and military award, the performance is regarded as the best fitness of each participant. This study was reviewed and approved by the Institutional Review Board of the Mennonite Christian Hospital (16-05-008) in Taiwan. Written informed consent was obtained from all participants.

Statistical Analysis

Continuous variables in the baseline characteristics were expressed as mean ± standard deviation (*SD*) and compared by ANOVA. If the Kolmogorov–Smirnov normality test was not fulfilled, the Wilcoxon signed rank test was used. Categorical variables were expressed as numbers (%) and compared by χ^2 test or Fisher's exact test.

Multiple linear regressions were used to determine the relationship of mild, moderate, and high myopia with each exercise performance when nonmyopia was treated as the reference. In addition, multiple logistic regressions were used to determine the odds ratio (OR) of the best (top 10 percentile) and the worst (last 10 percentile) performances in each exercise with mild, moderate, and high myopia relative to nonmyopia. Three models were constructed according to the stepwise adjustments for the covariates.

In model 1, age and service specialty were adjusted. In model 2, body mass index was additionally adjusted. In model 3, educational level, smoking status, alcohol intake status, heart rate, systolic blood pressure, hemoglobin levels, and exercise frequency were additionally adjusted. These potential confounders (covariates) were chosen for the models based on prior published associations with myopia severity and physical fitness (Earnest et al., 2013; Fernández, Canet, & Giné-Garriga, 2017; Schumacher, Ahlgrim, Ruthardt, & Pottgiesser, 2008). A value of $p <$ .0125 (0.05/4) was considered significant for four groups classified. SAS statistical software (SAS System for Windows, version 9.4; SAS Institute, Cary, NC, United States) was used for all statistical analyses.

Table 1. Characteristics of the Nonmyopic and Myopic Military Males.

	Nonmyopia (n = 2,412)	Mild myopia (n = 544)	Moderate myopia (n = 563)	High myopia (n = 150)	*P* value
Age (years)	29.3 ± 6.0	29.6 ± 5.8	29.3 ± 5.6	29.8 ± 5.6	.43
Service specialty, *n* (%)					
Air forces	741 (30.72)	132 (24.26)	122 (21.67)	32 (21.33)	<.0001
Army	1,147 (47.55)	297 (54.60)	325 (57.73)	85 (56.67)	
Navy	524 (21.72)	115 (21.14)	116 (20.60)	33 (22.00)	
Educational level, *n* (%)					<.0001
Graduate	63 (2.61)	17 (3.13)	14 (2.49)	6 (4.00)	
College/university	928 (38.47)	491 (90.26)	272 (48.31)	74 (49.33)	
Senior high school	1,421 (58.91)	36 (6.62)	277 (49.20)	70 (46.67)	
Body mass index (kg/m^2)	25.0 ± 3.1	24.7 ± 3.2	24.5 ± 3.1	24.9 ± 3.1	.0114
Waist size (cm)	83.7 ± 7.9	82.9 ± 8.3	82.3 ± 7.9	83.8 ± 7.6	.0011
Current smoking, *n* (%)	952 (39.47)	188 (34.56)	195 (34.64)	41 (27.33)	.0022
Alcohol intake, *n* (%)	1,085 (44.98)	237 (43.57)	244 (43.34)	50 (33.33)	.046
Systolic BP (mmHg)	119.1 ± 13.3	117.5 ± 12.8	116.3 ± 12.2	117.7 ± 13.1	<.0001
Diastolic BP (mmHg)	70.8 ± 10.2	70.2 ± 9.8	70.2 ± 10.1	70.6 ± 10.4	.51
Hemoglobin (g/dl)	15.2 ± 1.0	15.2 ± 1.0	15.2 ± 1.0	15.1 ± 0.9	.50
Exercise frequency (wk^{-1})					.43
Never or occasionally	504 (20.90)	111 (20.40)	120 (21.31)	34 (22.67)	
1–2 times/wk	882 (36.57)	206 (37.87)	230 (40.85)	60 (40.00)	
Over 3–5 times/wk	1,026 (42.54)	227 (41.73)	213 (37.83)	56 (37.33)	
3000-m running time, sec	856.29 (70.08)	864.71(70.00)	866.12 (69.92)	876.95 (69.85)	<.0001
2-min sit-up numbers, *n*	49.36 (11.75)	48.97 (11.60)	48.24 (11.55)	47.32 (11.52)	<.0001
2-min push-up numbers, *n*	47.63 (7.84)	47.92 (7.90)	46.81 (7.81)	46.29 (7.81)	<.0001

Note. BP = blood pressure. Continuous variables are expressed as mean ± standard deviation and categorical variables as number (percentage).

Table 2. Linear Regression of Mild, Moderate, and High Myopia With the Exercise Performances.

	Mild myopia		Moderate myopia		High myopia	
	β value (SE)	*P* value	β value (SE)	*P* value	β value (SE)	*P* value
Model 1						
3,000-m running time	8.41 (3.49)	.016	9.83 (3.44)	.0043	20.66 (6.33)	.0011
2-min sit-ups	0.28 (0.38)	.45	−0.83 (0.37)	.025	−1.34 (0.66)	.043
2-min push-ups	−0.39 (0.55)	.48	−1.13 (0.55)	.039	−2.04 (0.98)	.038
Model 2						
3,000-m running time	9.70 (3.38)	.0041	12.59 (3.34)	.0002	22.20 (6.13)	.0003
2-min sit-ups	0.26 (0.38)	.48	−0.87 (0.37)	.019	−1.36 (0.66)	.041
2-min push-ups	−0.61 (0.55)	.27	−1.47 (0.54)	.0065	−2.19 (0.97)	.024
Model 3						
3,000-m running time	9.64 (3.27)	.0033	12.41 (3.24)	.0001	20.87 (5.94)	.0004
2-min sit-ups	0.27 (0.37)	.46	−0.83 (0.36)	.023	−1.29 (0.65)	.047
2-min push-ups	−0.02 (0.54)	.26	−1.38 (0.53)	.0094	−2.10 (0.96)	.028

Note. Data are expressed as β value and standard errors (SE). Model 1: adjusted for age and service specialty; Model 2: adjusted for age, service specialty, and body mass index. Model 3: adjusted for age, service specialty, educational level, body mass index, systolic blood pressure, current smoking, alcohol intake, hemoglobin levels, and exercise frequency.

Results

Baseline Group Characteristics

The baseline characteristics of each group are displayed in Table 1. Of these 3,669 participants, the cases of nonmyopia, mild, moderate and high myopia were 2,412, 544, 563, and 150, respectively. In addition, 3,296 men underwent all of the exercise tests, 345 underwent two of the three exercise tests, and 13 underwent only one exercise test (data not shown). There was little difference in waist circumference and body mass index among groups. Nonmyopic men had a higher prevalence of low educational level, current smoking, and higher systolic blood pressure level than myopic men. There were no significant differences regarding age, pulse rate, diastolic blood pressure, alcohol intake prevalence, hemoglobin levels, and weekly exercise frequency among groups. Each exercise performance was different among groups where the severe myopic had the worst results, followed by the moderate myopic, and then the mild- or nonmyopic.

Multiple Linear Regressions

The results of multiple linear regression of each exercise performance, with mild, moderate, and high myopia relative to nonmyopia are presented in Table 2. In model 3, mild, moderate, and high myopia were dose-dependently correlated with longer 3,000-meter running time (β = 9.64, 12.41, and 20.87, respectively; all p values $< .0125$). However, there tended to be an inverse relationship of moderate and high myopia for numbers of 2-min push-ups ($\beta = -1.38$ and -2.10, corresponding for p values = .023 and .047, respectively) and 2-min sit-ups ($\beta = -0.83$ and -1.29, corresponding for p values = .0094 and .028, respectively), respectively.

Multiple Logistic Regressions

The results of multiple logistic regressions of the best 10% and the worst 10% performance in each exercise, with mild, moderate, and high myopia in reference to nonmyopia are presented in Table 3. There were bidirectional tendencies in that as compared with nonmyopic participants, higher myopic participants were less likely to have the best 10% performances and more likely to have the worst 10% performances in each exercise. However, only the associations of mild, moderate, and high myopia with the worst 10% 3,000-meter running time were significant in model 2 (OR: 1.57, 1.59, and 2.15, respectively), and model 3 (OR: 1.56, 1.61, and 2.13, respectively).

Discussion

According to the findings of this study, severity of myopia was negatively associated with physical fitness, particularly aerobic fitness among military males in Taiwan. Lower aerobic fitness, as measured by longer time to complete a 3,000-meter run test, was associated with higher myopia severity in a dose-dependent pattern. In addition, there was a tendency in an inverse relationship of lower muscular endurance, as measured by fewer numbers of sit-ups and push-ups performed within 2 min with moderate and high myopia. The inverse associations were independent of age, service specialty, educational level, body mass index, tobacco smoking status, alcohol intake, systolic blood pressure, hemoglobin levels, and exercise frequency.

The military volunteers in Taiwan are highly picked out from the young adult populations who have just

Table 3. Association of Mild, Moderate, and High Myopia With the Best 10% and the Worst 10% Exercise Performances.

	Mild myopia		Moderate myopia		High myopia	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
The best 10% performance						
Model 1						
3,000-m run ≤783 s	0.91 [0.65, 1.26]	.56	0.65 [0.45, 0.93]	.02	0.57 [0.27, 1.18]	.13
2-min sit-up ≥58 times	1.23 [0.92, 1.64]	.16	0.77 [0.55, 1.07]	.11	0.55 [0.28, 1.10]	.09
2-min push-up ≥60 times	1.11 [0.84, 1.47]	.46	0.92 [0.69, 1.23]	.46	0.85 [0.49, 1.47]	.57
Model 2						
3,000-m run ≤783 s	0.86 [0.62, 1.21]	.39	0.59 [0.41, 0.85]	.0046	0.54 [0.26, 1.13]	.10
2-min sit-up ≥58 times	1.22 [0.91, 1.63]	.17	0.76 [0.55, 1.05]	.10	0.55 [0.28, 1.10]	.09
2-min push-up ≥60 times	1.08 [0.81, 1.43]	.60	0.87 [0.65, 1.17]	.36	0.83 [0.48, 1.45]	.51
Model 3						
3,000-m run ≤783 s	0.81 [0.57, 1.15]	.24	0.57 [0.39, 0.83]	.0037	0.55 [0.26, 1.18]	.12
2-min sit-up ≥58 times	1.20 [0.90, 1.62]	.22	0.76 [0.55, 1.07]	.11	0.56 [0.28, 1.12]	.10
2-min push-up ≥60 times	1.05 [0.78, 1.40]	.76	0.88 [0.65, 1.19]	.40	0.83 [0.47, 1.45]	.50
The worst 10% performance						
Model 1						
3,000-m run ≥934 s	1.49 [1.10, 2.03]	.0096	1.43 [1.05, 1.94]	.022	1.97 [1.21, 3.23]	.0067
2-min sit-up ≤40 times	1.06 [0.76, 1.46]	.74	1.11 [0.80, 1.53]	.54	1.48 [0.87, 2.50]	.15
2-min push-up ≤37 times	1.10 [0.81, 1.49]	.56	1.16 [0.86, 1.56]	.34	1.49 [0.91, 2.44]	.11
Model 2						
3,000-m run ≥934 s	1.57 [1.15, 2.14]	.0047	1.59 [1.16, 2.17]	.0037	2.15 [1.30, 3.55]	.0029
2-min sit-ups ≤40 times	1.06 [0.77, 1.47]	.72	1.12 [0.81, 1.55]	.51	1.48 [0.87, 2.51]	.15
2-min push-ups ≤37 times	1.15 [0.84, 1.57]	.39	1.26 [0.93, 1.71]	.13	1.56 [0.95, 2.56]	.082
Model 3						
3,000-m run ≥934 s	1.56 [1.14, 2.14]	.0058	1.61 [1.17, 2.21]	.0033	2.13 [1.28, 3.55]	.0039
2-min sit-ups ≤40 times	1.02 [0.73, 1.43]	.90	1.05 [0.75, 1.46]	.79	1.44 [0.84, 2.47]	.18
2-min push-ups ≤37 times	1.12 [0.82, 1.54]	.47	1.25 [0.92, 1.69]	.16	1.50 [0.90, 2.48]	.12

Note. Data are expressed as odds ratios (OR) and 95% confidence intervals (CI). Model 1: adjusted for age and service specialty. Model 2: adjusted for age, service specialty, and body mass index. Model 3: adjusted for age, service specialty, educational level, body mass index, systolic blood pressure, current smoking, alcohol intake, hemoglobin levels, and exercise frequency.

graduated from senior high school or colleges and are 18–32 years of age at the prescreen stage of enlistment. Those with body mass index >31.0 kg/m^2 or <17.0 kg/m^2, any pathological findings in electrocardiography, and extreme myopia are precluded. At the enlistment, military volunteers have to pass a 9-week basic combat training program and maintain their physical fitness by mandatory daily exercises as deploying to the assigned military schools or troops. To our knowledge, both obesity and underweight have been identified as risk factors of myopia in young adult men in Asia (Lee, Lee, & Kim, 2018; Lim et al., 2018). Given the preclusion of severe obesity and underweight at enlistments, regular rigorous training could result in a similar profile of body stature between the myopic and nonmyopic military volunteers (Napradit & Hatthachote, 2016).

Based on findings from a small cohort of 131 males aged 31–35 years (Pärssinen, Era, & Leskinen, 1985), the myopic males who were characterized by lower body mass index and fat content had higher aerobic capacity and similar muscular strength compared with the nonmyopic males. The present study revealed a contrary result that the maximal aerobic fitness was reduced among military myopic males in Taiwan on a large scale. The disparity could be due to the area and population differences. The dose and frequency of exercise training in the troops were mostly regulated; for instance, military members were requested to run with the team for a 3,000-meter distance daily on weekdays. Rigorous training leads to a similar profile of body stature after the enlistments, an inverse relationship of aerobic fitness with myopia severity remained even after the adjustments for service specialty, body mass index, and other potential covariates. Notably, the military nonmyopic males had higher prevalence of unhealthy behaviors of tobacco smoking and alcohol drinking than the myopic males. This implies that as in their childhood and adolescence, the nonmyopic males might have fewer after-school tutorial classes or educational stress in the rural regions of eastern Taiwan and thus have higher physical activity level (Chen, 2001).

It is possible that myopia severity might reflect the superiority of physical fitness of military volunteers at the enlistment. Physical fitness of each participant would be improved by rigorous training after the enlistment, but the residual confounding such as differences in physical fitness at baseline could not be further modified.

There were several strengths in this study. First, both the ophthalmic and laboratory examinations and all exercise tests were standardly performed in a strict manner. Second, large numbers of voluntary military participants were included in this study providing sufficient power to detect the difference between those with and those without myopia. Third, many unmeasured confounding factors in the military had been strictly controlled at baseline since daily life—diet, training, and sources of stress—was unified in the military. By contrast, there were some limitations in this study. First, the study included only male subjects, making it difficult to apply the results to female subjects. Second, response bias in self-report measures might exist because of personal considerations to being good in the military.

Conclusion

The findings of this study suggested that quantitatively measured measures of physical fitness, particularly aerobic fitness, of the military male adults in Taiwan were associated with severity of myopia. Further studies should be performed to examine the casual association, if any, between physical fitness and severity of myopia.

Declaration of Conflicting Interests

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