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Longitudinal Changes In Chinese Minority College Students' Health-Related Fitness: A Multilevel Latent Growth Curve Modeling Approach

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ABSTRACT
Purpose: The study aimed to test the overall changes of health-related fitness (HRF) in minority Chinese college students and to examine HRF differences in gender, race, and year in college. **Method:** Participants (*n* = 1320) were minority college students with more than two-thirds females (ie 76.1%), and Hui, Tibetan, and Mongolia consisted of 13.8%, 13.8%, and 11.2%, respectively. Student HRF was tracked for four years. Data were analyzed using multilevel latent growth curve modeling. **Results:** Muscular strength and endurance were the weakest component in minority college students' HRF, while body mass index was within the category of "excellent". Males outperformed female on all components of HRF. **Conclusions:** It is suggested that interventions concerning minority females' HRF and muscular strength and endurance for both genders be constructed and tested.

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Health-related fitness (HRF) is generally defined as physical characteristics that mostly relate to health promotion and chronicle disease prevention.[1] To date, HRF has several well-documented components that do not compensate for deficiencies in one another.[2,3] Accordingly, fitness and measurement experts came to a consensus and stated that the following distinct components should be measured to effectively assess ones' overall fitness: (a) body composition, (b) muscle strength and endurance, including upper body and abdominal muscles, (c) cardiovascular endurance, and (d) flexibility.[4–7] As such, these five testing items are commonly evaluated in field-based youth testing batteries found in China, European Union (EU), USA, and Russia.[8–11] Respectively, these components are generally tested through body mass index (BMI); one-mile run or PACER, 800 m or 1000 m run; push-ups or pull-ups or modified push-ups; sit-ups; sit-ups or modified sit-ups, and sit-&-reach.[8] However, it is important to note that skill-related testing items, such as a 50 m sprint (ie speed), and a stand-still jump (ie power) are also included in Russia and China youth fitness tests, even though it has been widely accepted that skill-related testing items should not be included in field-based youth fitness testing.[8]

Since China's societal reform of allowing influences from western countries in 1978, much attention has been given to academic performance at all educational levels (ie K-16 programs), regardless of age, gender, and races.[12] Unfortunately, driven by extreme high expectations concerning student academic performance, physical education has been marginalized since. Some argue this may have contributed to the decline of fitness levels in China's youth.[13,14] Such concern is well supported by a steady decline of student performance on youth fitness tests, which has been mandated yearly since 1953.[15,16] Likely a result, Chen and colleagues[17] reported China issuing a number of youth fitness health policies in an attempt to improve students' fitness levels during 1979–present. In fact, the Chinese government developed a country-wide imitative, called "Health China 2030 Program," which outlined a specific goal of having more than 25% of students to reach an" excellence" rating on the National Student Physical Health Standard.[18]

The goal focused on college students as these young professionals are considered to be the primary future work force for the Chinese society.[19] Not to mention, their health was said to be a concern considering the high demand on academic performance, hectic social interactions, and a poor environment for adopting healthy behaviors.[20,21] In fact, researchers confirmed that students' physical activity and HRF actually become worse over their college career.[22–24] Keating and colleagues (2019) examined this phenomenon and found Chinese college students who did not meet the cutoff value for healthy aerobic fitness, increase from 13.3% as freshmen to 25.2% as seniors. Similar result was reported

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by others.[16,24,25] As a result, many call to improve Chinese college students' HRF and their health behaviors.[25]

Fitness testing in Chinese college students

Unlike many colleges in the western countries, Chinese colleges require students to take part in fitness testing every academic year, even though physical education is only mandated for freshmen and sophomores.[8,26] Their fitness test results are used as one aspect in issuing academic scholarships and a college graduation requirement.[8,27] The testing components, items, and procedures are nationally standardized, and resemble US and European counties' K-12 programs.[8,28] Proctors are physical education instructors who are professionally trained to follow pre-set test protocols.[25,27]

It is important to note that one claimed focus of fitness testing is on self-monitoring and self-assessment in China.[29] Unfortunately, to the best of our knowledge, no reported empirical research on the topic has been available in both English and Chinese. It is unclear how field-based fitness tests have been used for self-monitoring and self-assessment in China. With respect to the scoring system, it is the same as these used for K-12 students in China with higher cutoff values using a 100-point scale for VO_{2max}, muscular strength and endurance, and flexibility, in which a score for fail, passing, good, and excellent is below 60, 60, 80, 90 or above, respectively. However, the cutoff value for BMI is different: a score of 100 is given to those whose BMI is within the acceptable range while 80 is assigned to underweight and overweight. Surprisingly, passing score (ie 60) is given to those who are classified as obese. BMI is the only component without a failing score.[30]

Previous research on monitoring changes in minority college student HRF

The health of minority college students (typical age range of 18 to 23) is of concern in China. Unfortunately, research on minority students' fitness changes is rare,[31] and even more so in relation to Chinese minority students.[25,32,33] As such, there was even fewer studies found on longitudinal changes in Chinese minority college students' HRF, which hinders the endeavor of improving minority college students' overall health in China. Therefore, the following literature review was expanded to previous studies on college students' HRF and longitudinal research concerning student fitness changes, which informs the research design of the current study.

Minority college student HRF

It is surprising that descriptive research on Chinese minority college students' HRF was not available in English. Written in Chinese with an English abstract, Ma and Sun[34] used a cross-sectional research design to test changes in HRF of minority students at Xinjiang University. The authors reported a decline of fitness in minority students by the year in college, and male minority students to outperform their female counterparts on total HRF scores in all but the 2nd year of college. Overall, the majority of the existing studies on the topic focused on the comparisons with Han students. For example, it was found that minority colleges students' height and weight were below those of Han ethnicity, while Tang[35] reported minority male students were taller than Han male students. Yang and Li[36] found Yi ethnic male students' height was shorter than male Han students. However, Yi ethnic male students scored higher on the Harvard Step Test (a measurement on aerobic fitness, which is not included in the field-based fitness tests in China) than their Han male counterparts. Furthermore, Bai and colleagues[37] found that Han, Tibetan, and Uygur university students had lower obesity rates than these for the overweight rates. The authors also found underweight rates were also high in Han, Tibetan, and Uygur ethnic groups. Female Tibetan students demonstrated a higher normal weight rate, and lower overweight and obesity rates than their male Tibetan counterparts. However, to date, minority Chinese college students' overall HRF remains understudied. Furthermore, it is unclear if gender and year in college influences minority college students' HRF in higher education settings.

Previous longitudinal studies on fitness changes in college students

As noted earlier, although there are no studies found tracking minority college student overall HRF, there are studies found tracking college students' changes in HRF. For example, Keating and colleagues found Chinese preservice physical education teachers' HRF peaked at the 2nd year and later declined as their years in college increased with the worst being the last year of college. Interestingly, when tracking American college students' aerobic fitness measured by VO_{2max}, no significant changes in aerobic fitness were found in both male and female students, even though the values of aerobic fitness for both genders decreased.[36] The authors concluded knowledge alone was not sufficient to improve American college students' aerobic fitness. Similar result was also found by a study conducted by Hopper and colleagues.[38] However, Wetter and colleage[39] reported the decline of aerobic fitness, strength, and flexibility, and the increase in BMI in both gender among American college students. Racette and colleagues[40] also found that weight gain was common among college students in the US. It was also reported that Hungarian college students' fitness components were all improved in college due to their interventions on increasing college students' physical activity levels.[41] It is important to note, however, to the best of our knowledge, no studies were found from our search that tracked all the five components of HRF in Chinese college students, regardless of race, have been found in both Chinese and English literature.

Multilevel latent growth curve modeling (LGCM)

Repeated measure of ANOVA and MANOVA are usually used for tracking mean changes for the same variables which are tested multiple times.[25,42] However, such approaches require more rigorous data assumptions such as normality and sphericity.[43] On the other hand, multilevel LGCM is more flexible in testing a developmental trend and nonlinear changes.[44,45] It has been suggested that multilevel LGCM is appropriate to analyze longitudinal data such as college student HRF as a means of investigating individual and cluster trajectories.[25,45,46]

It is critical to understand if current minority college students' HRF levels are improving, decreasing, or unchanged. Additionally, discovering if minority college students are sufficiently physically fit for sound health and reduce the risk for disease based on the standards set by the Chinese government. Therefore, the purposes of the current study are to: (a) test the overall changes of HRF in minority Chinese college students using multilevel LGCM; and (b) examine HRF differences in gender, ethnical groups, and year in college. It is hoped that the results would provide baseline data to longitudinally compare Han and minority college students' HRF and stimulate more research on the topic, which is currently neglected. It is also hoped that this study would provide empirical data for designing effective interventional studies for minority college students in China. The information about Chinese minority college student fitness changes may also shed new lights on tracking changes of health-related fitness among American minority college students.

Methods

Ethics approval

No IRB approval was needed due to the use of existing data without personal deification information. However, the study followed the procedures to protest participants' privacy. No personal information was used in the study.

Participants

A total of 1320 minority students participated in the study. There were less than one third males. The average age of the participants was 22.8 years old with a very small standard deviation (SD = .4), which is reflected by the standardized educational system implemented in China making all students to begin their schooling at a very similar age. Participants consisted of 55 minority groups in China excluding international students. Because many minority groups had a few participants, only the ethnic groups with more than 100 participants were listed as a specific minority group and the rest were combined as the other minority group. Refer to Table 1 for more detailed demographic information concerning the participants.

Research design and measures

Based on the research purposes, our study employed the retrospective nonexperimental longitudinal research design over a duration of four years from minority college freshmen year in 2015 to the senior year in 2019. Specifically, each student's HRF was tested using the same tests around the same time by the same physical education instructor group for four times while students enrolled in college.

Table 1. Demographic information of participants.

Variables		*N* (%)	Mean (SD)
Age		1320	22.8 (.4)
Baseline BMI	Overall		21.7 (3.0)
(Year 1 BMI)	Underweight	143 (10.8)	
	< = 17.8 (male)		
	<=17.1 (female)		
	Acceptable weight	989 (74.9)	
	17.9 < = BMI < = 23.9 (male)		
	17.2 < = BMI < = 23.9		
	Overweight	152 (11.5)	
	24.9 < = BMI < = 27.9		
	Obese	36 (2.7)	
	BMI > 28		
Gender	Female	1005 (76.1)	
	Male	315 (23.9)	
Race	Hui	182 (13.8)	
	Tibetan	182 (13.8)	
	Mongolia	148 (11.2)	
	Tujia	109 (8.3)	
	Combine ethnic group	699 (52.9)	

Note: combined ethnic group consisted of minority studnets in 49 ethnic groups.

Measures. Same as to what has been reported in the literature,[8,27] the current measures included in the youth HRF tests in China were used worldwide for more than half of a century.[8,10,47] A number of studies have indicated that these testing items are reliable and valide.[10,48,49] Specifically, there were four test items: (a) BMI for body composition; (b) $VO_{2max,}$ and 800 and 1000 meter run for aerobic fitness for female and male, respectively; (c) sit-ups for females' abdominal muscular strength and endurance and pull-ups for male students' upper body muscular strength and endurance, respectively. This component was tested different from that in western courtiers such as the US and EU where both genders performed the same two tests (ie sit-ups/modified sit-ups and push-ups/modified push-ups) for muscular strength and endurance[8,10]; and (d) flexibility using sit-and reach for both genders. All the raw data were converted to scores with 100 as the best and 60 as the passing point (refer to Liu et al[27] for more detailed information concerning the point-scoring criteria). As noted earlier, these standardized cutoff values were pre-set by the Chinese government and each gender has its own cutoff standards by age.[30] As a result, college student HRF testing results were standardized on the same five measurement scale except for BMI, which only consists of three scales [ie pass (ie classified as obese, BMI > 28.0), good (ie classified as underweight or overweight, BMI < = 17.8 or 24.0 =< BMI >= 27.9), and excellent (ie classified as acceptable weight, 17.9 =< BMI <= 23.9)]. For the other HRF components, it used 0–100 points with 5 grading categories: a point of below 60 was "failed" while 60 was the "passing" score, a score of 70 and 80 was considered as "fair" and "good", respectively. A score of 90 and above was "excellent", regardless of gender and age, even though each testing item used different measurement units. For example, 800/1000 meter run used time in minutes as the measurement unit while sit & reach used centimeters for the scale unit. In addition, as noted earlier, sit-ups and pull ups are two different tests and the raw score of the two tests cannot be directly compared. However, the aforementioned standardized scoring method allowed the comparisons of students' muscular strength and endurance between the two genders and races. It is necessary to point out that 50 m run and stand-still long jump were also included in the field-based fitness testing in K-16 programs in China, which are widely viewed as the skill-related fitness.[8] Due to the focus of the current study on HRF, however, the scores for the two testing items were eliminated in the data analysis.

Data analyses

Data screening was completed before descriptive analyses (ie means and standard deviations, and percentages) were conducted using SPSS. Cases with more than 50% of missing data were eliminated from the data set. Outliers were also removed. Then descriptive analysis was performed, followed by tests of normality (Shapiro–Wilk) to ensure the validity of the model. Then, we began fitting the LCGM using traditional structural equation model methods, measuring model fit by calculating model-based standardized residuals (SRMR) given the multilevels of data in our model.[50,51] All four models in the study were below the 0.8 cutoff score for SRMR fit estimation.[52] Such a model allows researchers to understand changes at the individual level over time, along with how group membership (ie gender, and race) influences that change. One of the primary benefits of a LGCM is that it allows researchers to explore variable latency, which could explain outcomes more accurately than simply estimating effects of observed variables. Besides reporting the coefficients, the sigma values, which are the estimates standard deviation between subjects (u) and within subjects (e), are also presented. Furthermore, the rho provides information concerning the within-group variance, meaning that the higher the rho, the more variance there is within groups while the lower rho means more variance between groups. To maintain transparency and clarity, the authors can share their data and STATA code upon request.

Results

Overall descriptive analysis of changes in HRF in four years

In general, BMI was the only variable that minority students' mean score was above 90 points in all four years. Muscular endurance and strength were the weakest component, which had been below the passing score of 60 and remained at the same level for four years. Aerobic fitness measured by VO_{2max} was in the category of "fair to good" based on the cutoff values set by the Chinese government. The other aerobic fitness measure (800 m/1000 m run for females and males, respectively) decreased during the four years. Flexibility was in the range of "fair". Refer to Table 2 for more detailed descriptive information concerning changes in HRF in four years.

Random effects model predicting changes in aerobic fitness, flexibility, endurance, and strength by BMI, gender, race, and age

The four models yielded differences in Sigma u, Sigma e, and Rho (see Table 3). Based on the values of Sigma, there is tighter coupling in models 3 and 4 than models 1 and 2, suggesting that there were wider individual differences when considering aerobics and flexibility measurements. On the other hand, model 2 suggests "flexibility" has more variance within groups because its rho value was the largest among the four models, while the rho values for the other three models were about the same. As further explanation of model 2 suggests that females had larger variations in flexibility compared to the gender differences in other fitness components.

Gender and changes in HRF

Across all models, data suggest male students were much more likely to have higher VO_{2max}, flexibility, 800/1000 m run, and muscular strength and endurance than their female counterparts, evidenced by statistically negative coefficients (female students were the gender control group). Furthermore, male students demonstrated markedly more strength (Model 4; coefficient: −40.652) than female students, suggesting that physical fitness differences may be more present within tests of physical strength and endurance than other measures of HRF.

HRF changes in race and age

Regarding racial differences, only Tibetan and Hui students demonstrated more strength over time than their Mongolian, Tuija, and combined race peers, suggesting that there may be racial differences regarding the development of strength when controlling for a student's baseline BMI. The age of students also contributed to their development of HRF, as older students became less flexible over time, evidenced by the statistically significant negative coefficient in Model 2. However, age was not predictive of the development of any other measurement of HRF.

Baseline BMI and minority college students' changes in HRF

A student's baseline BMI was strongly predictive of their aerobic fitness (Model 1), endurance (Model 3), and strength (Model 4) but not flexibility (Model 2). First, a student's

Table 2. Descriptive analysis of Chinese minority college students' changes in HRF in four years.

Variables	Sub-variable		Year 1 Mean (SD)	Year 2 Mean (SD)	Year 3 Mean (SD)	Year 4 Mean (SD)
BMI		Overall	94.8 (10.5)	94.8 (10.7)	94.3 (11.1)	94.0 (11.3)
		Male	92.4 (9.5)	92.6 (13.0)	91.7 (13.8)	90.2 (14.0)
		Female	95.5 (9.5)	95.4 (9.8)	95.1 (10.0)	95.1 (10.1)
		Mongolia	94.6 (11.1)	94.7 (10.8)	94.5 (10.9)	94.1 (10.8)
		Hui	94.3 (10.6)	95.2 (10.6)	94.2 (10.9)	93.5 (11.7)
		Tibetan	94.9 (10.4)	94.8 (10.6)	94.1 (11.5)	93.2 (12.2)
		Tujia	94.5 (11.8)	94.1 (11.6)	93.2 (12.0)	93.8 (11.5)
		Combined	95.0 (10.2)	94.7 (10.7)	94.4 (11.0)	94.0 (11.1)
Aerobic fitness	VO_{2max}	Overall	78.5 (12.4)	79.0 (12.6)	75.9 (12.4)	76.2 (12.4)
		Male	77.5 (11.1)	78.9 (13.3)	74.7 (14.5)	76.2 (14.0)
		Female	78.9 (12.2)	79.0 (12.3)	76.2 (11.7)	76.3 (11.8)
		Mongolia	78.9 (12.6)	79.8 (12.5)	76.9 (13.4)	77.0 (12.3)
		Hui	78.8 (13.6)	79.2 (12.2)	76.1 (12.3)	77.5 (13.5)
		Tibetan	80.3 (13.2)	80.6 (12.9)	76.7 (12.9)	76.9 (12.7)
		Tujia	79.9 (11.9)	81.1 (12.1)	76.3 (12.1)	77.0 (13.2)
		Combined	77.7 (11.8)	78.0 (12.6)	75.3 (12.1)	75.4 (11.8)
	800/1000 m run	Overall	72.5 (11.4)	70.1 (11.9)	62.2 (15.3)	60.0 (16.9)
		Male	67.2 (14.1)	64.8 (13.4)	57.1 (16.3)	54.9 (16.5)
		Female	74.2 (9.8)	71.8 (10.8)	63.8 (14.7)	61.6 (16.7)
		Mongolia	71.3 (11.3)	68.0 (12.5)	60.1 (16.4)	58.8 (16.6)
		Hui	72.1 (12.5)	69.6 (12.9)	62.0 (15.2)	60.8 (16.9)
		Tibetan	72.3 (11.0)	69.9 (11.5)	60.7 (16.3)	58.1 (18.4)
		Tujia	70.8 (15.0)	69.6 (13.9)	61.3 (16.2)	58.9 (16.0)
		Combined	73.2 (10.5)	70.8 (11.2)	63.3 (14.7)	60.8 (16.6)
Muscular strength and endurance		Overall	44.0 (27.3)	51.7 (26.1)	59.0 (26.2)	49.4 (26.4)
		Male	16.7 (26.1)	19.0 (27.5)	15.4 (25.2)	59.8 (15.7)
		Female	52.5 (21.4)	61.9 (14.9)	60.8 (14.5)	16.3 (26.1)
		Mongolia	40.2 (28.3)	47.4 (29.2)	46.5 (28.2)	46.5 (28.0)
		Hui	44.9 (25.6)	51.7 (25.8)	49.6 (26.7)	49.0 (26.9)
		Tibetan	46.5 (25.6)	53.7 (25.9)	52.8 (24.9)	52.3 (25.7)
		Tujia	45.7 (26.3)	52.1 (25.1)	51.0 (24.6)	47.3 (26.6)
		Combined	43.6 (27.8)	52.0 (25.7)	49.9 (26.2)	49.7 (26.0)
Flexibility		Overall	77.6 (12.4)	80.5 (12.1)	77.7 (12.7)	78.8 (11.9)
		Male	73.9 (14.7)	77.0 (13.7)	73.5 (15.1)	74.9 (13.1)
		Female	78.8 (11.4)	81.5 (11.4)	79.0 (11.5)	80.0 (11.2)
		Mongolia	77.1 (12.9)	79.5 (13.4)	77.4 (14.3)	78.2 (11.7)
		Hui	79.1 (12.4)	81.7 (11.8)	77.7 (13.0)	78.7 (12.6)
		Tibetan	76.7 (11.9)	80.2 (10.7)	77.5 (11.2)	78.9 (11.1)
		Tujia	77.5 (12.1)	80.0 (12.0)	78.1 (12.7)	79.7 (10.8)
		Combined	77.6 (12.4)	80.5 (12.3)	77.7 (12.6)	78.7 (12.2)

Note: all raw data were converted to the 100 point scale for appropriate comparisons.

baseline BMI was strongly predictive of VO_{2max} development, meaning that as students' age increased, their VO_{2max} improved, evidenced by the statistically significant positive coefficient (Model 1; coefficient: .8953). However, BMI was negatively predictive of development of 800/1000 m run, which is the other variable for aerobic fitness, and muscular strength and endurance, supported by statistically significant negative coefficients. As such, a student's baseline BMI may influence their ability to develop greater levels of VO_{2max}, meaning that students with higher BMIs at the beginning of the college may be better able to develop their aerobic fitness but not for other components of HRF. Data also suggested students with higher BMIs are less likely to improve their 800/1000 m run and muscular strength and endurance over time, controlling for their age, gender, and race.

Discussion

It is important to examine minority college students' HRF given that the disparities in minority college student health have been well known.[33] Education should play an important role in bridging health gaps in the general population given that the adoption of a healthy lifestyle is a volitional behavior and fitness related knowledge and skills can be learned, make a huge difference in the overall health in the general population.[53,54] Higher education is the last opportunity to physically educate a large segment of minority college students with great potentials bridging the health gaps between minority and majority groups.[19] Thus, the role of higher education in helping improve college students' HRF cannot be overstated.

More importantly, minority college students will serve as role models for other minority students, which can have profound impact on the well-being of the entire minority population.[19,31,55,56] To this end, every effort is needed to help minority college students improve their HRF. To our knowledge, the current study marks the first study that has longitudinally examined the five components of HRF in minority Chinese college students. The results of the study could shed new lights on tracking changes in minority college students' health during their four years in higher education and provide baseline data for future interventional studies on improving minority college student HRF. Overall, our study contributes to the field of public health and health education in higher education by generating new knowledge

Table 3. Changes in HRF by gender analyzed by multi-level models.

Variables	Model 1: Aerobics	Model 2: Flexibility	Model 3: 800/1000 m Run	Model 4: Strength
Gender (Control = Woman) (standard error)	−2.15** (.68)	−4.83*** (.70)	−5.83*** (.73)	−40.65*** (.99)
Race (Control = Mongolian)				
Hui (standard error)	−.23 (1.15)	1.23 (1.19)	1.56 (1.23)	3.60* (1.67)
Tibetan (standard error)	.45 (1.15)	.01 (1.19)	.32 (1.23)	3.81* (1.68)
Tuija (standard error)	.86 (1.49)	1.74 (1.53)	−.45 (1.59)	2.62 (.22)
Combined Races (standard error)	−1.14 (.96)	−.29 (.99)	1.82 (1.03)	1.96 (1.40)
Age (standard error)	1.17 (.78)	−1.96* (.799)	−1.01 (.83)	.08 (1.13)
BMI (standard error)	.90*** (.07)	−.05 (.07)	−.64*** (.09)	−.85*** (.12)
Constant (standard error)	32.29 (17.91)	125.44 (18.47)	103.29 (10.77)	72.89 (26.12)
Sigma *u*	9.77	10.18	9.69	13.32
Sigma *e*	6.94	6.63	10.77	14.26
Rho	.66	.70	.45	.47
SRMR^	0.03	0.07	0.07	0.05

Note: Robust standard errors in parentheses, significant coefficients signaled by $p < 0.05$*, $p < 0.01$**, $p < 0.001$***; ^ = SRMR rounded to nearest hundredth.

concering how HRF changed among minority college students in China and how gender and race played a role in the changes of the components of HRF. It is important to note that a similar decline trend of aerobic fitness was found among American college students[57] while such a finding was not reported in the study completed in Hungarian college students.[41]

Overall changes in HRF in four years

Although the focus of the current study was on changes of fitness during college over four years, it is important to point out there is an urgent need to improve Chinese minority college students' fitness with a focus on muscular strength and endurance, which is the weakest among all the components (ie below the passing score), regardless of gender and race. It is alarming that Chinese minority students failed to pass the muscular strength and endurance test every year in four years, indicating a persist weakness in their HRF. In addition, except BMI, students' performance on the other fitness components was only in the category of "good". There is still more room for improvement as well. Moreover, based on the results found in model 4 in Table 3, students' muscular strengths decreased as their BMI increased during the four years. Hence, BMI and muscular strength and endurance should be targeted for interventions together in the future.

Changes in HRF by gender

While the gender gap enrolling in college is shrinking, examining gender differences in HRF among college students provides a comprehensive understanding of health differences by gender and informs future interventions and education to help college students maintain or develop better HRF. Unlike that found in many western countries, Chinese minority college students' BMI remained in the acceptable range in general given that the mean scores were in the category of "excellent" (see Table 1). This finding is in line with what have been reported in the literature.[25] However, the negative coefficients of BMI in models of flexibility, 800/1000 m run, and muscular strength and endurance (see Table 3) indicated that students with higher BMI at the first year would negatively impact their flexibility, 800/1000 m run and muscular strength and endurance, suggesting that they became less fit than those whose with lower BMI to begin with. As a result, researchers and physical education instructors should consider how curriculum and physical fitness activities can be developed to better support students with higher baseline BMIs.

It is unclear why minority male students significantly outperformed the female students in all components of HRF (ie BMI, VO_{2max}, 800/1000 m run, muscular strength and endurance, and flexibility) (see Tables 2 and 3). However, the finding is somewhat consistent with what was reported by Ma and Sun[34] using the cross-sectional research design to test changes in HRF of minority students at Xinjiang University. The authors also reported that male minority students outperformed their female counterparts on the total score for their HRF except for the 2nd year. More importantly, to our knowledge, ours is the first study, which reported that the largest gap lies in muscular strength and endurance between the two genders. Male students' low scores on muscular strength and endurance in four years call for more research on this topic given that a number of studies have indicated that muscular strength and endurance are a critical component of fitness and are positively correlated with college students' academic performance measured by the grade point average (GPA).[58] Therefore, there is a need to develop specific interventions to improve female minority college students' muscular strength and endurance in China, even though a great deal of attention should be given to all components of HRF in female students in general.

Changes in HRF by race

Tibetan and Hui students demonstrated more strength over time than their Mongolian, Tuija, and combined race peers, suggesting that there may be racial differences regarding the development of strength when controlling for a student's baseline BMI. To our knowledge, there is a rareness of research on individual minority group's HRF in colleges in China. Unfortunately, no data are available to explain why Tibetan and Hui students had a better score on strength and endurance than other minority students. Since ours is the first study comparing ethnic students' HRF changes in four years, there is a need for more studies on the topic in the future in order to better understand the gaps among the 54 ethnic groups in China.

Measurement issues found through tracking changes in HRF in minority college students

Two measurement issues should be noted based on the tracking changes of minority college students' HRF. First, Chen pointed out that the cutoff values for the field-based fitness test results could greatly affect the accuracy of assessment on students' HRF.[16] Although the HRF scores were given using the nationally standardized standards, the scoring method for BMI is problematic as only three cutoff points were given (ie 60 = overweight and/or obese; 80 = underweight, 100 = acceptable weight). It is not justified to give a passing (ie 60) and "good" (ie 80) score when a student's BMI is classified as overweight and/or obese, and underweight, respectively. In fact, both underweight and overweight/obese are widely considered as unhealthy weight and have negative effects on ones' HRF. It is puzzling why such misguiding cutoff values are used in a nationally mandated fitness test battery in China. In addition, fitness testing items must have enough sensibility to detect changes in HRF so that improvement can be monitored and intervention effects can be examined.[48,59,60] The inclusion of pull-ups for male students' muscular strength and endurance in the field-based test battery is problematic considering most male students could not perform even one pull-up, resulting in no changes in strength and endurance. Modified pull-ups or alternative testing items should be used to improve the measurement of strength and endurance. Overall, more research on the feasibility and accuracy of field-based fitness testing is needed in China.

Limitations

The results reported in the study must be interpreted within the context of the limitations. It is a longitudinal descriptive study, which does not allow inferences about causality. Due to the lack of data concerning each ethnic group's physical activity patterns, it is impossible to explain why racial differences in HRF were found. In addition, two-thirds of the participants were females. This disproportional distribution in gender may have skewed the results. It is also important to point out that the missing data can be from students who displayed different levels of fitness. BMI did not have scores below 60, even if the raw values of student BMI were within the categories of under- or overweight or obese. The different BMI assessment must be taken into consideration when interpreting the BMI results found in the current study. Caution needs to be exercised when transferring the results to the American college student population because regular fitness testing is not required in American colleges and universities.

Conclusions

Muscular strength and endurance were the weakest among minority college students. Male minority students outperformed their female counter parts on all components of HRF. Tibetan and Hui students had better HRF than other ethnic groups. Chinese minority college students' overall HRF is of concern. More research on the topic is needed in the future.

Author contributions

Xin Zhang, Shuhua Qu, Xiaofen D. Hamilton, Zach Taylor, Jianmin Guan, Mike Hodges, and Yong Huang conducted the study selection, data extraction, and quality assessment; all authors were involved in drafting and revising the manuscript. All authors approved the final version of the manuscript.

Conflict of interest disclosure

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The authors confirm that the research presented in this article met the ethical guidelines, including adherence to the legal requirements, of China.

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