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Being physically active increases risk for injury among university students: a multi-center cross-sectional study in China

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Title: Being physically active increases risk for injury among university students: a multi-center cross-sectional study in China

Running title: Physical activity-related injury among youth

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Abstract

Objectives: This study aimed to investigate the epidemiologic characteristics and identify risk factors of physical activity-related injury (PARI) among Chinese university students via a multi-center mixed survey.

Design: Cross-sectional study.

Participants: A total of 4758 undergraduates graded 1-3 in nine universities in three Chinese cities were invited and completed the self-administered online questionnaires via the method of cluster random sampling during March-April, 2017. Students in Years 4 were excluded as they are in the transition period to work and their university lives are significantly different from the others. In addition, those with study major in physical education (PE) were further excluded from data analysis, as they differ significantly from others in terms of physical activity (PA)/sports related factors.

Main outcome measures: Physical activity-related injury in the past 12 months.

Results: Of 4758 participants, 1081 sustained PARI in the past 12 months, with an overall PARI incidence rate of 22.7% (27.3% [367/1343] in males and 20.9% [714/3415] in females). Around one quarter of the injured (26.4%) experienced PARI at least three episodes. More than half of the injured experienced PA absenteeism and sought medical care. All PA indictors were significantly and positively associated with PARI, with frequency of leisure-time VPA being the strongest (adjusted OR: 1.079, 95% CI: 1.018-1.144). Moreover, males, Shantou students, Year 1 students, sports

team members, and those with insufficient sleep time were also at higher risks for PARI experience.

Conclusions: PARI was prevalent among university students in China. Frequency of leisure-time VPA was the strongest risk factor among all PA indicators. The above data can inform future programs for the injury-intervention in university students. Safety issues should also be involved and emphasized when promoting PA among the public to reduce PARI occurrence.

Article summary

Strengths and limitations of this study

1) It is the first of this kind of publications to explore the epidemic and risk factors of PARI among Chinese general university students.

2) The nature of cross-sectional study limits causal and temporal inference.

3) All information was self-reported, which have resulted in recall bias and report bias and threatened our results.

4) We could not examine their associations with PARI as the GPAQ does not capture the specific activities the participants undertook.

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Competing interests

The authors declare that they have no competing interests.

Introduction

Physical, social and psychological benefits of engaging in regular physical activity (PA) have been well documented, including increased cardiorespiratory and muscular fitness and bone density, and reduced risks for non-communicable diseases.[1-3] Insufficient PA has been recognized as one of the top three risk behaviors in development of morbidity and mortality associated with cardiovascular diseases and other major chronic diseases, such as diabetes and obesity.[4] In order to achieve and maintain individual health at an optimal level, the World Health Organization (WHO) has recommended that adults (18-64 years old) should undertake at least 150 minutes of moderate-intensity PA (MPA), or at least 75 minutes of vigorous-intensity PA (VPA), or an equivalent combination of moderate- and vigorous-intensity PA (MVPA) every week.[4] With these recommendations, almost all countries and regions in the world have been engaged in the current global campaign to promote PA.

Although the promotion of PA is a public health priority, being physically active might increase the risk for injury.[5-7] Physical activity-related injury (PARI), also known as sports and recreational activity-related injury, was defined as any injury resulting from participation in PE class, sports activities or leisure time PA, such as sprain, strain, fracture, contusion, and et al.[8] In fact, PARI contributes to all non-fatal injury most, which ranks the top one health threat to relatively healthy adolescents

and young adults in many countries.[4 9] In a long term, it can also increase risks for future injuries, osteoarthritis and other health problems in later life.[10] In addition, PARI may be a barrier to adopting more active lifestyle, which may further hinder people from achieving optimal health.[11 12]

We have been conducting a series of studies on PARI. Results from previous studies revealed that about 25.1%-32.1% of primary and secondary students in two Chinese cities had suffered from PARI in the past 12 months, suggesting that PARI is prevalent among children and adolescents. In China, students in universities might be more active than those in secondary schools, as they have been released from heavy academic burdens and pressure for university admission. They become independent from their parents and therefore are more likely to engage in relatively risky activities which their parents may not allow them to do before.[13] Thus, university students might be more vulnerable to PARI. Though there is plenty of evidence about PARI among collegiate athletes, it may not be suitable to general students given significant differences in risk factors between the two, such as sports skills, training intensity, competition level, and cardiorespiratory and muscle fitness level.[14 15] However, few studies have been addressed the general university students.[13 16] We therefore conducted a multi-center mixed study among a sample of general university students in China to obtain a better understanding of the PARI epidemic. The work was supported by the National Natural Science Foundation of China (Ref. No.: 31640038). This paper presents findings from its baseline survey, aiming to

investigate the epidemiologic characteristics and identify risk factors of PARI among Chinese university students.

Methods

Study Participants

The study was conducted in nine universities (eight comprehensive universities and one normal university (where students are trained to become teachers in kindergartens and primary and secondary schools)) in three Chinese cities, namely Jinan, Shantou, and Hong Kong. Each city represents northern, southern, and special regions of China respectively. Students in Years 1-3 were invited and voluntarily participated into the study during March and April, 2017. Seniors (students in Years 4) were excluded as they are in the transition period to work and their university lives are significantly different from the others. In addition, those with study major in physical education (PE) were further excluded from data analysis, as they differ significantly from others in terms of PA/sports related factors.

Data collection

The Qualtrics software (Qualtrics, Provo, UT) was used as the online platform of the baseline questionnaire survey. Participants were enrolled in classes, or from dormitories. The online questionnaire was self-administered, consisting of demographics, PA habits, sedentary behaviors, sleep duration, and PARI experiences in the past 12 months. The demographic variables included university, study major,

study year, gender, age, residence type (dormitory, home, or others), any diagnosed chronic disease/symptom, and sports team membership.

Participants' PA levels in a typical week in the past 12 months were asked using the Global Physical Activity Questionnaire (GPAQ) Chinese version.[17] It is one of the most commonly used PA questionnaires and possesses sound reliability and validity (spearman's rho=0.81, kappa=0.65).[18 19] The GPAQ collects frequency (days/week) and duration (averaged cumulative minutes/day) of VPA and MPA in three domains, including domestic/work/study, transportation (MPA only), and sports and leisure-time. PA volume (cumulative minutes/week) was then calculated by duration multiplied by frequency for each category of PA (VPA, MPA, and MVPA), in each domain and overall, generating a total of 20 PA-related variables. Given the GPAQ does not provide information on specific activities participated, all students were further asked if they had any sports or recreational activities they liked and participated often in the past 12 months (favorite activities). Those with a positive answer were further asked to provide the names of the activities (no more than three).

In terms of sedentary behaviors and sleep, duration (hours/day) was asked on a typical weekday and a typical weekend respectively. Averaged daily duration in a week was then calculated and used to group the students into five categories.

In this study, a countable PARI must meet at least one of the following three consequences: (1) have to immediately stop the PA and/or cannot participate in the

next planned PA; and/or (2) be absent from class the next day; and/or (3) need medical attention (including on-spot first aids, but excluding those using bandages only).[8] If suffering from such a PARI in the past 12 months, the participants were then asked to report the number of PARI in each consequence category.

Procedures

This study was strictly conducted in accordance with the Declaration of Helsinki. Prior to approaching potential students, approval was obtained from Shantou University Medical College ethics committee, Shandong University ethics committee, and Hong Kong Baptist University ethics committee. Explanatory statement and consent forms were distributed to all participants, and the questionnaires were subsequently given to the consenting students in the nominated classes or dormitories. The purpose and meaning of our study was verbally explained to the students prior to their completion of the questionnaires, and our trained personnel would answer any questions of clarification as participants arose during the session.

Statistical analysis

Statistical analyses were performed using SPSS version 19.0 (SPSS Inc. Chicago, IL, USA). Continuous and categorical variables were described using median (inter-quartile, IQR) or mean (standard deviation, SD) and number (percentage), and tested for between-group differences using nonparametric tests or *t*-tests and Pearson chi-square tests, respectively. Both univariate and multivariate logistic regression

were fitted to estimate the risk of each study variable for PARI, where crude and adjusted odds ratios (ORs) and their 95% confidence intervals (95% CIs) were derived respectively. Three steps were undertaken in the multivariate analyses: Step 1, in a multivariate model, all socio-demographic variables were selected in both forward and backward manners (likelihood ratio), with selection criteria of α_{in}=0.10 and α_{out}=0.15. Adjusted ORs and 95% CIs of variables kept in the final model (significant variables) were then derived from, including city, study year, gender, university/other sports team member, and any chronic disease/symptom. For variables outside of the final model (insignificant variables, including age and residence type), their adjusted ORs and 95% CIs were obtained after controlling for the significant variables; Step 2, the risk of each life-style variable (including PA habits, sedentary behaviors, and sleep duration) was assessed after controlling for the significant socio-demographic variables in the first step; Step 3, a hierarchical model was performed to consider all study variables together, with socio-demographic variables being selected in the first block and life-style variables in the second. A two-sided *P*-value less than 0.05 was considered statistically significant for all tests.

Results

A total of 4758 eligible students in Years 1-3 (aged 20.00 ± 1.382 years) completed the online survey. Table 1 presents the distribution of the social-demographic characteristics and their risk estimations for PARI. More students were female (71.8%), living in dormitory (61.1%), and studying in Shantou (44.6%).

Few students were sports team members or living with any chronic condition (3.7%-10.4%). About 1081 students (22.7%) suffered from at least one PARI in the past 12 months, with significantly higher risks being found in both types of sports team members and those living with chronic conditions (adjusted ORs: 1.559-3.118). In addition, students in Jinan and Hong Kong, females, and those in Years 2 and 3 were less likely to experience PARI (adjusted ORs: 0.783-0.254). Age and residence type were not significantly associated with PARI.

Table 1 Risks of socio-demographic characteristics for physical activity-related injury (PARI) among university students in China

Characteristics	All (N=4758) n (%)	Non-PARI (N=3677) n (%)	PARI (N=1081) n (%)	Adjusted OR	95% CI
City					
Shantou	2123 (44.6)	1403 (66.1)	720 (33.9)	1 (ref.)	
Jinan	1267 (26.6)	1111 (87.7)	156 (12.3)	0.254***	0.209～0.310
Hong Kong	1368 (28.8)	1163 (85.0)	205 (15.0)	0.276***	0.225～0.338
Study year					
Year 1	1496 (31.4)	1125 (75.2)	371 (24.8)	1 (ref.)	
Year 2	1462 (30.7)	1121 (76.7)	341 (23.3)	0.825*	0.681～0.999
Year 3	1800 (37.8)	1431 (79.5)	369 (20.5)	0.716**	0.568～0.832
Gender					
Male	1343 (28.2)	976 (72.7)	367 (27.3)	1 (ref.)	
Female	3415 (71.8)	2701 (79.1)	714 (20.9)	0.712***	0.610～0.832
Residence type					
Dormitory	2908 (61.1)	2210 (76.0)	698 (24.0)	1 (ref.)	
Home	1742 (36.6)	1377 (79.0)	365 (21.0)	1.016	0.861～1.198
Others	108 (2.3)	90 (83.3)	18 (16.7)	0.820	0.469～1.434
University sports team member					
No	4262 (89.6)	3380 (79.3)	882 (20.7)	1 (ref.)	
Yes	496 (10.4)	297 (59.9)	199 (40.1)	3.136***	2.528～3.889
Other sports team member					
No	4472 (94.0)	3512 (78.5)	960 (21.5)	1 (ref.)	
Yes	286 (6.0)	165 (57.7)	121 (42.3)	2.182***	1.678～2.838
Any chronic					

disease/symptom					
No	4583 (96.3)	3563 (77.7)	1020 (22.3)	1 (ref.)	
Yes	175 (3.7)	114 (65.1)	61 (34.9)	1.561*	1.111～2.195
	mean ± SD	*mean ± SD*	*mean ± SD*		
Age (years)	*20.00±1.382*	*20.01±1.426*	*19.98±1.386*	0.983	0.934～1.146

*: $P<0.05$; **: $P<0.01$; ***: $P<0.001$.

Adjusted ORs and 95% CIs of significant variables were calculated after controlling for each other, including city, study year, gender, university/other sports team member, and any chronic disease/symptom. Adjusted ORs and 95% CIs of insignificant variables (age and residence type) were obtained after controlling for the significant variables.

Table 2 shows the distribution of life-style variables and their risk assessments for PARI. The majority of the students engaged in leisure-time PA (87.5%) and transport-related PA (82.1%). Medians and interquartile ranges (IQRs) for total volumes of VPA, MPA and MVPA (min/week) were 0 (0, 100), 60.00 (0, 150) and 255.00 (120, 490) respectively. Overall, 70.2% of university students were physically active according to the WHO's recommended PA for adults.[4] All PA indicators were positively and significantly related with PARI (adjusted ORs: 1.001-1.171), with the risk of leisure-time VPA being highest. About 26.4% of students slept less than 7 hours/day. Insufficient sleep duration elevated the risk for PARI, with the highest being found in the group of less than 6 hours/day (adjusted OR: 1.428; 95% CI: 1.032～1.977).

Table 2 Risks of life-style variables for physical activity-related injury (PARI) among university students in China

Characteristics	All (N=4758) median (IQR)	Non-PARI (N=3677) median (IQR)	PARI (N=1081) median (IQR)	Adjusted OR	95% CI
Domestic/work/study					
VPA[1]					
Frequency, d/week	0 (0, 1)	0 (0, 1)	0 (0, 2)	1.168***	1.111～1.228
Duration, min/d	0 (0, 20)	0 (0, 15)	0 (0, 30)	1.008***	1.006～1.010
Volume, min/week	0 (0, 30)	0 (0, 20)	0 (0, 60)	1.002***	1.001～1.002

MPA[2]					
Frequency, d/week	1 (0, 2)	1 (0, 2)	1 (0, 3)	1.124***	1.082～1.167
Duration, min/d	10 (0, 30)	10 (0, 30)	20 (0, 30)	1.005***	1.004～1.007
Volume, min/week	20 (0, 60)	10 (0, 60)	40 (0, 100)	1.001***	1.001～1.002
MVPA[3]					
Volume, min/week	40 (0, 120)	30 (0, 105)	60 (0, 180)	1.001***	1.001～1.002
Transportation					
MPA[2]					
Frequency, d/week	5 (1, 7)	5 (1, 7)	5 (2, 7)	1.030*	1.003～1.059
Duration, min/d	30 (10, 40)	30 (10, 40)	30 (15, 50)	1.002**	1.001～1.004
Volume, min/week	120 (30, 210)	105 (30, 210)	140 (50, 210)	1.002***	1.001～1.003
Sports and leisure-time					
VPA[1]					
Frequency, d/week	0 (0, 1)	0 (0, 1)	0 (0, 2)	1.171***	1.116～1.229
Duration, min/d	0 (0, 30)	0 (0, 30)	0 (0, 47.5)	1.006***	1.004～1.008
Volume, min/week	0 (0, 60)	0 (0, 38)	0 (0, 90)	1.002***	1.001～1.003
MPA[2]					
Frequency, d/week	1 (0, 2)	0 (0, 2)	1 (0, 3)	1.125***	1.082～1.169
Duration, min/d	10 (0, 30)	0 (0, 30)	20 (0, 40)	1.006***	1.004～1.008
Volume, min/week	15 (0, 80)	0 (0, 75)	40 (0, 90)	1.002***	1.001～1.002
MVPA[3]					
Volume, min/week	45 (0, 130.5)	30 (0, 120)	80 (0, 210)	1.001***	1.001～1.002
Total VPA[1]					
Volume, min/week	0 (0, 100)	0 (0, 80)	40 (0, 180)	1.001***	1.001～1.002
Total MPA[2]					
Volume, min/week	60 (0, 150)	60 (0, 140)	100 (10, 200)	1.001***	1.001～1.001
Total MVPA[3]					
Volume, min/week	255 (120, 490)	235 (105, 450)	340 (180, 630)	1.001***	1.000～1.001
	n (%)	*n (%)*	*n (%)*		
Sedentary behaviors					
<4.00 h/d	*590 (12.4)*	*459 (77.8)*	*131 (22.2)*	1 (ref.)	
4.00-5.99 h/d	*869 (18.3)*	*664 (76.4)*	*205 (23.6)*	1.119	0.859～1.459
6.00-8.99 h/d	*1453 (30.5)*	*1119 (77.0)*	*334 (23.0)*	0.983	0.769～1.258
9.00-11.99 h/d	*978 (20.6)*	*752 (76.9)*	*226 (23.1)*	0.940	0.721～1.225
≥12.00 h/d	*868 (18.2)*	*683 (78.7)*	*185 (21.3)*	0.795	0.604～1.045
Sleep duration					
<6.00 h/d	*287(6.0)*	*223 (77.7)*	*64 (22.7)*	1.428*	1.032～1.977
6.00-6.99 h/d	*969 (20.4)*	*708 (73.0)*	*261 (27.0)*	1.425***	1. 175～1.729
7.00-7.99 h/d	*1882 (39.6)*	*1493 (79.3)*	*389 (20.7)*	1 (ref.)	
8.00-8.99 h/d	*1186 (24.9)*	*916 (77.2)*	*270 (22.8)*	1.131	0.939～1.361
≥ 9.00 h/d	*434 (9.1)*	*337 (77.6)*	*97 (22.4)*	1.020	0.782～1.331

#: $P<0.10$; *: $P<0.05$; **: $P<0.01$; ***: $P<0.001$.

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

Adjusted ORs and 95% CIs of each life-style variable were calculated after controlling for the significant socio-demographic variables in Table 1, including city, study year, gender, university/other sports team member, and any chronic disease/symptom.

We finally performed a hierarchical analysis and Table 3 presents results of its final model. Risk estimations of socio-demographic variables in Block 1 (including city, gender, study year, and chronic disease/symptom) did not change much before and after controlling for life-style variables, whilst those of the two variables of sports team member reduced largely after adjustment for life-style variables. In addition, adjusted ORs of all life-style variables (in Block 2) decreased after controlling for each other.

Table 3 Final model of hierarchical logistic regression to estimate risks of both socio-demographic and life-style variables for PARI among university students in China

Characteristics	*P*-value	Adjusted OR	95% CI
Block 1			
City			
Shantou		1 (ref.)	
Jinan	0.000	0.236	0.194～0.288
Hong Kong	0.000	0.222	0.181～0.273
Study year			
Year 1		1 (ref.)	
Year 2	0.054	0.836	0.697～1.003
Year 3	0.041	0.830	0.695～0.992
Gender			
Male		1 (ref.)	
Female	0.033	0.838	0.712～0.986
University sports team member			
No		1 (ref.)	
Yes	0.000	2.360	1.881～2.961
Other sports team member			
No		1 (ref.)	
Yes	0.000	1.717	1.309～2.253
Any chronic disease/symptom			
No		1 (ref.)	

Yes	0.013	1.548	1.096～2.187
Block 2			
Leisure-time VPA[1], frequency (d/week)	0.010	1.079	1.018～1.144
Leisure-time VPA[1], duration (min/d)	0.000	1.006	1.003～1.008
Leisure-time MPA[2], frequency (d/week)	0.000	1.004	1.002～1.006
Sleep duration			
<6.00 h/d	0.045	1.333	1.006～1.766
6.00-6.99 h/d	0.014	1.262	1.048～1.519
7.00-7.99 h/d		1 (ref.)	
8.00-8.99 h/d	0.314	1.111	0.905～1.365
≥ 9.00 h/d	0.692	1.061	0.791～1.425

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

In terms of favorite activities, three fifths of the students (59.7%) reported at least one specific activity that they liked and participated often in the past 12 months. Common favorite activities reported included running (36.0%), badminton (27.2%), basketball (25.2%), cycling (24.3%), swimming (18.1%), table tennis (15.1%), soccer (14.3%), dance (13.8%) and volleyball (10.1%). Gender difference existed, with male students favoring basketball (54.1%) and football (32.2%), whilst females preferring badminton (26.9%) and dance (14.6%).

Table 4 summarizes the number and consequences of reported PARIs among the 1081 injured participants, before and after stratified by gender. In the past 12 months, around one quarter of the injured (26.4%) experienced PARIs three times or more. More than half reported that they immediately stropped the activity or could not participate in the next activity (58.5%), or sought medical care (55.0%) after injured. Males were more likely than females to experience multiple PARI episodes (≥ 3 episodes) and result in negative influences on PA participation.

Table 4 Number and consequences of physical activity-related injury (PARI) among injured university students in China (N=1081)

Characteristics	All (N=1081) n (%)	Male (N=367) n (%)	Female (N=714) n (%)	χ^2	*P*-value
Number of PARI episodes				29.837	<0.001
1	534 (49.4)	146 (39.8)	388 (54.3)		
2	262 (24.2)	89 (24.3)	173 (24.2)		
≥3	285 (26.4)	132 (36.0)	153 (21.4)		
Consequences of PARI					
Stop quickly and/or can't participate in the next PA				4.084	0.044
No	449 (41.5)	137 (37.3)	312 (43.7)		
Yes	632 (58.5)	230 (62.7)	402 (56.3)		
Being absent from class				2.416	0.120
No	778 (72.0)	275 (74.9)	503 (70.4)		
Yes	303 (28.0)	92 (25.1)	211 (29.6)		
Seeking medical attention				0.267	0.605
No	486 (45.0)	169 (46.0)	317 (44.4)		
Yes	595 (55.0)	198 (54.0)	397 (55.6)		

Discussion

A total of 4758 university students in China completed the online questionnaire survey. PARI experiences in the past 12 months were prevalent among the sample, with an overall incidence rate of 22.7%. Among the 1081 injured participants, the majority of the injured experienced a time loss from PA or required medical care due to the injuries. Multivariate analyses revealed that males, Shantou students, Year 1 students, sports team members, and those with a chronic disease/symptom were more vulnerable to PARI. PA engagements, no matter at which intensity (MPA, VPA, or MVPA), in which domain (domestic/work/study, transportation, or sports and leisure-time), or by which parameter (frequency, duration, or volume), were all

significantly and positively related with PARI. Of them, frequency of leisure-time VPA was the strongest PA indicator after controlling for both socio-demographic and life-style variables (adjusted OR: 1.079, 95% CI: 1.018-1.144, *P*=0.010, Table 3). Moreover, insufficient sleep was common, which elevated the risk for PARI, especially for a sleep duration less than 6 hours/day.

As far as we knew, it is the first of this kind of publications to investigate the epidemic and risk factors of PARI among general university students. In this study, one out of five participants (22.7%) experienced PARI in the past 12 months, suggesting that PARI is common among this population. The problem should not be ignored, especially under the contemporary global campaign to promote PA for health for all. Except for direct adverse effects on physical health, PARI can also result in fear or even stop to be engaged into similar activities or movements, and further result in reduced PA level.[11 12] Those consequences are against the initial purpose of PA promotion for health. Though we did not investigate detailed consequences for each PARI episode, our results still revealed that more than half of the injured experienced PA absenteeism or required medical attention. There is an urgent call for effective strategies to reduce injuries when undertaking physical activities. Otherwise, the effectiveness of the global campaign would be compromised.

We found that males were more vulnerable to PARI than females, is highly consistent with other research.[20 21] Several reasons may have contributed to the discrepancy: 1) males are more active than females. In our study, male students held

higher values than females for all PA indicators (Supplementary Table S1), supporting this possibility; 2) males are more likely to participate in competitive team sports, such as basketball and soccer. Most of these sports involve a high rate of contact, jumping, sprinting and/or pivoting, which are often involved in the mechanism of injury in sports. The gender difference in favorite activities in this study is in line with this explanation; 3) even in the same activity, males are also more likely to experience injuries due to high competitiveness and resistance.[22] Collectively, males are more vulnerable to PARI than females. Future interventions should address the gender discrepancy.

In our study, more than 70% of the participants were physically active according to the WHO's recommendations (70.2%), with the prevalence being higher than those found in other similar studies on Chinese university students (in which PA levels were also self-reported).[23] Increased PA has been reported in several recent studies as a result of the global PA promotion campaign.[24] In the past decades, the Chinese government has been making great efforts to promote PA. Our results may also reflect its effect on university students. Nevertheless, individuals turn to over-report their PA levels.[25] We could not avoid this possibility, which may have resulted in over-estimated PA levels of the participants. However, it may not be reasonable to assume that students with PARI would be more (or less) likely to over-report their PA than non-PARI ones. Thus, the estimations of the elevated risks of PA might be still robust.

We found that PA involvements were positively and significantly related with PARI occurrences, with frequency of leisure-time VPA being the predominant risk factor. Highly consistent results have been found on the elevated risks of some training characteristics for injuries, including high frequency, high vigorous intensity, and long duration,[22 26] which should receive sufficient attentions from researchers and policy-makers when promoting PA among the public. Unfortunately, neither the WHO's information sheet on recommended PA, which is most commonly disseminated to the public, nor its full report provides any suggestion on frequency and duration for safety.[4] It is stated in the full report that "activity-related adverse events such as musculoskeletal injuries are common but are usually minor especially for moderate-intensity activities such as walking."[4] However, PARI may not be as minor as it states, if being given a full consideration on both short-term and long-term adverse effects on health.[11 27] For instances, acutely, PARI counts for the largest proportion of non-fatal injuries, a top health problem among young adults.[9]Chronically, previous joint injury history, a major type of PARI, was found to increase the likelihood of osteoarthritis by 2.8- to 6.4-fold.[27] Osteoarthritis is the single most common cause of disability in the elderly, affecting about 15% of the entire population.[28] There are several recommendations related to frequency and duration existing. For example, the American Diabetes Association (ADA) suggests a frequency of MVPA at least 3 days/week with a non-exercise interval less than two consecutive days, and that of resistance exercise at least 2 times/week on

non-consecutive days.[29] A training frequency of 3-5 days/week at an intensity level of 55/65% to 90% of maximum heart rate and a duration of 20-60 minutes of continuous or intermittent of aerobic activity are recommended for developing and maintaining fitness effects.[30] However, none of them is made for the safety purpose. Obviously, there is a knowledge gap in safe frequency and duration of PA (in particular VPA), which warrants further studies. In addition, safety issues should be emphasized and disseminated to the public along with the recommendations.

In this study, Year 1 students, sports team members, and those with insufficient sleep duration were more likely to suffer from PARI. Two possibilities might be attributed to the higher risk among Year 1 students: 1) after being released from heavy academic burdens undertaken in secondary schools and becoming independent from their parents, there might be a sharp increase in PA among them and result in the elevated risk for injury;[13] 2) they are younger than those in Years 2 and 3. Thus, adventurousness and impulsiveness inherent in youth, with relatively poor self-restrain might also play a role.[31 32] Compared to their counterparts, sports team members in this study were about 1- to 2-fold more likely to suffer from PARI. This further proves that we may not simply apply the results observed from collegiate athletes to the general students. Insufficient sleep duration may increase the risk for PARI via physical fatigue and impaired cognitive performance, such as cognitive slowing and decreased vigilance.[33]

To our surprise, we found that the PARI incidence rate among Shantou students

was double those in the other two cities (33.9% vs. 12.3% and 15.0%), which could not be explained by all variables in this study, including study year, sports team member, PA indicators, and sleep duration (Supplementary Table S2). Both Shantou and Hong Kong are located in southern China, sharing similar climate and climate related sports habits, whilst Jinan is a northern city. Thus, it may be impossible that the large between-city difference in PARI was attributable to the geographical factors. Though the sports infrastructure of a university might have potential influences on PARI occurrences among its students, both Shantou and Jinan belong to the Mainland China, where sports facilities and surveillance system across universities are similar. We therefore ruled out this possibility. In addition, the economic in Shantou is developed least among the three cities, its less developed urban environments outside universities might have resulted in its highest PARI incidence rate, compared to the other two cities.[34] Unfortunately, we could not provide supporting evidence on this hypothesis, as we did not collect detailed information about places of the PARI occurrences. It is worth further studying on possible reasons of the large between-city difference in PARI.

Conclusions

We concluded that PARI was common among university students in China. Frequency of leisure-time VPA was the strongest risk factor among all PA variables. In addition, males, Year 1 students, sports team members, and those with insufficient sleep were more vulnerable to PARI. Further studies, with a prospective study design

and adopting both objective and subjective PA measurements, are warranted to confirm our findings. Nevertheless, there is an urgent call for actions to prevent them from PARI, with a full consideration of the risk factors found in this study. Safety issues should also be involved and emphasized when promoting PA among the public.

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Table S1 Comparison of all PA indicators between-gender among university students in China (N=4758)

Characteristics	Male (N=1343) median (IQR)	Female (N=3415) median (IQR)	Z	*P*-value
Domestic/work/study				
VPA[1]				
Frequency, d/week	0 (0, 2)	0 (0, 1)	-13.763	<0.001
Duration, min/d	0 (0, 30)	0 (0, 10)	-14.181	<0.001
Volume, min/week	0 (0, 90)	0 (0, 10)	-14.336	<0.001
MPA[2]				
Frequency, d/week	1 (0, 3)	1 (0, 2)	-9.007	<0.001
Duration, min/d	20 (0, 40)	10 (0, 30)	-10.488	<0.001
Volume, min/week	40 (0, 120)	10 (0, 60)	-10.352	<0.001
MVPA[3]				
Volume, min/week	60 (0, 150)	20 (0, 90)	-13.226	<0.001
Transportation				
MPA[2]				
Frequency, d/week	5 (2, 7)	5 (1, 7)	-4.213	<0.001
Duration, min/d	30 (12, 50)	30 (10, 40)	-1.571	0.116
Volume, min/week	135 (40, 240)	120 (30, 210)	-3.496	<0.001
Sports and leisure-time				
VPA[1]				
Frequency, d/week	1 (0, 2)	0 (0, 1)	-15.195	<0.001
Duration, min/d	15 (0, 60)	0 (0, 20)	-15.473	<0.001
Volume, min/week	20 (0, 100)	0 (0, 30)	-15.846	<0.001
MPA[2]				
Frequency, d/week	1 (0, 3)	0 (0, 2)	-7.851	<0.001

Duration, min/d	20 (0, 40)	0 (0, 30)	-8.601	<0.001
Volume, min/week	40 (0, 100)	0 (0, 75)	-8.766	<0.001
MVPA[3]				
Volume, min/week	90 (0, 210)	30 (0, 120)	-13.808	<0.001
Total VPA[1]				
Volume, min/week	60 (0, 180)	0 (0, 60)	-17.387	<0.001
Total MPA[2]				
Volume, min/week	90 (0, 210)	56 (0, 140)	-10.616	<0.001
Total MVPA[3]				
Volume, min/week	360 (170, 645)	230 (105, 420)	-12.527	<0.001

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

Table S2 Comparison of all variables among university students in three Chinese cities (N=4758)

Characteristics	Shantou (N=2123) median (IQR)	Jinan (N=1267) median (IQR)	Hong Kong (N=1368) median (IQR)	χ^2	*P*-value
Domestic/work/study					
VPA[1]					
Frequency, d/week	0 (0, 0)	0 (0, 1)	1 (0, 2)	430.847	<0.001
Duration, min/d	0 (0, 0)	0 (0, 10)	10 (0, 40)	459.346	<0.001
Volume, min/week	0 (0, 0)	0 (0, 10)	15 (0, 90)	451.585	<0.001
MPA[2]					
Frequency, d/week	1 (0, 2)	1 (0, 3)	1 (0, 2)	41.561	<0.001
Duration, min/d	10 (0, 30)	15 (0, 30)	20 (0, 40)	54.763	<0.001
Volume, min/week	10 (0, 60)	30 (0, 90)	30 (0, 90)	37.396	<0.001
MVPA[3]					

Volume, min/week	20 (0, 80)	40 (0, 120)	60 (0, 180)	162.353	<0.001
Transportation					
MPA[2]					
Frequency, d/week	5 (2, 7)	5 (2, 7)	4 (1, 6)	35.462	<0.001
Duration, min/d	30 (10, 40)	30 (15, 50)	30 (10, 40)	12.776	0.002
Volume, min/week	140 (40, 210)	120 (40, 210)	100 (30, 210)	13.614	0.001
Sports and leisure-time					
VPA[1]					
Frequency, d/week	0 (0, 1)	0 (0, 1)	1 (0, 2)	167.345	<0.001
Duration, min/d	0 (0, 15)	0 (0, 30)	10 (0, 60)	215.755	<0.001
Volume, min/week	0 (0, 20)	0 (0, 60)	10 (0, 90)	196.872	<0.001
MPA[2]					
Frequency, d/week	1 (0, 2)	1 (0, 3)	1 (0, 2)	53.535	<0.001
Duration, min/d	0 (0, 30)	20 (0, 30)	10 (0, 30)	48.271	<0.001
Volume, min/week	0 (0, 80)	30 (0, 90)	15 (0, 78.75)	52.548	<0.001
MVPA[3]					
Volume, min/week	30 (0, 100)	60 (0, 150)	60 (0, 180)	89.474	<0.001
Total VPA[1]					
Volume, min/week	0 (0, 60)	0 (0, 90)	60 (0, 180)	428.887	<0.001
Total MPA[2]					
Volume, min/week	50 (0, 140	80 (0, 180)	60 (0, 168.75)	51.876	<0.001
Total MVPA[3]					
Volume, min/week	230 (110, 440)	270 (125, 500)	286.5 (120, 570)	41.574	<0.001
	n (%)	*n (%)*	*n (%)*		
Study Year					
Year 1	*698 (32.9)*	*453 (35.8)*	*345 (25.2)*	147.006	<0.01

Year 2	*691 (32.5)*	*443 (35.0)*	*328 (24.0)*		
Year 3	*734(34.6)*	*371 (29.3)*	*695 (50.8)*		
University sports team member					
No	*1977 (93.1)*	*1153 (91.0)*	*1132 (82.7)*	99.654	<0.01
Yes	*146 (6.9)*	*114 (9.0)*	*236 (17.3)*		
Other sports team member					
No	*1989 (93.7)*	*1196 (94.4)*	*1287 (94.1)*	*0.732*	0.694
Yes	*134 (6.3)*	*71 (5.6)*	*81 (5.9)*		
Sleep duration					
<6.00 h/d	*69 (3.3)*	*29 (2.3)*	*189 (13.87)*	338.655	<0.01
6.00-6.99 h/d	*406 (19.1)*	*187 (14.8)*	*376 (27.5)*		
7.00-7.99 h/d	*841 (39.6)*	*608 (48.0)*	*433(31.7)*		
8.00-8.99 h/d	*563 (26.5)*	*353 (27.9)*	*270 (19.7)*		
≥ 9.00 h/d	*244 (11.5)*	*90(7.1)*	*100 (7.3)*		

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

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Physical activity-related injuries among university students: a multi-center cross-sectional study in China

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Title: Physical activity-related injuries among university students: a multi-center cross-sectional study in China

Running title: Physical activity-related injury among youth

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Abstract

Objectives: This study aimed to investigate the epidemiologic characteristics and preliminarily explore risk factors of physical activity-related injury (PARI) occurrences among Chinese university students via a multi-center mixed survey.

Design: Cross-sectional study.

Participants: By the method of cluster random sampling, a total of 4758 undergraduates graded 1-3 in nine universities in three Chinese cities were invited and completed the self-administered online questionnaires during March and April, 2017.

Main outcome measures: PARI in the past 12 months.

Results: Of 4758 participants, 1081 sustained PARI in the past 12 months, with an overall PARI incidence rate of 22.7% (27.3% [367/1343] in males and 20.9% [714/3415] in females). Around one quarter of the injured (26.4%) suffered from PARI at least three episodes. More than half of the injured experienced physical activity (PA) absenteeism and sought medical attention. All PA indictors were significantly and positively associated with PARI, with the frequency of sports and leisure-time vigorous-intensity PA (VPA) participation being the strongest (adjusted OR: 1.079, 95% CI: 1.018-1.144). Moreover, males (OR=1.199), Shantou students (OR=4.239), Year 1 students (OR=1.287), university and other sports team members (OR=1.717-2.360), and those with insufficient sleep time (OR=1.262-1.333) were also at higher risks for PARI experience.

Conclusions: PARI was prevalent among university students in China. The frequency of sports and leisure-time VPA participation was the strongest risk factor of PARI among all PA indicators. The above data can inform future programs for the injury-intervention in university students. Safety issues should also be involved and emphasized when promoting PA among the public to reduce PARI occurrence.

Article summary

Strengths and limitations of this study

1) It is the first of this kind of publications to explore the epidemic and risk factors of PARI among Chinese general university students.

2) The cross-sectional study design and retrospectively collected data limit causal and temporal inference in this study. For example, it is plausible that some injured students would rate their PA levels higher if not injured since their PA levels might have been affected by their injuries, which may have resulted in the under-estimation of the PA's risk for injuries. In addition, it is also plausible that students who were more often engaged in PA would be more likely to remember their injuries since the injuries might have a greater impact on these students. This possibility may have led us to over-estimating the relationship between PA levels and PARI. PA levels in this study were measured once only, we therefore could not explain the rationale that PARI contributes to the reduction of PA. Our team group is conducting a prospective cohort study to confirm findings of this study.

3) All information was self-reported, which have resulted in recall bias (e.g., some participants may have forgotten to report minor and earlier injury episodes) and report bias (e.g., some participants may have over-reported on their PA levels, as it is a socially desirable behavior) and threatened our results to some extent.

4) We could not investigate activity-specific PARI occurrences as the Global Physical Activity Questionnaire (GPAQ) does not capture specific activities the participants undertook.

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Competing interests

The authors declare that they have no competing interests.

Introduction

Physical, social and psychological benefits of engaging in regular physical activity (PA) have been well documented, including increased cardiorespiratory and muscular fitness and bone density, and reduced risks for non-communicable diseases.[1-3] Insufficient PA has been recognized as one of the top three risk behaviors in the development of morbidity and mortality associated with cardiovascular diseases and other major chronic diseases, such as diabetes and obesity.[4] In order to achieve and maintain individual health at an optimal level, World Health Organization (WHO) has recommended that adults (18-64 years old) should undertake at least 150 minutes

of moderate-intensity PA (MPA), or at least 75 minutes of vigorous-intensity PA (VPA), or an equivalent combination of moderate- and vigorous-intensity PA (MVPA) every week.[4] With these advantages and recommendations of PA participation, almost all countries and regions in the world have been engaged in the current global campaign to promote PA.

Although the promotion of PA is a public health priority, being physically active might increase the risk for injury.[5-7] Physical activity-related injury (PARI), also known as sports and recreational activity-related injury, was defined as any injury resulting from participation in PE class, sports activities or leisure time PA, such as sprain, strain, fracture, contusion, and et al.[8] In fact, PARI contributes mostly to all non-fatal injury, which ranks the top one health threat to relatively healthy adolescents and young adults in many countries.[4 9] In a long term, it can also increase risks for future injuries, osteoarthritis and other health problems in later life.[10] In addition, PARI may be a barrier to adopting a more active lifestyle, which may further hinder people from achieving optimal health.[11 12]

We have been conducting a series of studies on PARI. Results from previous studies revealed that about 25.1%-32.1% of primary and secondary school students in two Chinese cities had suffered from PARI in the past 12 months, suggesting that PARI is prevalent among children and adolescents (Data not published yet). In China, students in universities might be more active than those in primary and secondary schools, as they have been released from heavy academic burdens and pressure for

university admission. Moreover, they become independent from their parents and therefore are more likely to engage in relatively risky activities which their parents may not allow them to do before.[13] Thus, university students might be more vulnerable to PARI. Though there is plenty of evidence about PARI among collegiate athletes, it may not be suitable for general students because of the significant differences in risk factors between the two groups, such as sports skills, training intensity, competition level, and cardiorespiratory and muscle fitness level.[14 15] However, few studies have been addressed the problem of PARI among general university students.[13 16] We therefore conducted a multi-center cross-sectional study among a sample of general university students in China, funded by the National Natural Science Foundation of China (Grant No. 31640038), to obtain a better understanding of the PARI epidemic. This paper presents findings from its baseline survey, aiming to investigate the epidemiologic characteristics and preliminarily identify potential risk factors of PARI occurrences among Chinese university students.

Methods

Study Participants

The study was conducted in nine universities (eight comprehensive universities and one normal university [where students are trained to become teachers in kindergartens and primary and secondary schools]) in three Chinese cities, namely

Jinan, Shantou, and Hong Kong. Each city represents northern, southern, and special regions of China respectively. Via the method of cluster random sampling, a total of 5115 eligible students in Years 1-3 were invited to participate in the study during March and April, 2017. Seniors (students in Years 4) were excluded as they are in the transition period to work and their university lives are significantly different from the others. In addition, those majoring in physical education (PE) were further excluded from data analysis, as they differ significantly from others in terms of PA/sports related factors. At last, a totally final valid sample of 4758 non-PE students in Years 1-3 completed the online survey, with a response rate of about 93.0%.

Data collection

The Qualtrics software (Qualtrics, Provo, UT) was used as the online platform of the baseline questionnaire survey. Participants were enrolled in classes, or from dormitories. The online questionnaire was self-administered, consisting of demographics, PA habits, sedentary behaviors, sleep duration, and PARI experiences in the past 12 months.

The demographic variables included university, study major, study year, gender, age, residence type (dormitory, home, or others), any diagnosed chronic disease/symptom, and sports team membership.

Participants' PA levels in a typical week in the past 12 months were asked using the Global Physical Activity Questionnaire (GPAQ) Chinese version.[17] It is one of the

most commonly used PA questionnaires and possesses sound reliability and validity (spearman's rho=0.81, kappa=0.65).[18 19] The GPAQ collects frequency (days/week) and duration (cumulative minutes/day) of VPA and MPA in three domains, including domestic/work/study, transportation (MPA only), and sports and leisure-time activities. PA volume (cumulative minutes/week) was then calculated by duration multiplied by frequency for each category of PA (VPA, MPA, and MVPA), in each domain and overall, generating a total of 20 PA-related variables. Given that the GPAQ does not provide information on specific activities the students participated, all participants were further asked whether they had any sports or recreational activities they liked and participated in often (i.e., favorite activities) in the past 12 months. Those with a positive answer were further requested to provide the names of the activities (no more than three).

In terms of sedentary behaviors and sleep, duration (hours/day) was asked on both a typical weekday and a typical weekend respectively. Average daily duration in a week was then calculated and used to group the students into five categories.

In this study, a countable PARI must meet at least one of the following three consequences: the student 1) has to immediately stop the PA and/or cannot participate in the next planned PA; and/or 2) is absent from class the next day; and/or 3) needs to seek medical attention (including on-spot first aids, but excluding those using bandages only).[8] If suffering from such a PARI in the past 12 months, the participants were then asked to report the number of PARI in each consequence category.

Ethics approval

This study was strictly conducted in accordance with the Declaration of Helsinki. Prior to approaching potential students, approval was obtained from Shantou University Medical College ethics committee, Shandong University ethics committee, and Hong Kong Baptist University ethics committee. Explanatory statement and consent forms were distributed to all potential participants, and the hyperlink or QR code of questionnaire was subsequently given to the consenting students in the nominated classes or dormitories. The purpose and meaning of our study was verbally explained to the subjects prior to their completion of the questionnaires, and our trained personnel would answer any questions of clarification as participants arose during the session.

Statistical analysis

Statistical analyses were performed using SPSS version 19.0 (SPSS Inc. Chicago, IL, USA). Continuous data which is normally (i.e., age) or not normally distributed (i.e., 20 PA-related variables) was described using mean (standard deviation, SD) or median (inter-quartile, IQR) respectively, while categorical variables were presented as number (percentage). In addition to the Pearson chi-square tests applied to evaluate the numbers and consequences of PARI between females and males, both univariate and multivariate logistic regression were fitted to estimate the risk of each study variable for PARI, where crude and adjusted odds ratios (ORs) and their 95%

confidence intervals (95% CIs) were generated respectively. Three steps were undertaken in the multivariate analyses: Step one, in a multivariate model, all socio-demographic variables were selected in both forward and backward manners (likelihood ratio), with selection criteria of α_{in}=0.10 and α_{out}=0.15. Adjusted ORs and 95% CIs of variables kept in the final model (i.e., significant variables) were then derived from, including city, study year, gender, university/other sports team member, and any chronic disease/symptom. For variables outside of the final model (i.e., insignificant variables, including age and residence type), their adjusted ORs and 95% CIs were obtained after controlling for the significant variables (Table 1); Step two, the risk of each life-style variable (including PA habits, sedentary behaviors, and sleep duration) was assessed after controlling for the significant socio-demographic variables in the first step (Table 2); Step three, a hierarchical model was performed to consider all significant study variables together, with socio-demographic variables being selected in the first block and life-style variables in the second (Table 3). A two-sided *P*-value less than 0.05 was considered statistically significant for all tests.

Patient involvement

No patients were involved in the development of the research question or the outcome measures, nor were they involved in developing plans for design or implementation of the study. There are no plans to disseminate the results of the research to study participants.

Results

Table 1 presents the distribution of the social-demographic characteristics and their risk estimations for PARI. Overall, the 4758 participants aged from 17 to 25 years old, with a mean age of 20.00 (SD: 1.382). More students were females (71.8%), living in dormitory (61.1%), and studying in Shantou (44.6%). Few students were sports team members or living with any chronic condition (3.7%-10.4%). About 1081 students (22.7%) suffered from at least one PARI in the past 12 months, with significantly higher risks being found in both types of sports team members and those living with chronic conditions (adjusted ORs: 1.561-3.136). In addition, students in Shantou, males, and those in Years 1 were more likely to experience PARI than their counterparts (adjusted ORs: 1.397-3.932). Age and residence type were not significantly associated with PARI.

Table 1 Risks of socio-demographic characteristics for physical activity-related injury (PARI) among university students in China

Characteristics	All (N=4758) n (%)	Non-PARI (N=3677) n (%)	PARI (N=1081) n (%)	Adjusted OR	95% CI
City					
Jinan	1267 (26.6)	1111 (87.7)	156 (12.3)	1 (ref.)	
Shantou	2123 (44.6)	1403 (66.1)	720 (33.9)	3.932***	3.230～4.786
Hong Kong	1368 (28.8)	1163 (85.0)	205 (15.0)	1.084	0.841～1.396
Study year					
Year 1	1496 (31.4)	1125 (75.2)	371 (24.8)	1.397**	1.109～1.760
Year 2	1462 (30.7)	1121 (76.7)	341 (23.3)	1.153	0.948～1.401
Year 3	1800 (37.8)	1431 (79.5)	369 (20.5)	1 (ref.)	
Gender					
Male	1343 (28.2)	976 (72.7)	367 (27.3)	1.404***	1.202～1.640
Female	3415 (71.8)	2701 (79.1)	714 (20.9)	1 (ref.)	
Residence type					

Dormitory	2908 (61.1)	2210 (76.0)	698 (24.0)	1 (ref.)	
Home	1742 (36.6)	1377 (79.0)	365 (21.0)	1.016	0.861～1.198
Others	108 (2.3)	90 (83.3)	18 (16.7)	0.820	0.469～1.434
University sports team member					
No	4262 (89.6)	3380 (79.3)	882 (20.7)	1 (ref.)	
Yes	496 (10.4)	297 (59.9)	199 (40.1)	3.136***	2.528～3.889
Other sports team member					
No	4472 (94.0)	3512 (78.5)	960 (21.5)	1 (ref.)	
Yes	286 (6.0)	165 (57.7)	121 (42.3)	2.182***	1.678～2.838
Any chronic disease/symptom					
No	4583 (96.3)	3563 (77.7)	1020 (22.3)	1 (ref.)	
Yes	175 (3.7)	114 (65.1)	61 (34.9)	1.561*	1.111～2.195
Age ($\bar{x}$±s, years)	20.00±1.382	20.01±1.426	19.98±1.386	0.983	0.934～1.146

*: $P<0.05$; **: $P<0.01$; ***: $P<0.001$.

Adjusted ORs and 95% CIs of significant variables were calculated after controlling for each other, including city, study year, gender, university/other sports team member, and any chronic disease/symptom. Adjusted ORs and 95% CIs of insignificant variables (age and residence type) were obtained after controlling for the significant variables.

Table 2 shows the distribution of life-style variables and their risk assessments for PARI. The majority of the students engaged in sports and leisure-time PA (87.5%) and transport-related PA (82.1%). Medians and interquartile ranges (IQRs) for total volumes of VPA, MPA and MVPA (min/week) were 0 (0, 100), 60 (0, 150) and 255 (120, 490) respectively (Means and SDs for these 20 PA-related variables were available in supplementary table S1). Overall, 70.2% of university students were physically active according to the WHO's recommended PA for adults.[4] All PA indicators were positively and significantly related with PARI (adjusted ORs: 1.001-1.171), with the risk of the frequency of sports and leisure-time VPA participation being the highest. About 26.4% of students slept less than seven hours per day, and they were more prone to sustain PARI events (adjusted ORs: 1.425-1.428).

Table 2 Risks of life-style variables for physical activity-related injury (PARI) among

university students in China

Characteristics	All (N=4758) median (IQR)	Non-PARI (N=3677) median (IQR)	PARI (N=1081) median (IQR)	Adjusted OR	95% CI
Domestic/work/study					
VPA[1]					
Frequency, d/week	0 (0, 1)	0 (0, 1)	0 (0, 2)	1.168***	1.111～1.228
Duration, min/d	0 (0, 20)	0 (0, 15)	0 (0, 30)	1.008***	1.006～1.010
Volume, min/week	0 (0, 30)	0 (0, 20)	0 (0, 60)	1.002***	1.001～1.002
MPA[2]					
Frequency, d/week	1 (0, 2)	1 (0, 2)	1 (0, 3)	1.124***	1.082～1.167
Duration, min/d	10 (0, 30)	10 (0, 30)	20 (0, 30)	1.005***	1.004～1.007
Volume, min/week	20 (0, 60)	10 (0, 60)	40 (0, 100)	1.001***	1.001～1.002
MVPA[3]					
Volume, min/week	40 (0, 120)	30 (0, 105)	60 (0, 180)	1.001***	1.001～1.002
Transportation					
MPA[2]					
Frequency, d/week	5 (1, 7)	5 (1, 7)	5 (2, 7)	1.030*	1.003～1.059
Duration, min/d	30 (10, 40)	30 (10, 40)	30 (15, 50)	1.002**	1.001～1.004
Volume, min/week	120 (30, 210)	105 (30, 210)	140 (50, 210)	1.002***	1.001～1.003
Sports and leisure-time					
VPA[1]					
Frequency, d/week	0 (0, 1)	0 (0, 1)	0 (0, 2)	1.171***	1.116～1.229
Duration, min/d	0 (0, 30)	0 (0, 30)	0 (0, 47.5)	1.008***	1.006～1.011
Volume, min/week	0 (0, 60)	0 (0, 38)	0 (0, 90)	1.002***	1.001～1.003
MPA[2]					
Frequency, d/week	1 (0, 2)	0 (0, 2)	1 (0, 3)	1.125***	1.082～1.169
Duration, min/d	10 (0, 30)	0 (0, 30)	20 (0, 40)	1.006***	1.004～1.008
Volume, min/week	15 (0, 80)	0 (0, 75)	40 (0, 90)	1.002***	1.001～1.002
MVPA[3]					
Volume, min/week	45 (0, 130.5)	30 (0, 120)	80 (0, 210)	1.001***	1.001～1.002
Total VPA[1]					
Volume, min/week	0 (0, 100)	0 (0, 80)	40 (0, 180)	1.001***	1.001～1.002
Total MPA[2]					
Volume, min/week	60 (0, 150)	60 (0, 140)	100 (10, 200)	1.001***	1.001～1.001
Total MVPA[3]					
Volume, min/week	255 (120, 490)	235 (105, 450)	340 (180, 630)	1.001***	1.000～1.001
	n (%)	*n (%)*	*n (%)*		
Sedentary behaviors					
<4.00 h/d	*590 (12.4)*	*459 (77.8)*	*131 (22.2)*	1 (ref.)	
4.00-5.99 h/d	*869 (18.3)*	*664 (76.4)*	*205 (23.6)*	1.119	0.859～1.459
6.00-8.99 h/d	*1453 (30.5)*	*1119 (77.0)*	*334 (23.0)*	0.983	0.769～1.258

9.00-11.99 h/d	*978 (20.6)*	*752 (76.9)*	*226 (23.1)*	0.940	0.721～1.225
≥12.00 h/d	*868 (18.2)*	*683 (78.7)*	*185 (21.3)*	0.795	0.604～1.045
Sleep duration					
7.00-7.99 h/d	*1882 (39.6)*	*1493 (79.3)*	*389 (20.7)*	1 (ref.)	
<6.00 h/d	*287 (6.0)*	*223 (77.7)*	*64 (22.7)*	1.428*	1.032～1.977
6.00-6.99 h/d	*969 (20.4)*	*708 (73.0)*	*261 (27.0)*	1.425***	1. 175～1.729
8.00-8.99 h/d	*1186 (24.9)*	*916 (77.2)*	*270 (22.8)*	1.131	0.939～1.361
≥ 9.00 h/d	*434 (9.1)*	*337 (77.6)*	*97 (22.4)*	1.020	0.782～1.331

#: $P<0.10$; *: $P<0.05$; **: $P<0.01$; ***: $P<0.001$.

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

Adjusted ORs and 95% CIs of each life-style variable were calculated after controlling for the significant socio-demographic variables in Table 1, including city, study year, gender, university/other sports team member, and any chronic disease/symptom.

We finally performed a hierarchical analysis and Table 3 presents the results of its final model. Risk estimations of socio-demographic variables in Block 1 (including city, gender, study year, and chronic disease/symptom) did not change much before and after controlling for life-style variables, whilst those of the two variables of sports team member reduced largely after the adjustment of life-style variables. In addition, frequency and duration of sports and leisure-time VPA, duration of sports and leisure-time MPA, and sleep duration (in Block 2) were significantly related with PARI, with the adjusted ORs slightly decreasing after controlling for socio-demographic variables.

Table 3 Final model of hierarchical logistic regression to estimate risks of both socio-demographic and life-style variables for PARI among university students in China

Characteristics	*P*-value	Adjusted OR	95% CI
Block 1			
City			
Jinan		1 (ref.)	
Shantou	0.000	4.239	3.475～5.171
Hong Kong	0.468	0.913	0.713～1.168
Study year			
Year 1	0.039	1.287	1.099～1.515

Year 2	0. 883	1.014	0.846～1.215
Year 3		1 (ref.)	
Gender			
Male	0.028	1.199	1.020～1.410
Female		1 (ref.)	
University sports team member			
No		1 (ref.)	
Yes	0.000	2.360	1.881～2.961
Other sports team member			
No		1 (ref.)	
Yes	0.000	1.717	1.309～2.253
Any chronic disease/symptom			
No		1 (ref.)	
Yes	0.013	1.548	1.096～2.187
Block 2			
Sports and leisure-time VPA[1], frequency (d/week)	0.010	1.079	1.018～1.144
Sports and leisure-time VPA[1], duration (min/d)	0.000	1.006	1.003～1.008
Sports and leisure-time MPA[2], duration (min/d)	0.000	1.004	1.002～1.006
Sleep duration			
7.00-7.99 h/d		1 (ref.)	
<6.00 h/d	0.045	1.333	1.006～1.766
6.00-6.99 h/d	0.014	1.262	1.048～1.519
8.00-8.99 h/d	0.314	1.111	0.905～1.365
≥ 9.00 h/d	0.692	1.061	0.791～1.425

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

In terms of favorite activities, three fifths of the students (59.7%) reported at least one specific activity that they liked and participated in often in the past 12 months. Common favorite activities reported included running (36.0%), badminton (27.2%), basketball (25.2%), cycling (24.3%), swimming (18.1%), table tennis (15.1%), soccer (14.3%), dance (13.8%) and volleyball (10.1%). Gender difference existed in choosing PA participation, with male students favoring basketball (54.1%) and football (32.2%), whilst females preferring badminton (26.9%) and dance (14.6%).

Table 4 summarizes the numbers and consequences of reported PARI among the 1081 injured participants before and after being stratified by gender. In the past 12 months, around one quarter of the injured (26.4%) experienced PARIs three times or more. More than half of the students reported that they immediately stopped the activity and/or could not participate in the next planned activity (58.5%), or sought medical care (55.0%) after getting injured. Males were inclined to experience multiple PARI episodes (≥ three injury episodes) and breaks from PA participation than their counterparts.

Table 4 Numbers and consequences of physical activity-related injury (PARI) among injured university students in China (N=1081)

Characteristics	All (N=1081) n (%)	Male (N=367) n (%)	Female (N=714) n (%)	χ^2	*P*-value
Numbers of PARI episodes				29.837	<0.001
1	534 (49.4)	146 (39.8)	388 (54.3)		
2	262 (24.2)	89 (24.3)	173 (24.2)		
≥3	285 (26.4)	132 (36.0)	153 (21.4)		
Consequences of PARI					
Stop quickly and/or can't participate in the next PA				4.084	0.044
No	449 (41.5)	137 (37.3)	312 (43.7)		
Yes	632 (58.5)	230 (62.7)	402 (56.3)		
Being absent from class				2.416	0.120
No	778 (72.0)	275 (74.9)	503 (70.4)		
Yes	303 (28.0)	92 (25.1)	211 (29.6)		
Seeking medical attention				0.267	0.605
No	486 (45.0)	169 (46.0)	317 (44.4)		
Yes	595 (55.0)	198 (54.0)	397 (55.6)		

Discussion

A total of 4758 university students in China completed the online questionnaire

survey. PARI experiences in the past 12 months were prevalent among the samples, with an overall incidence rate of 22.7%. Among the 1081 injured participants, the majority of the injured experienced a time loss from PA or required medical care due to the injuries. Multivariate analyses revealed that males, Shantou students, Year 1 students, sports team members, and those with a chronic disease/symptom were more vulnerable to sustain PARI. PA engagements, no matter at which intensity (MPA, VPA, or MVPA), in which domain (domestic/work/study, transportation, or sports and leisure-time), or by which parameter (frequency, duration, or volume), were all significantly and positively related with PARI. Of them, the frequency of sports and leisure-time VPA participation was the strongest PA indicator after controlling for both socio-demographic and life-style variables (adjusted OR: 1.079, 95% CI: 1.018-1.144). Moreover, insufficient sleep was common, and these students tended to suffer from PARI, especially those with sleep duration less than six hours per day.

To our best knowledge, it is the first of this kind of publications to investigate the epidemic and risk factors of PARI among general university students. In this study, one out of five participants (22.7%) experienced PARI in the past 12 months, suggesting that PARI was common among this population. The problem should not be ignored, especially under the contemporary global campaign to promote PA for the health for all. Apart from the direct adverse effects on physical health, according to the earlier reports, PARI can also result in fear or even discontinuity of engaging in similar activities or movements, and further lead to the reduced PA level.[11 12] Those

consequences are against the initial purpose of PA promotion for health. Though we did not investigate detailed consequences for each PARI episode, our results still revealed that more than half of the injured experienced PA absenteeism or required medical attention. There is an urgent call for effective strategies to reduce injuries when undertaking physical activities. Otherwise, the effectiveness of the global campaign would be compromised.

We found that males were more vulnerable to PARI than females, which is highly consistent with other research.[20 21] Several reasons may contribute to the discrepancy: 1) males are more active than females. In our study, male students held higher values than females for all PA indicators (see supplementary tables S2 and S3), supporting this possibility; 2) males are more likely to participate in competitive team sports, such as basketball and football. Most of these sports involve a high rate of contact, jumping, sprinting and/or pivoting, which are often involved in the mechanism of injury.[22] The gender difference in favorite activities in this study is in line with this explanation; 3) even in the same activity, males are also more prone to experience injuries due to high competitiveness and resistance.[23] Collectively, males have a greater tendency to experience PARI than females. Future sex-specific interventions should address the discrepancy.

As showed in our study, approximately 70% of the participants were physically active according to the WHO's recommendations (70.2%), with the prevalence being higher than those found in other similar studies on Chinese university students (in

which PA levels were also self-reported).[24] Increased PA has been reported in several recent studies as a result of the global PA promotion campaign.[25] In the past decades, the Chinese government has been making great efforts to promote PA. Our results may also reflect its positive effect on university students. Nevertheless, individuals turn to over-reporting their PA levels, as it is a socially desirable behavior.[26] We could not avoid this possibility, which might have resulted in the over-estimated PA levels of the participants. However, it may not be reasonable to assume that students with PARI would be more (or less) likely to over-report their PA than non-PARI ones. Thus, the estimations of the elevated participation of PA might still be robust.

We found that PA involvements were positively and significantly related with PARI occurrences, with the frequency of sports and leisure-time VPA participation being the predominant risk factor. Highly consistent results have been found on the elevated risks of some training characteristics for injuries, including high frequency, high vigorous intensity, and long duration,[23 27] which should receive sufficient attentions from researchers and policy-makers when promoting PA among the public. Unfortunately, neither the WHO's information sheet on recommended PA, which is most commonly disseminated to the public, nor its full report provides any suggestion on frequency and duration for safety.[4] It is stated in the full report that "activity-related adverse events such as musculoskeletal injuries are common but are usually minor especially for moderate-intensity activities such as walking."[4] However, PARI may not be as minor as it states if a full consideration was given on both

short-term and long-term adverse effects on health.[11 28] For instances, acutely, PARI counts for the largest proportion of non-fatal injuries, a top health problem among young adults.[9] Chronically, previous joint injury history, a major type of PARI, was found to increase the likelihood of osteoarthritis by 2.8- to 6.4-fold.[28] Osteoarthritis is the most common single cause of disability in the elderly, affecting about 15% of the entire population.[29] There are several recommendations related to frequency and duration existing. For example, the American Diabetes Association (ADA) suggests a frequency of MVPA at least three days per week with a non-exercise interval less than two consecutive days, and that of resistance exercise at least two times per week on non-consecutive days.[30] A training frequency of three to five days per week at an intensity level of 55/65% to 90% of maximum heart rate and a duration of 20-60 minutes of continuous or intermittent of aerobic activity are recommended for developing and maintaining fitness effects.[31] However, none of them is made for the safety purpose. Obviously, there is a knowledge gap in safe frequency and duration of PA (in particular VPA), which warrants further studies. In addition, safety issues should be emphasized and disseminated to the public along with the recommendations.

In this study, Year 1 students, sports team members, and those with insufficient sleep duration were more likely to suffer from PARI. Two possibilities might be attributed to the higher injury risk among Year 1 students: 1) after being released from heavy academic burdens undertaken in secondary schools and becoming independent

from their parents, there might be a sharp increase in PA among them and result in the elevated risk for injury;[13] 2) they are younger than those in Years 2 and 3. Thus, adventurousness and impulsiveness inherent in youth, with relatively poor self-restraint might also play a role.[32 33] Compared to their counterparts, sports team members in this study had about 2-fold greater possibility to suffer from PARI. This further proves that we may not simply apply the results observed from collegiate athletes to the general students. Insufficient sleep duration may increase the risk for PARI via physical fatigue and impaired cognitive performance, such as cognitive slowing and decreased vigilance.[34]

To our surprise, we found that the PARI incidence rate among Shantou students was twice as high as that in the other two cities (33.9% vs. 12.3% and 15.0%), which could not be explained by all variables in this study, including study year, sports team members, PA indicators, and sleep duration (see supplementary tables S4 and S5). In addition, incidence rates of the two participating universities in Shantou were also similarly high (30.1% and 35.4% respectively). Both Shantou and Hong Kong are located in southern China, sharing with similar climate and its related sports habits, whilst Jinan is a northern city. Thus, it may be impossible that the large between-city difference in PARI was attributable to the geographical factors. Though the sports infrastructure of a university might have potential influences on PARI occurrences among its students, both Shantou and Jinan belong to Mainland China, where sports facilities and surveillance system across universities are similar. We therefore ruled

out this possibility. In addition, economically, Shantou is the least developed among the three cities, its less developed urban environments outside universities might have contributed to its highest PARI incidence rate.[35] Unfortunately, we could not provide supporting evidence on this hypothesis, as we did not collect detailed information about places of the PARI occurrences. It is worth further studying on the possible reasons of the large between-city difference in PARI.

Conclusions

We concluded that PARI was common among university students in China. The frequency of sports and leisure-time VPA participation was the strongest risk factor among all PA variables. In addition, males, Shantou students, Year 1 students, sports team members, and those with insufficient sleep were more vulnerable to PARI. Further studies, with a prospective study design and adopting both objective and subjective PA measurements, are warranted to confirm our findings. Nevertheless, there is an urgent call for actions to prevent university students from PARI, with a full consideration of the risk factors found in this study. Safety issues should also be involved and emphasized when promoting PA among the public.

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Table S1 Risks of life-style variables for physical activity-related injury (PARI) among university students in China

Characteristics	All (N=4758) mean ± SD	Non-PARI (N=3677) mean ± SD	PARI (N=1081) mean ± SD	Adjusted OR	95% CI
Domestic/work/study					
VPA[1]					
Frequency, d/week	0.76±1.421	0.70±1.365	0.99±1.576	1.168***	1.111～1.228
Duration, min/d	15.38±35.438	13.69±31.560	23.14±45.522	1.008***	1.006～1.010
Volume, min/week	41.50±110.929	35.14±99.929	63.13±140.018	1.002***	1.001～1.002
MPA[2]					
Frequency, d/week	1.48±1.849	1.39±1.818	1.81±1.917	1.124***	1.082～1.167
Duration, min/d	23.49±40.429	20.80±35.704	32.64±52.486	1.005***	1.004～1.007
Volume, min/week	64.85±147.661	55.46±120.500	96.80±212.822	1.001***	1.001～1.002
MVPA[3]					
Volume, min/week	106.35±213.513	90.60±181.366	159.93±291.752	1.001***	1.001～1.002
Transportation					
MPA[2]					
Frequency, d/week	4.06±2.671	3.98±2.691	4.33±2.584	1.030*	1.003～1.059
Duration, min/d	35.29±43.228)	34.08±39.866	39.42±52.909	1.002**	1.001～1.004
Volume, min/week	184.92±279.290	176.48±254.442	213.61±349.498	1.002***	1.001～1.003
Sports and leisure-time					
VPA[1]					
Frequency, d/week	0.87±1.477	0.78±1.414	1.19±1.634	1.171***	1.116～1.229
Duration, min/d	20.09±36.454	17.37±33.594	29.34±43.604	1.008***	1.006～1.011
Volume, min/week	49.90±118.395	41.10±101.766	79.79±159.167	1.002***	1.001～1.003
MPA[2]					
Frequency, d/week	1.39±1.819	1.30±1.786	1.73±1.892	1.125***	1.082～1.169
Duration, min/d	22.87±34.299	20.90±32.247	29.58±39.802	1.006***	1.004～1.008
Volume, min/week	60.48±118.560	53.41±103.125	84.56±158.007	1.002***	1.001～1.002
MVPA[3]					
Volume, min/week	110.39±200.961	94.52±172.085	164.35±270.769	1.001***	1.001～1.002
Total VPA[1]					
Volume, min/week	91.40±198.722	76.25±173.784	142.92±260.208	1.001***	1.001～1.002
Total MPA[2]					
Volume, min/week	310.25±401.051	285.35±344.310	394.98±543.731	1.001***	1.001～1.001
Total MVPA[3]					
Volume, min/week	401.65±516.546	361.60±439.591	537.90±702.472	1.001***	1.000～1.001
	n (%)	*n (%)*	*n (%)*		
Sedentary behaviors					
<4.00 h/d	*590 (12.4)*	*459 (77.8)*	*131 (22.2)*	1 (ref.)	
4.00-5.99 h/d	*869 (18.3)*	*664 (76.4)*	*205 (23.6)*	1.119	0.859～1.459
6.00-8.99 h/d	*1453 (30.5)*	*1119 (77.0)*	*334 (23.0)*	0.983	0.769～1.258
9.00-11.99 h/d	*978 (20.6)*	*752 (76.9)*	*226 (23.1)*	0.940	0.721～1.225

≥12.00 h/d	*868 (18.2)*	*683 (78.7)*	*185 (21.3)*	0.795	0.604～1.045
Sleep duration					
7.00-7.99 h/d	*1882 (39.6)*	*1493 (79.3)*	*389 (20.7)*	1 (ref.)	
<6.00 h/d	*287(6.0)*	*223 (77.7)*	*64 (22.7)*	1.428*	1.032～1.977
6.00-6.99 h/d	*969 (20.4)*	*708 (73.0)*	*261 (27.0)*	1.425***	1. 175～1.729
8.00-8.99 h/d	*1186 (24.9)*	*916 (77.2)*	*270 (22.8)*	1.131	0.939～1.361
≥ 9.00 h/d	*434 (9.1)*	*337 (77.6)*	*97 (22.4)*	1.020	0.782～1.331

#: $P<0.10$; *: $P<0.05$; **: $P<0.01$; ***: $P<0.001$.

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

Adjusted ORs and 95% CIs of each life-style variable were calculated after controlling for the significant socio-demographic variables in Table 1, including city, study year, gender, university/other sports team member, and any chronic disease/symptom.

Table S2 Comparison of all PA indicators between-gender among university students in China (N=4758)

Characteristics	Male (N=1343) mean ± SD	Female (N=3415) mean ± SD	Z	*P*-value
Domestic/work/study				
VPA[1]				
Frequency, d/week	1.19±1.691	0.60±1.260	-13.763	<0.001
Duration, min/d	25.96±43.060	11.85±31.061	-14.181	<0.001
Volume, min/week	72.85±150.714	29.17±87.625	-14.336	<0.001
MPA[2]				
Frequency, d/week	1.81±1.897	1.36±1.814	-9.007	<0.001
Duration, min/d	29.63±40.040	21.08±40.332	-10.488	<0.001
Volume, min/week	85.94±166.422	56.56±138.744	-10.352	<0.001
MVPA[3]				
Volume, min/week	158.80±267.748	85.72±183.939	-13.226	<0.001
Transportation				
MPA[2]				
Frequency, d/week	4.30±2.700	3.97±2.654	3.867 [a]	<0.001
Duration, min/d	36.96±45.340	34.64±42.358	-1.571	0.116
Volume, min/week	201.67±291.588	178.33±274.065	-3.496	<0.001
Sports and leisure-time				
VPA[1]				
Frequency, d/week	1.34±1.698	0.69±1.338	-15.195	<0.001
Duration, min/d	32.05±44.364	15.39±31.618	-15.473	<0.001
Volume, min/week	83.45±153.156	36.71±98.458	-15.846	<0.001
MPA[2]				
Frequency, d/week	1.67±1.883	1.29±1.782	-7.851	<0.001

Duration, min/d	28.64±37.019	20.61±32.889	-8.601	<0.001
Volume, min/week	78.74±140.188	53.31±108.066	-8.766	<0.001
MVPA[3]				
Volume, min/week	162.19±257.836	190.01±169.320	-13.808	<0.001
Total VPA[1]				
Volume, min/week	156.30±262.926	65.87±159.819	-17.387	<0.001
Total MPA[2]				
Volume, min/week	366.36±431.825	288.19±386.119	-10.616	<0.001
Total MVPA[3]				
Volume, min/week	522.66±608.699	354.06±467.024	-12.527	<0.001

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

[a]: t-value, the between-group difference was tested by *t*-test.

Table S3 Comparison of all PA indicators between-gender among university students in China (N=4758)

Characteristics	Male (N=1343) median (IQR)	Female (N=3415) median (IQR)	Z	*P*-value
Domestic/work/study				
VPA[1]				
Frequency, d/week	0 (0, 2)	0 (0, 1)	-13.763	<0.001
Duration, min/d	0 (0, 30)	0 (0, 10)	-14.181	<0.001
Volume, min/week	0 (0, 90)	0 (0, 10)	-14.336	<0.001
MPA[2]				
Frequency, d/week	1 (0, 3)	1 (0, 2)	-9.007	<0.001
Duration, min/d	20 (0, 40)	10 (0, 30)	-10.488	<0.001
Volume, min/week	40 (0, 120)	10 (0, 60)	-10.352	<0.001
MVPA[3]				
Volume, min/week	60 (0, 180)	20 (0, 90)	-13.226	<0.001
Transportation				
MPA[2]				
Frequency, d/week	5 (2, 7)	5 (1, 7)	3.867 [a]	<0.001
Duration, min/d	30 (12, 50)	30 (10, 40)	-1.571	0.116
Volume, min/week	135 (40, 240)	120 (30, 210)	-3.496	<0.001
Sports and leisure-time				
VPA[1]				
Frequency, d/week	1 (0, 2)	0 (0, 1)	-15.195	<0.001
Duration, min/d	15 (0, 60)	0 (0, 20)	-15.473	<0.001
Volume, min/week	20 (0, 100)	0 (0, 30)	-15.846	<0.001
MPA[2]				

Frequency, d/week	1 (0, 3)	0 (0, 2)	-7.851	<0.001
Duration, min/d	20 (0, 40)	0 (0, 30)	-8.601	<0.001
Volume, min/week	40 (0, 100)	0 (0, 75)	-8.766	<0.001
MVPA[3]				
Volume, min/week	90 (0, 210)	30 (0, 120)	-13.808	<0.001
Total VPA[1]				
Volume, min/week	60 (0, 180)	0 (0, 60)	-17.387	<0.001
Total MPA[2]				
Volume, min/week	250 (120, 450)	180 (80, 340)	-10.616	<0.001
Total MVPA[3]				
Volume, min/week	360 (170, 645)	230 (105, 420)	-12.527	<0.001

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

[a]: t-value, the between-group difference was tested by *t*-test.

Table S4 Comparison of all related variables among university students in three Chinese cities (N=4758)

Characteristics	Shantou (N=2123) mean ± SD	Jinan (N=1267) mean ± SD	Hong Kong (N=1368) mean ± SD	χ^{2} [b]	*P*-value
Domestic/work/study					
VPA[1]					
Frequency, d/week	0.49±1.211	0.65±1.360	1.30±1.618	430.847	<0.001
Duration, min/d	9.54±30.385	11.95±26.858	29.20±44.886	459.346	<0.001
Volume, min/week	26.26±97.002	29.63±84.260	76.13±141.237	451.585	<0.001
MPA[2]					
Frequency, d/week	1.37±1.794	1.39±1.818	1.35±1.630	41.561	<0.001
Duration, min/d	22.04±46.981	20.96±28.376	28.09±38.545	54.763	<0.001
Volume, min/week	62.81±179.510	65.11±110.745	67.79±120.332	37.396	<0.001
MVPA[3]					
Volume, min/week	89.07±233.198	94.75±157.456	143.92±221.951	162.353	<0.001
Transportation					
MPA[2]					
Frequency, d/week	4.19±2.677	4.19±2.719	3.75±2.593	13.264 [a]	<0.001
Duration, min/d	33.48±37.862	36.06±36.294	37.40±55.204	12.776	0.002
Volume, min/week	183.04±243.689	184.01±229.371	188.67±361.267	13.614	0.001
Sports and leisure-time					
VPA[1]					
Frequency, d/week	0.66±1.330	0.91±1.590	1.16±1.532	167.345	<0.001
Duration, min/d	13.43±28.847	18.12±30.861	32.26±47.221	215.755	<0.001
Volume, min/week	33.30±90.518	43.20±93.836	81.88±162.518	196.872	<0.001

MPA[2]					
Frequency, d/week	1.29±1.789	1.73±2.029	1.25±1.610	53.535	<0.001
Duration, min/d	19.49±31.618	25.21±39.452	25.96±39.452	48.271	<0.001
Volume, min/week	53.45±115.262	67.89±107.243	64.54±132.276	52.548	<0.001
MVPA[3]					
Volume, min/week	86.75±170.705	111.09±161.263	146.42±262.774	89.474	<0.001
Total VPA[1]					
Volume, min/week	59.56±164.161	72.83±155.848	158.01±258.381	428.887	<0.001
Total MPA[2]					
Volume, min/week	299.29±378.162	317.01±334.969	321.00±483.178	15.821	<0.001
Total MVPA[3]					
Volume, min/week	358.85±469.466	389.84±408.753	479.01±650.137	41.574	<0.001
	n (%)	*n (%)*	*n (%)*		
Study year				147.006	<0.001
Year 1	*698 (32.9)*	*453 (35.8)*	*345 (25.2)*		
Year 2	*691 (32.5)*	*443 (35.0)*	*328 (24.0)*		
Year 3	*734 (34.6)*	*371 (29.3)*	*695 (50.8)*		
University sports team member				99.654	<0.001
No	*1977 (93.1)*	*1153 (91.0)*	*1132 (82.7)*		
Yes	*146 (6.9)*	*114 (9.0)*	*236 (17.3)*		
Other sports team member				0.732	0.694
No	*1989 (93.7)*	*1196 (94.4)*	*1287 (94.1)*		
Yes	*134 (6.3)*	*71 (5.6)*	*81 (5.9)*		
Sleep duration				338.655	<0.001
7.00-7.99 h/d	*69 (3.3)*	*29 (2.3)*	*189 (13.8)*		
<6.00 h/d	*406 (19.1)*	*187 (14.8)*	*376 (27.5)*		
6.00-6.99 h/d	*841 (39.6)*	*608 (48.0)*	*433 (31.7)*		
8.00-8.99 h/d	*563 (26.5)*	*353 (27.9)*	*270 (19.7)*		
≥ 9.00 h/d	*244 (11.5)*	*90 (7.1)*	*100 (7.3)*		

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

[a]: *F*-value, tested by one-way ANOVA.

[b]: The between-group differences of study year, university/other sports team member, and sleep duration were tested by Pearson chi-square tests, and 20 PA-related variables were tested by Kruskal-Wallis H tests.

Table S5 Comparison of all related variables among university students in three Chinese cities (N=4758)

Characteristics	Shantou (N=2123) median (IQR)	Jinan (N=1267) median (IQR)	Hong Kong (N=1368) median (IQR)	$\chi^{2\,b}$	*P*-value
Domestic/work/study					

VPA[1]					
Frequency, d/week	0 (0, 0)	0 (0, 1)	1 (0, 2)	430.847	<0.001
Duration, min/d	0 (0, 0)	0 (0, 10)	10 (0, 40)	459.346	<0.001
Volume, min/week	0 (0, 0)	0 (0, 10)	15 (0, 90)	451.585	<0.001
MPA[2]					
Frequency, d/week	1 (0, 2)	1 (0, 3)	1 (0, 2)	41.561	<0.001
Duration, min/d	10 (0, 30)	15 (0, 30)	20 (0, 40)	54.763	<0.001
Volume, min/week	10 (0, 60)	30 (0, 90)	30 (0, 90)	37.396	<0.001
MVPA[3]					
Volume, min/week	20 (0, 80)	40 (0, 120)	60 (0, 180)	162.353	<0.001
Transportation					
MPA[2]					
Frequency, d/week	5 (2, 7)	5 (2, 7)	4 (1, 6)	13.264 [a]	<0.001
Duration, min/d	30 (10, 40)	30 (15, 50)	30 (10, 40)	12.776	0.002
Volume, min/week	140 (40, 210)	120 (40, 210)	100 (30, 210)	13.614	0.001
Sports and leisure-time					
VPA[1]					
Frequency, d/week	0 (0, 1)	0 (0, 1)	1 (0, 2)	167.345	<0.001
Duration, min/d	0 (0, 15)	0 (0, 30)	10 (0, 60)	215.755	<0.001
Volume, min/week	0 (0, 20)	0 (0, 60)	10 (0, 90)	196.872	<0.001
MPA[2]					
Frequency, d/week	0 (0, 2)	1 (0, 3)	1 (0, 2)	53.535	<0.001
Duration, min/d	0 (0, 30)	20 (0, 30)	10 (0, 30)	48.271	<0.001
Volume, min/week	0 (0, 80)	30 (0, 90)	15 (0, 78.75)	52.548	<0.001
MVPA[3]					
Volume, min/week	30 (0, 100)	60 (0, 150)	60 (0, 180)	89.474	<0.001
Total VPA[1]					
Volume, min/week	0 (0, 60)	0 (0, 90)	60 (0, 180)	428.887	<0.001
Total MPA[2]					
Volume, min/week	200 (90, 360)	210 (100, 420)	190 (80, 375)	15.821	<0.001
Total MVPA[3]					
Volume, min/week	230 (110, 440)	270 (125, 500)	286.5 (120, 570)	41.574	<0.001
	n (%)	*n (%)*	*n (%)*		
Study year				147.006	<0.001
Year 1	*698 (32.9)*	*453 (35.8)*	*345 (25.2)*		
Year 2	*691 (32.5)*	*443 (35.0)*	*328 (24.0)*		
Year 3	*734 (34.6)*	*371 (29.3)*	*695 (50.8)*		
University sports team member				99.654	<0.001
No	*1977 (93.1)*	*1153 (91.0)*	*1132 (82.7)*		
Yes	*146 (6.9)*	*114 (9.0)*	*236 (17.3)*		
Other sports team member				0.732	0.694
No	*1989 (93.7)*	*1196 (94.4)*	*1287 (94.1)*		
Yes	*134 (6.3)*	*71 (5.6)*	*81 (5.9)*		

Sleep duration				338.655	<0.001
7.00-7.99 h/d	*69 (3.3)*	*29 (2.3)*	*189 (13.8)*		
<6.00 h/d	*406 (19.1)*	*187 (14.8)*	*376 (27.5)*		
6.00-6.99 h/d	*841 (39.6)*	*608 (48.0)*	*433 (31.7)*		
8.00-8.99 h/d	*563 (26.5)*	*353 (27.9)*	*270 (19.7)*		
≥ 9.00 h/d	*244 (11.5)*	*90 (7.1)*	*100 (7.3)*		

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

[a]: *F*-value, tested by one-way ANOVA.

[b]: The between-group differences of study year, university/other sports team member, and sleep duration were tested by Pearson chi-square tests, and 20 PA-related variables were tested by Kruskal-Wallis H tests.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-9
Bias	9	Describe any efforts to address potential sources of bias	*None*
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10
		(*b*) Describe any methods used to examine subgroups and interactions	10
		(*c*) Explain how missing data were addressed	None
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	None
		(*e*) Describe any sensitivity analyses	None
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	None
		(c) Consider use of a flow diagram	None
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11 & 12
		(b) Indicate number of participants with missing data for each variable of interest	None
Outcome data	15*	Report numbers of outcome events or summary measures	11, 16 & 17
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-16
		(*b*) Report category boundaries when continuous variables were categorized	13-15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	None
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	16 & 17
Discussion			
Key results	18	Summarise key results with reference to study objectives	17 &18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	3 & 4 & 19 & 21 &22
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	23
Generalisability	21	Discuss the generalisability (external validity) of the study results	None
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	4

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Physical activity-related injuries among university students: a multi-center cross-sectional study in China

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Title: Physical activity-related injuries among university students: A multi-center cross-sectional study in China

Running title: Physical activity-related injury among youth

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Abstract

Objectives: This study aimed to investigate the epidemiologic characteristics and preliminarily explore possible risk factors of physical activity-related injury (PARI) occurrences among Chinese university students via a multi-center mixed survey.

Design: Cross-sectional study.

Participants: A total of 4758 undergraduates graded 1-3 in nine universities in three Chinese cities were enrolled via cluster random sampling and completed the self-administered online questionnaires during March and April, 2017.

Main outcome measures: PARI in the past 12 months.

Results: Of the 4758 participants, 1081 sustained PARI in the past 12 months, with an overall PARI incidence rate of 22.7% (27.3% [367/1343] in males and 20.9% [714/3415] in females). Around one quarter of the injured (26.4%) suffered from PARI over at least three episodes. More than half of the injured subjects experienced physical activity (PA) absenteeism and sought medical attention. All PA indictors were significantly and positively associated with PARI, with a frequency of sports and leisure-time vigorous-intensity PA (VPA) participation being the strongest (adjusted OR: 1.079, 95% CI: 1.018-1.144). Moreover, males (OR=1.199), Shantou students (OR=4.239), Year 1 students (OR=1.287), university and other sports team members (OR=1.717-2.360), and those with insufficient sleep time (OR=1.262-1.333) were also at a higher risk of PARI.

Conclusions: PARI is prevalent among university students in China. The frequency of sports and leisure-time VPA participation was most strongly associated with PARI among all PA indicators. These data can inform future programs for injury-intervention among university students. Safety issues should also be emphasized when promoting PA among the public to reduce PARI.

Article summary

Strengths and limitations of this study

1) This is the first study to explore the epidemic and possible risk factors of PARI among Chinese general university students.

2) The cross-sectional study design limits causal and temporal inferences.

3) All information was self-reported, which may have resulted in recall bias and reporting bias and therefore somewhat limits our results.

4) We could not investigate activity-specific PARI occurrences because the Global Physical Activity Questionnaire (GPAQ) does not capture the specific activities that the participants undertook.

Funding statement

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Competing interests

The authors declare that they have no competing interests.

Introduction

Physical, social and psychological benefits of engaging in regular physical activity (PA) have been well documented, including increased cardiorespiratory and muscular fitness and bone density and reduced risks for non-communicable diseases.[1-3] Insufficient PA has been recognized as one of the top three risk behaviours in the development of morbidity and mortality associated with cardiovascular diseases and other major chronic diseases, such as diabetes and obesity.[4] To achieve and maintain optimal individual health, the World Health Organization (WHO) has recommended that adults (18-64 years old) undertake at least 150 minutes of moderate-intensity PA (MPA) or at least 75 minutes of vigorous-intensity PA (VPA), or an equivalent combination of moderate- and vigorous-intensity PA (MVPA) every week.[4] In light of these advantages and recommendations of PA participation, almost all countries and regions of the world promote PA.

Although the promotion of PA is a public health priority, being physically active can also increase the risk of injury.[5-7] Physical activity-related injury (PARI), also known as sports and recreational activity-related injury, is any injury resulting from participation in physical education (PE) class, sports activities, or leisure time PA, e.g., sprains, strains, fractures, and contusions.[8] In fact, PARI contributes mostly to all non-fatal injuries and is the one health threat to relatively healthy adolescents and young adults in many countries.[4 9] Over the long term, it can also increase the risk of

future injuries, osteoarthritis, and other health problems later in life.[10] PARI may also be a barrier to adopting a more active lifestyle, which may further hinder people from achieving optimal health.[11 12]

Injury incidence is well documented among many active populations. For example, the injury incidence densities among soccer players were 8.07-8.44/1000 athlete exposures (AE),[13] and tennis players were 4.88-4.89/1000 AE.[14] However, there are knowledge gaps about the PARI incidence in the general population. To obtain better understanding on these research questions, we conducted a series of studies. Prior studies revealed that about 25.1%-32.4% of primary and secondary school students in two Chinese cities had suffered from PARI in the past 12 months, suggesting that PARI is prevalent among children and adolescents.[8 15] In China, students in universities might be more active than those in primary and secondary schools because they have been released from heavy academic burdens and pressure for university admission. Moreover, they become independent of their parents and are therefore more likely to engage in relatively risky activities that their parents might not allow prior.[16] Thus, university students might be more vulnerable to PARI.

While there is ample evidence about PARI among collegiate athletes, it might not be suitable for general students because of the significant differences in risk factors between the two groups, such as sports skills, training intensity, competition level, and cardiorespiratory/muscle fitness.[17 18] We therefore conducted a multi-center cross-sectional study among a sample of general university students in

China, funded by the National Natural Science Foundation of China (Grant No. 31640038), to obtain a better understanding of the PARI epidemic. This paper presents a baseline survey and reports the epidemiologic characteristics and preliminary risk factors of PARI among Chinese university students.

Methods

Study Participants

The study was conducted at nine universities in Jinan, Shantou, and Hong Kong (eight comprehensive universities and one normal university). Students at normal university in China are trained to become teachers in kindergartens and primary and secondary schools. These cities represent northern, southern, and special regions of China, respectively. The cluster random sampling method was used to identify 5115 eligible students in Years 1-3. These persons were invited to participate in the study in March and April, 2017. Seniors (students in Years 4) were excluded because they are in the transition period to work, and their university lives are significantly different from the others. In addition, those majoring in PE were further excluded from data analysis because they differ significantly from the others in terms of PA/sports related factors. Finally, 4758 students in Years 1-3 completed the online survey, with a response rate of about 93.0%.

Data collection

Qualtrics software (Qualtrics, Provo, UT) was used as the online platform for the

baseline questionnaire survey. Participants were enrolled in classes or dormitories. The online questionnaire was self-administered and consisted of demographics, PA habits, sedentary behaviours, sleep duration, and PARI experiences in the past 12 months.

The demographic variables included university, study major, study year, gender, age, residence type (dormitory, home, or others), any diagnosed chronic disease/symptom, and sports team membership.

Participants' PA levels in a typical week in the past 12 months were evaluated using the Global Physical Activity Questionnaire (GPAQ) Chinese version.[19] It is one of the most commonly used PA questionnaires and has sound reliability and validity (Spearman's rho=0.81, kappa=0.65).[20 21] The GPAQ collects frequency (days/week) and duration (cumulative minutes/day) of VPA and MPA in three domains: domestic/work/study, transportation (MPA only), and sports and leisure-time activities. The PA volume (cumulative minutes/week) was then calculated by duration multiplied by frequency for each category of PA (VPA, MPA, and MVPA) in each domain and overall to generate 20 PA-related variables. The GPAQ does not provide information on the students' specific activities, and all participants were further asked whether they had any favourite sports or recreational activities in the past 12 months. Those with a positive answer were further requested to provide the names of the activities (no more than three).

In terms of sedentary behaviours and sleep, the duration (hours/day) was asked on both a typical weekday and a typical weekend. The average daily duration in a week was then calculated and used to group the students into five categories.

For this study, a countable PARI must meet at least one of the following three consequences: 1) the student has to immediately stop the PA and/or cannot participate in the next planned PA; and/or 2) the student is absent from class the next day; and/or 3) the student needs to seek medical attention (including local first aids but excluding bandages only).[8] Persons suffering from such a PARI in the past 12 months were asked to report the number of PARI in each category.

Ethics approval

This study was strictly conducted in accordance with the Declaration of Helsinki. Prior to approaching potential subjects, approval was obtained from Shantou University Medical College ethics committee, Shandong University ethics committee, and Hong Kong Baptist University ethics committee. During a plenary session, explanatory statements and consent forms were distributed to all potential participants, and the hyperlink or QR code of questionnaire was subsequently given to the consenting students in the target classes or dormitories. The purpose and meaning of our study was verbally explained to the subjects prior to their completion of the questionnaires, and our trained personnel answered any questions that arose during the session.

Statistical analysis

Statistical analyses were performed using SPSS version 19.0 (SPSS Inc. Chicago, IL, USA). Continuous data that is normally (i.e., age) or not normally distributed (i.e., 20 PA-related variables) was described using mean (standard deviation, SD) or median (inter-quartile, IQR), respectively; categorical variables were presented as number (percentage). The Pearson chi-square tests were applied to evaluate the numbers and consequences of PARI between females and males—both univariate and multivariate logistic regression were fitted to estimate the risk of each study variable for PARI, where crude and adjusted odds ratios (ORs) and their 95% confidence intervals (95% CIs) were generated, respectively.

Three steps were undertaken in the multivariate analyses. In step one, all socio-demographic variables were selected in both forward and backward manners (likelihood ratio), with a selection criteria of α_{in}=0.10 and α_{out}=0.15. Adjusted ORs and 95% CIs of the variables remaining in the final model (i.e., significant variables) were calculated and derived from, including city, study year, gender, university/other sports team member, and any chronic disease/symptom. For variables outside of the final model (i.e., insignificant variables, including age and residence type), their adjusted ORs and 95% CIs were obtained after controlling for the significant variables (Table 1). In step two, the risk of each lifestyle variable (including PA habits, sedentary behaviours, and sleep duration) was assessed after controlling for the significant socio-demographic variables in the first step (Table 2). In step three, a

hierarchical model was performed to consider all significant study variables together, with socio-demographic variables selected in the first block and lifestyle variables in the second (Table 3). A two-sided *p*-value less than 0.05 was considered statistically significant for all tests.

Patient involvement

No patients were involved in the development of the research question or the outcome measures, nor were they involved in developing plans for design or implementation of the study. There are no plans to disseminate the results of the research to study participants.

Results

Table 1 presents the distribution of the social-demographic characteristics and their risk estimations for PARI. Overall, the 4758 participants aged from 17 to 25 years old, with a mean age of 20.00 (SD: 1.382). More students were females (71.8%), living in dormitory (61.1%), and studying in Shantou (44.6%). Few students were university/other sports team members (10.4%/6.0%) or living with any chronic condition (3.7%). About 1081 students (22.7%) suffered from at least one PARI in the past 12 months, with a significantly higher incidence found in both types of sports team members and those living with chronic conditions (adjusted ORs: 1.561-3.136). In addition, students in Shantou, males, and those in Years 1 were more likely to experience PARI than their counterparts (adjusted ORs: 1.397-3.932). Age and

residence type were not significantly associated with PARI.

Table 1 Risks of socio-demographic characteristics for physical activity-related injury (PARI) among university students in China

Characteristics	All (N=4758) n (%)	Non-PARI (N=3677) n (%)	PARI (N=1081) n (%)	Adjusted OR	95% CI
City					
Jinan	1267 (26.6)	1111 (87.7)	156 (12.3)	1 (ref.)	
Shantou	2123 (44.6)	1403 (66.1)	720 (33.9)	3.932***	3.230～4.786
Hong Kong	1368 (28.8)	1163 (85.0)	205 (15.0)	1.084	0.841～1.396
Study year					
Year 1	1496 (31.4)	1125 (75.2)	371 (24.8)	1.397**	1.109～1.760
Year 2	1462 (30.7)	1121 (76.7)	341 (23.3)	1.153	0.948～1.401
Year 3	1800 (37.8)	1431 (79.5)	369 (20.5)	1 (ref.)	
Gender					
Male	1343 (28.2)	976 (72.7)	367 (27.3)	1.404***	1.202～1.640
Female	3415 (71.8)	2701 (79.1)	714 (20.9)	1 (ref.)	
Residence type					
Dormitory	2908 (61.1)	2210 (76.0)	698 (24.0)	1 (ref.)	
Home	1742 (36.6)	1377 (79.0)	365 (21.0)	1.016	0.861～1.198
Others	108 (2.3)	90 (83.3)	18 (16.7)	0.820	0.469～1.434
University sports team member					
No	4262 (89.6)	3380 (79.3)	882 (20.7)	1 (ref.)	
Yes	496 (10.4)	297 (59.9)	199 (40.1)	3.136***	2.528～3.889
Other sports team member					
No	4472 (94.0)	3512 (78.5)	960 (21.5)	1 (ref.)	
Yes	286 (6.0)	165 (57.7)	121 (42.3)	2.182***	1.678～2.838
Any chronic disease/symptom					
No	4583 (96.3)	3563 (77.7)	1020 (22.3)	1 (ref.)	
Yes	175 (3.7)	114 (65.1)	61 (34.9)	1.561*	1.111～2.195
Age ($\bar{x}$±s, years)	20.00±1.382	20.01±1.426	19.98±1.386	0.983	0.934～1.146

*: $p<0.05$; **: $p<0.01$; ***: $p<0.001$.

Adjusted ORs and 95% CIs of significant variables were calculated after controlling for each other, including city, study year, gender, university/other sports team member, and any chronic disease/symptom. Adjusted ORs and 95% CIs of insignificant variables (age and residence type) were obtained after controlling for the significant variables.

Table 2 shows the distribution of lifestyle variables and their risk assessments for PARI. Most students were engaged in sports and leisure-time PA (87.5%) and transport-related PA (82.1%). Medians and interquartile ranges (IQRs) for total

volumes of VPA, MPA, and MVPA (min/week) were 0 (0, 100), 60 (0, 150), and 255 (120, 490), respectively. The means and SDs for these 20 PA-related variables are available in supplementary table S1. Overall, 70.2% of university students were physically active according to the WHO's recommended PA for adults.[4] All PA indicators were positively and significantly related with PARI (adjusted ORs: 1.001-1.171), with a risk of the frequency of sports and leisure-time VPA participation being the highest. About 26.4% of students slept less than seven hours per day, and they sustained more PARI events (adjusted ORs: 1.425-1.428).

Table 2 Risks of life-style variables for physical activity-related injury (PARI) among university students in China

Characteristics	All (N=4758) median (IQR)	Non-PARI (N=3677) median (IQR)	PARI (N=1081) median (IQR)	Adjusted OR	95% CI
Domestic/work/study					
VPA[1]					
Frequency, d/week	0 (0, 1)	0 (0, 1)	0 (0, 2)	1.168***	1.111～1.228
Duration, min/d	0 (0, 20)	0 (0, 15)	0 (0, 30)	1.008***	1.006～1.010
Volume, min/week	0 (0, 30)	0 (0, 20)	0 (0, 60)	1.002***	1.001～1.002
MPA[2]					
Frequency, d/week	1 (0, 2)	1 (0, 2)	1 (0, 3)	1.124***	1.082～1.167
Duration, min/d	10 (0, 30)	10 (0, 30)	20 (0, 30)	1.005***	1.004～1.007
Volume, min/week	20 (0, 60)	10 (0, 60)	40 (0, 100)	1.001***	1.001～1.002
MVPA[3]					
Volume, min/week	40 (0, 120)	30 (0, 105)	60 (0, 180)	1.001***	1.001～1.002
Transportation					
MPA[2]					
Frequency, d/week	5 (1, 7)	5 (1, 7)	5 (2, 7)	1.030*	1.003～1.059
Duration, min/d	30 (10, 40)	30 (10, 40)	30 (15, 50)	1.002**	1.001～1.004
Volume, min/week	120 (30, 210)	105 (30, 210)	140 (50, 210)	1.002***	1.001～1.003
Sports and leisure-time					
VPA[1]					
Frequency, d/week	0 (0, 1)	0 (0, 1)	0 (0, 2)	1.171***	1.116～1.229
Duration, min/d	0 (0, 30)	0 (0, 30)	0 (0, 47.5)	1.008***	1.006～1.011
Volume, min/week	0 (0, 60)	0 (0, 38)	0 (0, 90)	1.002***	1.001～1.003

MPA[2]					
Frequency, d/week	1 (0, 2)	0 (0, 2)	1 (0, 3)	1.125***	1.082～1.169
Duration, min/d	10 (0, 30)	0 (0, 30)	20 (0, 40)	1.006***	1.004～1.008
Volume, min/week	15 (0, 80)	0 (0, 75)	40 (0, 90)	1.002***	1.001～1.002
MVPA[3]					
Volume, min/week	45 (0, 130.5)	30 (0, 120)	80 (0, 210)	1.001***	1.001～1.002
Total VPA[1]					
Volume, min/week	0 (0, 100)	0 (0, 80)	40 (0, 180)	1.001***	1.001～1.002
Total MPA[2]					
Volume, min/week	60 (0, 150)	60 (0, 140)	100 (10, 200)	1.001***	1.001～1.001
Total MVPA[3]					
Volume, min/week	255 (120, 490)	235 (105, 450)	340 (180, 630)	1.001***	1.000～1.001
	n (%)	*n (%)*	*n (%)*		
Sedentary behaviors					
<4.00 h/d	*590 (12.4)*	*459 (77.8)*	*131 (22.2)*	1 (ref.)	
4.00-5.99 h/d	*869 (18.3)*	*664 (76.4)*	*205 (23.6)*	1.119	0.859～1.459
6.00-8.99 h/d	*1453 (30.5)*	*1119 (77.0)*	*334 (23.0)*	0.983	0.769～1.258
9.00-11.99 h/d	*978 (20.6)*	*752 (76.9)*	*226 (23.1)*	0.940	0.721～1.225
≥12.00 h/d	*868 (18.2)*	*683 (78.7)*	*185 (21.3)*	0.795	0.604～1.045
Sleep duration					
7.00-7.99 h/d	*1882 (39.6)*	*1493 (79.3)*	*389 (20.7)*	1 (ref.)	
<6.00 h/d	*287 (6.0)*	*223 (77.7)*	*64 (22.7)*	1.428*	1.032～1.977
6.00-6.99 h/d	*969 (20.4)*	*708 (73.0)*	*261 (27.0)*	1.425***	1. 175～1.729
8.00-8.99 h/d	*1186 (24.9)*	*916 (77.2)*	*270 (22.8)*	1.131	0.939～1.361
≥ 9.00 h/d	*434 (9.1)*	*337 (77.6)*	*97 (22.4)*	1.020	0.782～1.331

*: $p<0.05$; **: $p<0.01$; ***: $p<0.001$.

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

Adjusted ORs and 95% CIs of each life-style variable were calculated after controlling for the significant socio-demographic variables in Table 1, including city, study year, gender, university/other sports team member, and any chronic disease/symptom.

Finally, we performed a hierarchical analysis, and Table 3 presents the results of its final model. Risk estimations of socio-demographic variables in Block 1 (including city, gender, study year, and chronic disease/symptom) did not change markedly before and after controlling for lifestyle variables. However, the risks of the two sports team membership variables reduced markedly after adjustment for lifestyle variables. In addition, the frequency and duration of sports and leisure-time VPA,

duration of sports and leisure-time MPA, and sleep duration (in Block 2) were significantly related to PARI, with adjusted ORs slightly decreasing after controlling for socio-demographic variables.

Table 3 Final model of hierarchical logistic regression to estimate risks of both socio-demographic and life-style variables for PARI among university students in China

Characteristics	*p*-value	Adjusted OR	95% CI
Block 1			
City			
Jinan		1 (ref.)	
Shantou	0.000	4.239	3.475～5.171
Hong Kong	0.468	0.913	0.713～1.168
Study year			
Year 1	0.039	1.287	1.099～1.515
Year 2	0. 883	1.014	0.846～1.215
Year 3		1 (ref.)	
Gender			
Male	0.028	1.199	1.020～1.410
Female		1 (ref.)	
University sports team member			
No		1 (ref.)	
Yes	0.000	2.360	1.881～2.961
Other sports team member			
No		1 (ref.)	
Yes	0.000	1.717	1.309～2.253
Any chronic disease/symptom			
No		1 (ref.)	
Yes	0.013	1.548	1.096～2.187
Block 2			
Sports and leisure-time VPA[1], frequency (d/week)	0.010	1.079	1.018～1.144
Sports and leisure-time VPA[1], duration (min/d)	0.000	1.006	1.003～1.008
Sports and leisure-time MPA[2], duration (min/d)	0.000	1.004	1.002～1.006
Sleep duration			
7.00-7.99 h/d		1 (ref.)	
<6.00 h/d	0.045	1.333	1.006～1.766
6.00-6.99 h/d	0.014	1.262	1.048～1.519
8.00-8.99 h/d	0.314	1.111	0.905～1.365
≥ 9.00 h/d	0.692	1.061	0.791～1.425

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

In terms of favourite activities, three fifths of the students (59.7%) reported at least one specific activity that they often enjoyed in the past 12 months. Common favourite activities included running (36.0%), badminton (27.2%), basketball (25.2%), cycling (24.3%), swimming (18.1%), table tennis (15.1%), soccer (14.3%), dance (13.8%), and volleyball (10.1%). Gender difference existed in choosing PA participation with male students favouring basketball (54.1%) and football (32.2%), and females preferring badminton (26.9%) and dance (14.6%).

Table 4 summarizes the numbers and consequences of reported PARI among the 1081 injured participants before and after being stratified by gender. In the past 12 months, around one quarter of the injured participants (26.4%) experienced PARIs three times or more. More than half of the students reported that they immediately stopped the activity and/or could not participate in the next planned activity (58.5%) or sought medical care (55.0%) after getting injured. Males were inclined to experience multiple PARI episodes (≥ three injury episodes) and breaks from PA participation than their counterparts.

Table 4 Numbers and consequences of physical activity-related injury (PARI) among injured university students in China (N=1081)

Characteristics	All (N=1081) n (%)	Male (N=367) n (%)	Female (N=714) n (%)	χ^2	*p*-value
Numbers of PARI episodes				29.837	<0.001
1	534 (49.4)	146 (39.8)	388 (54.3)		
2	262 (24.2)	89 (24.3)	173 (24.2)		
≥3	285 (26.4)	132 (36.0)	153 (21.4)		
Consequences of PARI					
Stop quickly and/or can't participate in the next PA				4.084	0.044

No	449 (41.5)	137 (37.3)	312 (43.7)		
Yes	632 (58.5)	230 (62.7)	402 (56.3)		
Being absent from class				2.416	0.120
No	778 (72.0)	275 (74.9)	503 (70.4)		
Yes	303 (28.0)	92 (25.1)	211 (29.6)		
Seeking medical attention				0.267	0.605
No	486 (45.0)	169 (46.0)	317 (44.4)		
Yes	595 (55.0)	198 (54.0)	397 (55.6)		

Discussion

A total of 4758 university students in China completed the online questionnaire. PARI experiences in the past 12 months were prevalent among the samples, with an overall incidence rate of 22.7%. Of the 1081 injured participants, most injured students experienced a time loss from PA or required medical care due to the injuries. Multivariate analyses indicated that males, Shantou students, Year 1 students, sports team members, and those with a chronic disease/symptom were more vulnerable to sustain PARI. PA engagements—regardless of the intensity (MPA, VPA, or MVPA), domain (domestic/work/study, transportation, or sports and leisure-time), or parameter (frequency, duration, or volume) were all significantly and positively related with PARI. The frequency of sports and leisure-time VPA participation was the strongest PA indicator after controlling for both socio-demographic and lifestyle variables (adjusted OR: 1.079, 95% CI: 1.018-1.144). Moreover, insufficient sleep was common, and these students tended to suffer from PARI—especially those with a sleep duration of less than six hours per day.

To the best of our knowledge, this is the first publication to investigate the

epidemic and risk factors of PARI among general university students. In this study, one out of five participants (22.7%) experienced PARI in the past 12 months, suggesting that PARI was common among this population. The problem should not be ignored—especially under the contemporary global campaign to promote PA for health. Other than the direct adverse effects on physical health, PARI can also result in fear or can even prevent people from exercising, leading to further reduced PA levels.[11 12] Such a consequence is against the initial purpose of PA promotion for health. Though we did not investigate detailed consequences for each PARI episode, our results still revealed that more than half of the injured students experienced PA absenteeism or required medical attention. There is an urgent need for effective strategies to reduce injuries when undertaking physical activities. Otherwise, the effectiveness of the global campaign would be compromised.

We found that males were more vulnerable to PARI than females, which is highly consistent with most previous studies.[22 23] This might be males are more active than females. In our study, male students had higher values than females for all PA indicators (see supplementary tables S2 and S3). Also, males are more likely to participate in competitive team sports, such as basketball and football. Most of these sports involve a high rate of contact, jumping, sprinting and/or pivoting, which are often involved in the mechanism of injury.[24] The gender difference in favourite activities in this study is in line with this explanation. Furthermore, even in the same activity, males are often more prone to experience injuries due to high

competitiveness and resistance than females.[25] Collectively, males have a greater tendency to experience PARI than females. Future sex-specific interventions should address the discrepancy.

Our study shows that approximately 70% of the participants were physically active according to the WHO's recommendations (70.2%), with the prevalence being higher than those found in other similar studies on Chinese university students (in which PA levels were also self-reported).[26] Increased PA has been reported in several recent studies as a result of the global PA promotion campaign.[27] In the past decades, the Chinese government has actively promoted PA. Our results may also reflect its positive effect on university students. Nevertheless, individuals often over-report their PA levels because it is a socially desirable behaviour.[28] We could not avoid this possibility, which might have resulted in over-estimated PA levels of the participants. However, it may not be reasonable to assume that students with PARI would be more (or less) likely to over-report their PA than non-PARI ones. Thus, the estimates of the elevated participation of PA might still be robust.

We found that PA involvements were positively and significantly related with PARI occurrences—the frequency of sports and leisure-time VPA participation was the predominant factor. Highly consistent results have also been found on the elevated risks of some training characteristics for injuries, including high frequency, high vigorous intensity, and long duration.[25 29] These should receive sufficient attentions from researchers and policy-makers when promoting PA among the public.

Unfortunately, the WHO's information sheet on recommended PA (commonly disseminated to the public) does not provide any suggestion on frequency and duration for safety (nor does the WHO's full report).[4] The full report does state that "activity-related adverse events such as musculoskeletal injuries are common but are usually minor especially for moderate-intensity activities such as walking."[4] However, PARI may not be minor if we fully considerate both short-term and long-term adverse effects on health.[11 30] For instance, acute PARI is the largest proportion of non-fatal injuries, which is a top health problem among young adults.[9] Chronically, joint injury (a major type of PARI) was found to increase the likelihood of osteoarthritis by 2.8- to 6.4-fold.[30] Osteoarthritis is the most common single cause of disability in the elderly. It affects about 15% of the entire population.[31]

There are several recommendations related to frequency and duration of exercise. For example, the American Diabetes Association (ADA) suggests a frequency of MVPA at least three days per week with a non-exercise interval less than two consecutive days. Resistance exercise is recommended at least twice per week on non-consecutive days.[32] A training frequency of three to five days per week at an intensity level of 55/65% to 90% of maximum heart rate and a duration of 20-60 minutes of continuous or intermittent aerobic activity are recommended for developing and maintaining fitness effects.[33] However, none of these recommendations are from a safety perspective. Obviously, there is a knowledge gap in the safe frequency and duration of PA (in particular VPA), which warrants further

study. In addition, safety issues should be emphasized and disseminated to the public along with the recommendations.

In this study, Year 1 students, sports team members, and those with insufficient sleep duration were more likely to suffer from PARI. The higher injury among Year 1 students might be because they do more PA after being released from the heavy academic burdens undertaken in secondary schools and becoming independent from their parents.[16] They are younger than those in Years 2 and 3. Thus, the adventurousness and impulsiveness inherent in youth might also play a role.[34 35] Compared to their counterparts, sports team members had a 2-fold greater possibility of suffering from PARI. This further proves that we may not simply apply the results observed from collegiate athletes to the general students. Insufficient sleep duration may increase the risk for PARI via physical fatigue and impaired cognitive performance, such as cognitive slowing and decreased vigilance.[36]

To our surprise, we found that the PARI incidence rate among Shantou students was twice as high as that in the other two cities (33.9% vs. 12.3% and 15.0%), which could not be explained by all variables in this study, including study year, sports team members, PA indicators, and sleep duration (see supplementary tables S4 and S5). In addition, the incidence rates of the two participating universities in Shantou were also similarly high (30.1% and 35.4% respectively). Both Shantou and Hong Kong are located in southern China. They have a similar climate and its related sports habits whilst Jinan is a northern city. Thus, it may be impossible that the large between-city

difference in PARI was attributable to the geographical factors. Though the sports infrastructure of a university might impact PARI among the students, both Shantou and Jinan belong to Mainland China where sports facilities and surveillance systems across universities are similar. We therefore ruled out this possibility. Economically, Shantou is the least developed of the three cities. The less developed urban environments outside of the universities might have contributed to its higher PARI incidence rate.[37] Unfortunately, we could not provide supporting evidence for this hypothesis because we did not collect detailed information about the location of PARI incidents; however, the possible reasons underlying the large between-city PARI differences should be studied.

Several limitations should be considered. First, the cross-sectional study design limits causal and temporal inferences in the risk evaluation analyses. For example, it is plausible that some injured students would rate their PA levels higher if not injured because their PA levels might have been affected by their injuries—this may have resulted in an under-estimation of the PA's risk for injuries. It is also plausible that students who were more often engaged in PA would be more likely to remember their injuries because the injuries might have a greater impact on these students. This possibility may have led us to over-estimate the relationship between PA levels and PARI. PA levels in this study were measured once only, and we could not explain the rationale that PARI contributes to a PA reduction. Our team is conducting a prospective cohort study to confirm these findings. Second, all information was

self-reported, which may have resulted in recall bias (e.g., some participants may have forgotten to report minor and earlier injury episodes) and reporting bias (e.g., some participants may have over-reported their PA levels because it is a socially desirable behaviour). This limits our results somewhat. Finally, we could not investigate activity-specific PARI occurrences because the GPAQ does not capture the specific activities that the participants undertook.

Conclusions

We concluded that PARI was common among university students in China. The frequency of sports and leisure-time VPA participation was most strongly associated with PARI among all PA variables. In addition, males, Shantou students, Year 1 students, sports team members, and those with insufficient sleep were more vulnerable to PARI. Further prospective studies that adopt both objective and subjective PA measurements are warranted to confirm our findings. Nevertheless, there is an urgent call for actions to prevent university students from PARI with a full consideration of the possible risk factors involved. Safety issues should also be involved and emphasized when promoting PA among the public.

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Table S1 Risks of life-style variables for physical activity-related injury (PARI) among university students in China

Characteristics	All (N=4758) mean ± SD	Non-PARI (N=3677) mean ± SD	PARI (N=1081) mean ± SD	Adjusted OR	95% CI
Domestic/work/study					
VPA[1]					
Frequency, d/week	0.76±1.421	0.70±1.365	0.99±1.576	1.168***	1.111～1.228
Duration, min/d	15.38±35.438	13.69±31.560	23.14±45.522	1.008***	1.006～1.010
Volume, min/week	41.50±110.929	35.14±99.929	63.13±140.018	1.002***	1.001～1.002
MPA[2]					
Frequency, d/week	1.48±1.849	1.39±1.818	1.81±1.917	1.124***	1.082～1.167
Duration, min/d	23.49±40.429	20.80±35.704	32.64±52.486	1.005***	1.004～1.007
Volume, min/week	64.85±147.661	55.46±120.500	96.80±212.822	1.001***	1.001～1.002
MVPA[3]					
Volume, min/week	106.35±213.513	90.60±181.366	159.93±291.752	1.001***	1.001～1.002
Transportation					
MPA[2]					
Frequency, d/week	4.06±2.671	3.98±2.691	4.33±2.584	1.030*	1.003～1.059
Duration, min/d	35.29±43.228)	34.08±39.866	39.42±52.909	1.002**	1.001～1.004
Volume, min/week	184.92±279.290	176.48±254.442	213.61±349.498	1.002***	1.001～1.003
Sports and leisure-time					
VPA[1]					
Frequency, d/week	0.87±1.477	0.78±1.414	1.19±1.634	1.171***	1.116～1.229
Duration, min/d	20.09±36.454	17.37±33.594	29.34±43.604	1.008***	1.006～1.011
Volume, min/week	49.90±118.395	41.10±101.766	79.79±159.167	1.002***	1.001～1.003
MPA[2]					
Frequency, d/week	1.39±1.819	1.30±1.786	1.73±1.892	1.125***	1.082～1.169
Duration, min/d	22.87±34.299	20.90±32.247	29.58±39.802	1.006***	1.004～1.008
Volume, min/week	60.48±118.560	53.41±103.125	84.56±158.007	1.002***	1.001～1.002
MVPA[3]					
Volume, min/week	110.39±200.961	94.52±172.085	164.35±270.769	1.001***	1.001～1.002
Total VPA[1]					
Volume, min/week	91.40±198.722	76.25±173.784	142.92±260.208	1.001***	1.001～1.002
Total MPA[2]					
Volume, min/week	310.25±401.051	285.35±344.310	394.98±543.731	1.001***	1.001～1.001
Total MVPA[3]					
Volume, min/week	401.65±516.546	361.60±439.591	537.90±702.472	1.001***	1.000～1.001
	n (%)	*n (%)*	*n (%)*		
Sedentary behaviors					
<4.00 h/d	*590 (12.4)*	*459 (77.8)*	*131 (22.2)*	1 (ref.)	
4.00-5.99 h/d	*869 (18.3)*	*664 (76.4)*	*205 (23.6)*	1.119	0.859～1.459
6.00-8.99 h/d	*1453 (30.5)*	*1119 (77.0)*	*334 (23.0)*	0.983	0.769～1.258
9.00-11.99 h/d	*978 (20.6)*	*752 (76.9)*	*226 (23.1)*	0.940	0.721～1.225

≥12.00 h/d	*868 (18.2)*	*683 (78.7)*	*185 (21.3)*	0.795	0.604～1.045
Sleep duration					
7.00-7.99 h/d	*1882 (39.6)*	*1493 (79.3)*	*389 (20.7)*	1 (ref.)	
<6.00 h/d	*287(6.0)*	*223 (77.7)*	*64 (22.7)*	1.428*	1.032～1.977
6.00-6.99 h/d	*969 (20.4)*	*708 (73.0)*	*261 (27.0)*	1.425***	1. 175～1.729
8.00-8.99 h/d	*1186 (24.9)*	*916 (77.2)*	*270 (22.8)*	1.131	0.939～1.361
≥ 9.00 h/d	*434 (9.1)*	*337 (77.6)*	*97 (22.4)*	1.020	0.782～1.331

#: $P<0.10$; *: $P<0.05$; **: $P<0.01$; ***: $P<0.001$.

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

Adjusted ORs and 95% CIs of each life-style variable were calculated after controlling for the significant socio-demographic variables in Table 1, including city, study year, gender, university/other sports team member, and any chronic disease/symptom.

Table S2 Comparison of all PA indicators between-gender among university students in China (N=4758)

Characteristics	Male (N=1343) mean ± SD	Female (N=3415) mean ± SD	Z	*P*-value
Domestic/work/study				
VPA[1]				
Frequency, d/week	1.19±1.691	0.60±1.260	-13.763	<0.001
Duration, min/d	25.96±43.060	11.85±31.061	-14.181	<0.001
Volume, min/week	72.85±150.714	29.17±87.625	-14.336	<0.001
MPA[2]				
Frequency, d/week	1.81±1.897	1.36±1.814	-9.007	<0.001
Duration, min/d	29.63±40.040	21.08±40.332	-10.488	<0.001
Volume, min/week	85.94±166.422	56.56±138.744	-10.352	<0.001
MVPA[3]				
Volume, min/week	158.80±267.748	85.72±183.939	-13.226	<0.001
Transportation				
MPA[2]				
Frequency, d/week	4.30±2.700	3.97±2.654	3.867 [a]	<0.001
Duration, min/d	36.96±45.340	34.64±42.358	-1.571	0.116
Volume, min/week	201.67±291.588	178.33±274.065	-3.496	<0.001
Sports and leisure-time				
VPA[1]				
Frequency, d/week	1.34±1.698	0.69±1.338	-15.195	<0.001
Duration, min/d	32.05±44.364	15.39±31.618	-15.473	<0.001
Volume, min/week	83.45±153.156	36.71±98.458	-15.846	<0.001
MPA[2]				
Frequency, d/week	1.67±1.883	1.29±1.782	-7.851	<0.001

Duration, min/d	28.64±37.019	20.61±32.889	-8.601	<0.001
Volume, min/week	78.74±140.188	53.31±108.066	-8.766	<0.001
MVPA[3]				
Volume, min/week	162.19±257.836	190.01±169.320	-13.808	<0.001
Total VPA[1]				
Volume, min/week	156.30±262.926	65.87±159.819	-17.387	<0.001
Total MPA[2]				
Volume, min/week	366.36±431.825	288.19±386.119	-10.616	<0.001
Total MVPA[3]				
Volume, min/week	522.66±608.699	354.06±467.024	-12.527	<0.001

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

[a]: t-value, the between-group difference was tested by *t*-test.

Table S3 Comparison of all PA indicators between-gender among university students in China (N=4758)

Characteristics	Male (N=1343) median (IQR)	Female (N=3415) median (IQR)	Z	*P*-value
Domestic/work/study				
VPA[1]				
Frequency, d/week	0 (0, 2)	0 (0, 1)	-13.763	<0.001
Duration, min/d	0 (0, 30)	0 (0, 10)	-14.181	<0.001
Volume, min/week	0 (0, 90)	0 (0, 10)	-14.336	<0.001
MPA[2]				
Frequency, d/week	1 (0, 3)	1 (0, 2)	-9.007	<0.001
Duration, min/d	20 (0, 40)	10 (0, 30)	-10.488	<0.001
Volume, min/week	40 (0, 120)	10 (0, 60)	-10.352	<0.001
MVPA[3]				
Volume, min/week	60 (0, 180)	20 (0, 90)	-13.226	<0.001
Transportation				
MPA[2]				
Frequency, d/week	5 (2, 7)	5 (1, 7)	3.867 [a]	<0.001
Duration, min/d	30 (12, 50)	30 (10, 40)	-1.571	0.116
Volume, min/week	135 (40, 240)	120 (30, 210)	-3.496	<0.001
Sports and leisure-time				
VPA[1]				
Frequency, d/week	1 (0, 2)	0 (0, 1)	-15.195	<0.001
Duration, min/d	15 (0, 60)	0 (0, 20)	-15.473	<0.001
Volume, min/week	20 (0, 100)	0 (0, 30)	-15.846	<0.001
MPA[2]				

Frequency, d/week	1 (0, 3)	0 (0, 2)	-7.851	<0.001
Duration, min/d	20 (0, 40)	0 (0, 30)	-8.601	<0.001
Volume, min/week	40 (0, 100)	0 (0, 75)	-8.766	<0.001
MVPA[3]				
Volume, min/week	90 (0, 210)	30 (0, 120)	-13.808	<0.001
Total VPA[1]				
Volume, min/week	60 (0, 180)	0 (0, 60)	-17.387	<0.001
Total MPA[2]				
Volume, min/week	250 (120, 450)	180 (80, 340)	-10.616	<0.001
Total MVPA[3]				
Volume, min/week	360 (170, 645)	230 (105, 420)	-12.527	<0.001

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

[a]: t-value, the between-group difference was tested by *t*-test.

Table S4 Comparison of all related variables among university students in three Chinese cities (N=4758)

Characteristics	Shantou (N=2123) mean ± SD	Jinan (N=1267) mean ± SD	Hong Kong (N=1368) mean ± SD	χ^{2} [b]	*P*-value
Domestic/work/study					
VPA[1]					
Frequency, d/week	0.49±1.211	0.65±1.360	1.30±1.618	430.847	<0.001
Duration, min/d	9.54±30.385	11.95±26.858	29.20±44.886	459.346	<0.001
Volume, min/week	26.26±97.002	29.63±84.260	76.13±141.237	451.585	<0.001
MPA[2]					
Frequency, d/week	1.37±1.794	1.39±1.818	1.35±1.630	41.561	<0.001
Duration, min/d	22.04±46.981	20.96±28.376	28.09±38.545	54.763	<0.001
Volume, min/week	62.81±179.510	65.11±110.745	67.79±120.332	37.396	<0.001
MVPA[3]					
Volume, min/week	89.07±233.198	94.75±157.456	143.92±221.951	162.353	<0.001
Transportation					
MPA[2]					
Frequency, d/week	4.19±2.677	4.19±2.719	3.75±2.593	13.264 [a]	<0.001
Duration, min/d	33.48±37.862	36.06±36.294	37.40±55.204	12.776	0.002
Volume, min/week	183.04±243.689	184.01±229.371	188.67±361.267	13.614	0.001
Sports and leisure-time					
VPA[1]					
Frequency, d/week	0.66±1.330	0.91±1.590	1.16±1.532	167.345	<0.001
Duration, min/d	13.43±28.847	18.12±30.861	32.26±47.221	215.755	<0.001
Volume, min/week	33.30±90.518	43.20±93.836	81.88±162.518	196.872	<0.001

MPA[2]					
Frequency, d/week	1.29±1.789	1.73±2.029	1.25±1.610	53.535	<0.001
Duration, min/d	19.49±31.618	25.21±39.452	25.96±39.452	48.271	<0.001
Volume, min/week	53.45±115.262	67.89±107.243	64.54±132.276	52.548	<0.001
MVPA[3]					
Volume, min/week	86.75±170.705	111.09±161.263	146.42±262.774	89.474	<0.001
Total VPA[1]					
Volume, min/week	59.56±164.161	72.83±155.848	158.01±258.381	428.887	<0.001
Total MPA[2]					
Volume, min/week	299.29±378.162	317.01±334.969	321.00±483.178	15.821	<0.001
Total MVPA[3]					
Volume, min/week	358.85±469.466	389.84±408.753	479.01±650.137	41.574	<0.001
	n (%)	*n (%)*	*n (%)*		
Study year				147.006	<0.001
Year 1	*698 (32.9)*	*453 (35.8)*	*345 (25.2)*		
Year 2	*691 (32.5)*	*443 (35.0)*	*328 (24.0)*		
Year 3	*734 (34.6)*	*371 (29.3)*	*695 (50.8)*		
University sports team member				99.654	<0.001
No	*1977 (93.1)*	*1153 (91.0)*	*1132 (82.7)*		
Yes	*146 (6.9)*	*114 (9.0)*	*236 (17.3)*		
Other sports team member				0.732	0.694
No	*1989 (93.7)*	*1196 (94.4)*	*1287 (94.1)*		
Yes	*134 (6.3)*	*71 (5.6)*	*81 (5.9)*		
Sleep duration				338.655	<0.001
7.00-7.99 h/d	*69 (3.3)*	*29 (2.3)*	*189 (13.8)*		
<6.00 h/d	*406 (19.1)*	*187 (14.8)*	*376 (27.5)*		
6.00-6.99 h/d	*841 (39.6)*	*608 (48.0)*	*433 (31.7)*		
8.00-8.99 h/d	*563 (26.5)*	*353 (27.9)*	*270 (19.7)*		
≥ 9.00 h/d	*244 (11.5)*	*90 (7.1)*	*100 (7.3)*		

[1]: VPA, vigorous-intensity physical activity.

[2]: MPA, moderate-intensity physical activity.

[3]: MVPA, moderate- and vigorous-intensity physical activity.

[a]: *F*-value, tested by one-way ANOVA.

[b]: The between-group differences of study year, university/other sports team member, and sleep duration were tested by Pearson chi-square tests, and 20 PA-related variables were tested by Kruskal-Wallis H tests.

Table S5 Comparison of all related variables among university students in three Chinese cities (N=4758)

Characteristics	Shantou (N=2123) median (IQR)	Jinan (N=1267) median (IQR)	Hong Kong (N=1368) median (IQR)	$\chi^{2\,b}$	*P*-value
Domestic/work/study					

VPA[1]					
Frequency, d/week	0 (0, 0)	0 (0, 1)	1 (0, 2)	430.847	<0.001
Duration, min/d	0 (0, 0)	0 (0, 10)	10 (0, 40)	459.346	<0.001
Volume, min/week	0 (0, 0)	0 (0, 10)	15 (0, 90)	451.585	<0.001
MPA[2]					
Frequency, d/week	1 (0, 2)	1 (0, 3)	1 (0, 2)	41.561	<0.001
Duration, min/d	10 (0, 30)	15 (0, 30)	20 (0, 40)	54.763	<0.001
Volume, min/week	10 (0, 60)	30 (0, 90)	30 (0, 90)	37.396	<0.001
MVPA[3]					
Volume, min/week	20 (0, 80)	40 (0, 120)	60 (0, 180)	162.353	<0.001
Transportation					
MPA[2]					
Frequency, d/week	5 (2, 7)	5 (2, 7)	4 (1, 6)	13.264 [a]	<0.001
Duration, min/d	30 (10, 40)	30 (15, 50)	30 (10, 40)	12.776	0.002
Volume, min/week	140 (40, 210)	120 (40, 210)	100 (30, 210)	13.614	0.001
Sports and leisure-time					
VPA[1]					
Frequency, d/week	0 (0, 1)	0 (0, 1)	1 (0, 2)	167.345	<0.001
Duration, min/d	0 (0, 15)	0 (0, 30)	10 (0, 60)	215.755	<0.001
Volume, min/week	0 (0, 20)	0 (0, 60)	10 (0, 90)	196.872	<0.001
MPA[2]					
Frequency, d/week	0 (0, 2)	1 (0, 3)	1 (0, 2)	53.535	<0.001
Duration, min/d	0 (0, 30)	20 (0, 30)	10 (0, 30)	48.271	<0.001
Volume, min/week	0 (0, 80)	30 (0, 90)	15 (0, 78.75)	52.548	<0.001
MVPA[3]					
Volume, min/week	30 (0, 100)	60 (0, 150)	60 (0, 180)	89.474	<0.001
Total VPA[1]					
Volume, min/week	0 (0, 60)	0 (0, 90)	60 (0, 180)	428.887	<0.001
Total MPA[2]					
Volume, min/week	200 (90, 360)	210 (100, 420)	190 (80, 375)	15.821	<0.001
Total MVPA[3]					
Volume, min/week	230 (110, 440)	270 (125, 500)	286.5 (120, 570)	41.574	<0.001
	n (%)	*n (%)*	*n (%)*		
Study year				147.006	<0.001
Year 1	*698 (32.9)*	*453 (35.8)*	*345 (25.2)*		
Year 2	*691 (32.5)*	*443 (35.0)*	*328 (24.0)*		
Year 3	*734 (34.6)*	*371 (29.3)*	*695 (50.8)*		
University sports team member				99.654	<0.001
No	*1977 (93.1)*	*1153 (91.0)*	*1132 (82.7)*		
Yes	*146 (6.9)*	*114 (9.0)*	*236 (17.3)*		
Other sports team member				0.732	0.694
No	*1989 (93.7)*	*1196 (94.4)*	*1287 (94.1)*		
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Sleep duration				338.655	<0.001
7.00-7.99 h/d	*69 (3.3)*	*29 (2.3)*	*189 (13.8)*		
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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-9
Bias	9	Describe any efforts to address potential sources of bias	*None*
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10
		(*b*) Describe any methods used to examine subgroups and interactions	10
		(*c*) Explain how missing data were addressed	None
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	None
		(*e*) Describe any sensitivity analyses	None
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	None
		(c) Consider use of a flow diagram	None
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11 & 12
		(b) Indicate number of participants with missing data for each variable of interest	None
Outcome data	15*	Report numbers of outcome events or summary measures	11, 16 & 17
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-16
		(*b*) Report category boundaries when continuous variables were categorized	13-15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	None
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	16 & 17
Discussion			
Key results	18	Summarise key results with reference to study objectives	17 &18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	3 & 4 & 19 & 21 &22
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	23
Generalisability	21	Discuss the generalisability (external validity) of the study results	None
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	4

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.