The association between prior physical fitness and depression in young adults during the COVID-19 pandemic – a cross-sectional, retrospective study

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Background: The COVID-19 pandemic has led to a spike in deleterious mental health. This dual-center retrospective cross-sectional study assessed the prevalence of depression in young adults during this pandemic and explored its association with various physical fitness measures. **Methods:** This study enrolled 12,889 (80% female) young adults (mean age 20 ± 1) who performed a National Student Physical Fitness battery from December 1st, 2019, to January 20th, 2020, and completed a questionnaire including Beck's Depression Inventory in May 2020. Independent associations between prior physical fitness and depression during the pandemic were assessed using multivariable linear and binary logistic regressions accordingly, covariates including age, dwelling location, economic level, smoking, alcohol, living status, weight change, and exercise volume during the pandemic. Sex- and baseline stress-stratified analyses were performed. **Results:** Of the study population 13.9% of men and 15.0% of women sampled qualified for a diagnosis of depression. After multivariable adjustment, anaerobic (mean change [95% CI], -3.3 [-4.8 to 1.8]) aerobic (-1.5 [-2.64 to -0.5]), explosive (-1.64 [-2.7 to -0.6]) and muscular (-1.7 [-3.0 to -0.5]) fitness were independently and inversely associated with depression for the overall population. These remained consistent after sex- and baseline stress-stratification. In binary logistic regression, the combined participants with moderate, high or excellent fitness also showed a much lower risk compared to those least fit in anaerobic (odd ratio (OR) [95% CI], 0.68 [0.55 to 0.82]), aerobic (0.80 [0.68 to 0.91]), explosive (0.72 [0.61 to 0.82]), and muscular (0.66 [0.57 to 0.75]) fitness. **Conclusions:** These findings suggest that prior physical fitness may be inversely associated with depression in young adults

during a pandemic.

Title page

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ABSTRACT

Background: The COVID-19 pandemic has led to a spike in deleterious mental health. This dual-center retrospective cross-sectional study assessed the prevalence of depression in young adults during this pandemic and explored its association with various physical fitness measures.

Methods: This study enrolled 12,889 (80% female) young adults (mean age 20 ± 1) who performed a National Student Physical Fitness battery from December 1st, 2019, to January 20th, 2020, and completed a questionnaire including Beck's Depression Inventory in May 2020. Independent associations between prior physical fitness and depression during the pandemic were assessed using multivariable linear and binary logistic regressions accordingly, covariates including age, dwelling location, economic level, smoking, alcohol, living status, weight change, and exercise volume during the pandemic. Sex- and baseline stress-stratified analyses were performed.

Results: Of the study population 13.9% of men and 15.0% of women sampled qualified for a diagnosis of depression. After multivariable adjustment, anaerobic (mean change [95% CI], -3.3 [-4.8 to 1.8]) aerobic (-1.5 [-2.64 to -0.5]), explosive (-1.64 [-2.7 to -0.6]) and muscular (-1.7 [-3.0 to -0.5]) fitness were independently and inversely associated with depression for the overall population. These remained consistent after sex- and baseline stress-stratification. In binary logistic regression, the combined participants with moderate, high or excellent fitness also showed a much lower risk compared to those least fit in anaerobic (odd ratio (OR) [95% CI], 0.68 [0.55 to 0.82]), aerobic (0.80 [0.68 to 0.91]), explosive (0.72 [0.61 to 0.82]), and muscular (0.66 [0.57 to 0.75]) fitness.

Conclusions: These findings suggest that prior physical fitness may be inversely associated with depression in young adults during a pandemic.

Keywords: Physical fitness; Exercise; COVID-19; Depression; Mental health.

INTRODUCTION

Since its onset, coronavirus-2019 (COVID-19) has personified overwhelming stresses, stemming from - infections, loss of work, loss of freedoms, isolation, and death, leaving behind an aura of uncertainty amongst the world's citizens. COVID-19 has led to a spike in deleterious mental health issues (Wang et al. 2020), particularly in depression (Brooks et al. 2020). There's concern that such a surge may lead to an increased rate of suicides,(Reger et al. 2020) domestic abuse, economic, and somatic health issues. (Moulton et al. 2015) Hence, evidence-based research is needed to address the rise in depression across multiple populations as a result of COVID-19.

Physical fitness, particularly cardiorespiratory fitness, and exercise training have repeatedly been shown to be negatively associated with future CVD and diabetes risk (Dun et al. 2019a; Dun et al. 2019b; Myers et al. 2015; Pedersen et al. 2019) as well as having a positive relationship with mental health in multiple populations. (Baumeister et al. 2017; Cho et al. 2019; Kerling et al. 2015) Studies have been published on COVID-19 and previous outbreaks and their adverse effects on mental health.(Brooks et al. 2020; Torales et al. 2020) Furthermore, recent studies have alluded to an association between current physical activity and mental health during the pandemic (Lopez-Bueno et al. 2020; Stanton et al. 2020), with a commonality that decreased physical activity appears with lockdowns. However, these studies are largely limited to current physical activity and mental health. To our knowledge, none have explored the possible association between prior multiple physical fitness and pandemic-related depression.

From the existing evidence, it may be hypothesized that physical fitness factors are inversely correlated with depression during COVID-19. Therefore, this retrospective cross-sectional study's aims are two-fold: to assess the prevalence of depression in young adults during the pandemic and to investigate the associations between a variety of different measures of physical fitness, including prior anaerobic, aerobic, explosive, muscular, flexibility, and pulmonary fitness on the prevalence of depression during the COVID-19 pandemic.

METHODS

Study design and participants

This retrospective cross-sectional study enrolled two universities (Hunan Traditional Chinese Medical College, Hunan, China, and Medical College of Jinhua Polytechnic, Zhejiang, China) selected by convenience sampling, that performed the Chinese National Student Physical Fitness Standard (CNSPFS) battery between December 1st, 2019 to January 20th, 2020 when government-issued sanctioned lockdowns and social distancing. A total of 14,059 university students who were free of chronic diseases and had completed a CNSPFS were screened. Of these, 13,013 participants (response rate of 93.2%) completed a follow-up questionnaire from May 1st to 23rd, 2020. Participants who provided poor quality questionnaires were excluded (n = 124). The criteria of poor quality were: (1) If the ID information in the CNSPFS system did not match that of the follow-up questionnaire; or (2) If the 81-question survey was completed in less than three minutes. A total of 12,889 participants were included in the study. All baseline data

were extracted from the CNSPFS system; the data during the COVID-19 pandemic were collected from the survey platform (https://www.wjx.cn). Data from the two time-points were linked by identifying each participant's university student ID number and matching them accordingly. This study was evaluated and approved by the Review Board of Xiangya Hospital Central South University (approval No. 202005126). Written informed consent was documented during the baseline, and digital informed consent was given upon initiating the survey. All participants were codified and anonymized to protect the confidentiality of individual participants.

Physical fitness

Fitness measures were obtained from the completion of the CNSPFS battery, and scores were attained through the standardized scoring system that weighted each fitness indicator score by age- and sex-specific percentage. The CNSPFS battery included a 50-m sprint,(Duffield et al. 2004) an 800-m (women) and 1,000-m (men),(Margaria et al. 1975) a standing long jump,(Robertson & Fleming 1987) timed sit-ups (women) and pull-ups (men), (Rutherford & Corbin 1994) sit and reach test and vital lung capacity respectively. (Ranu et al. 2011) Anaerobic, aerobic, explosive, muscular fitness, flexibility, and pulmonary fitness were assessed through these tests. The scores were classified as follows: low fitness (<60), moderate fitness (60 - 79), high fitness (80 - 89), and excellent fitness (>90). All tests were administered by trained physical education teachers following the CNSPFS standard operating procedures. The test-retest

148 reliability across all assessments employed as an intraclass correlation coefficient (ICC) > 0.90.
149 The details about performing CNSPFS have been described previously. (Yi et al. 2019; Zhu et al.
150 2017)
151
152 **Baseline stress and depression during the COVID-19 pandemic**
153 Baseline stress was assessed concurrently with the CNSPFS test through a modified question as
154 described previously. (Frazier et al. 2014) Beck's Depression Inventory, second edition (BDI-II)
155 was also administered during the follow-up questionnaire performed in May. (Yang & Stewart
156 2020) The BDI-II is a 21-item self-report questionnaire validated in young Chinese adults (Yang
157 & Stewart 2020; Zhu et al. 2018) and well correlated with a clinical diagnosis of
158 depression,(Moullec et al. 2015) with four response options for each item. The added total scores
159 of the BDI-II can vary from 0 to 63 and are classified as: 0–13 no depression, 14–19 mild
160 depression, 20–28 moderate depression, and 29–63 severe depression. (Beck et al. 1996; Zhu et
161 al. 2018)
162
163 **Covariates**
164 Exercise and physical activity habits were collected through a modified version with added items
165 of the International Physical Activity Questionnaire-Long form-Chinese (IPAQ-LC) which had
166 shown adequate reliability and reasonable validity for use in Chinese students(Macfarlane et al.
167 2011). Questions regarded exercise pre-and during the lockdown, including frequency, duration,

and intensity of aerobic exercise and strength exercise. Smoking status and alcohol intake were assessed as daily and weekly consumption, respectively. Socioeconomic status and dwelling location were retrieved from the university databases. Pre-pandemic body weight was assessed at the time of the CNSPFS test, while body weight during the COVID-19 pandemic was obtained via a self-reported questionnaire throughout May 2020. (Ross et al. 2019)

Characteristics of Lockdown

The first lockdown order in China was delivered on January 23rd, 2020 by the government of Wuhan, Hubei province, followed by the other provinces across China. The main requirements were: (1) all individuals were ordered to stay home or at their place of residence, except for permitted work, local shopping, or other permitted errands, or as otherwise authorized. (2) all schools, sports facilities, entertainment, and recreational venues, personal care and beauty services, and the majority of factories and markets were closed.

Statistical methods

For data of participants' demographics and characteristics, independent t-test and Chi-square test were used for assessment in mean difference between sexes of continuous and categorical variables, respectively.

The primary outcomes of the present study were the BDI-II depression scores (continuous

188 variable) and the prevalence of depression (categorical variable), defined as a BDI-II score ⩾ 14,
189 (Beck et al. 1996; Zhu et al. 2018) during the COVID-19 pandemic. The independent variables
190 included prior fitness factors, stress, socioeconomic status, dwelling location, and smoking,
191 alcohol, living status, changes in body weight, and exercise volume per week during the
192 pandemic. The associations between each independent variable and BDI-II depression score
193 change were assessed by univariate analyses. The independent relationships of prior physical
194 fitness factors and BDI-II depression score change were assessed using multivariable linear
195 regression. The associations between prior physical fitness factors and the presence of
196 depression, defined as a BDI-II depression score ≥ 14, were evaluated via binary logistic
197 regression in which the lowest level was set as the reference. The variables included in the
198 regression models were demographics, the independent variables mentioned above and
199 potentially associated with depression or those with a p value < 0.20 in the univariate analyses
200 were included in the multivariable linear and binary logistic regression analyses. To minimize
201 confounding from baseline psychological status, baseline stress-stratified multivariable linear
202 regression was performed. Analyses were carried out using SAS software, version 9.4 (SAS
203 Institute), a two-tailed alpha level of 0.05 was considered to be statistically significant.
204
205 **RESULTS**
206 **Demographic**

Demographics of 12,889 participants are presented in Table 1. Male participants were proportionally a smaller percentage of the population. In the overall population, there were 12.2%, 60.6%, and 27.3% of participants that came from lower-income, middle-income, and upper-income families, respectively, and 35.4%, 42.4%, and 22.2% of participants lived in a rural, urban-rural junction, and urban areas, respectively. During the COVID-19 pandemic, 41% and 59% of participants lived alone or with family/friends, respectively.

Characteristics of prior physical fitness and prevalence of depression during the COVID-19 pandemic

Each of five physical fitness parameters was scored and graded as low fitness (not pass), moderate fitness, good, or excellent according to CNSPFS that was established referring to national physical fitness test data while taking age and sex into account. Across multiple physical fitness tests, the mean score ranged from 53 to 78 in men and 67 to 78 in women, there were significant differences in physical fitness score between sexes (P<0.001 for each comparison except pulmonary fitness score). The grade distributions were evaluated by the histogram and conformed to a normal distribution; the majority of participants were graded between moderate and high fitness. Less than 25% of participants were graded as low fitness or excellent. The median BDI-II depression during the pandemic scores were 2 for men and 1 for women (P<0.001). Men and women who presented depression made up 13.9% and 15.0% of their respective populations, no significance was found between sexes (P=0.14) (More in Table 1).

227

228 **Association between anaerobic fitness and depression during the pandemic**

229 After multivariable adjustment, anaerobic fitness was independently and negatively associated
230 with the BDI-II score. Across four grades, participants with excellent anaerobic fitness had an
231 average BDI-II score that was -3.3 (95% CI, -4.8 to -1.8) points lower BDI-II score than those
232 with low fitness (Table 2 and 3). This finding showed consistency in subjects with and without
233 baseline stress (-2.7 [-4.2 to -1.2]) (Table 4). In binary (participants with depression versus
234 without depression) logistic regression, compared to low fitness participants, participants with an
235 excellent anaerobic fitness had less than half the risk of the presence of depression during the
236 pandemic (OR [95% CI], 0.58 [0.37 to 0.90]), and combined participants with moderate, high or
237 excellent anaerobic fitness also showed a much lower risk 0.68 [0.55 to 0.82]) (Figure 1).

238

239 **Association between aerobic fitness and depression during the pandemic**

240 Aerobic fitness showed a similar association with BDI-II score. Across four grades of aerobic
241 fitness, participants categorized as excellent had an average BDI-II score on average -1.5 (95%
242 CI, -2.6 to -0.5) lower than those with low fitness (Table 3). This finding was consistent in
243 participants with and without baseline stress (mean diff. [95% CI], -1.8 [-2.8 to -0.7]) (Table 4).
244 In binary logistic regression, compared to those who had low fitness scores, combined
245 participants with moderate, high, or excellent aerobic fitness grades showed a lower risk of the
246 presence of depression (OR [95% CI], 0.80 [0.68 to 0.91]) (Figure 1).

247

248 **Association between explosive fitness and depression during the pandemic**

249 Explosive fitness was inversely correlated with depression during the COVID-19 pandemic.
250 Participants with excellent explosive fitness had an average of -1.6 (95% CI, -2.7 to -0.6) lower
251 BDI-II score than participants with low fitness (Table 2 and 3). This finding was in participants
252 with and without baseline stress across sex (mean diff. [95% CI], -1.8 [-2.9 to -0.8]) (Table 4). In
253 binary logistic regression, compared to those with low fitness scores, participants with excellent
254 explosive fitness had a 36% lower risk of the presence of depression (OR [95% CI], 0.62 [0.46 to
255 0.85]), and combined participants with moderate, high or excellent explosive fitness scores also
256 showed a lower risk (0.72 [0.61 to 0.82]) (Figure 1).

257

258 **Association between muscular fitness and depression during the pandemic**

259 Muscular fitness was also independently and negatively correlated with depression. Participants
260 with excellent muscular fitness had an average of -1.7 (95% CI, -3.0 to -0.5) lower BDI-II score
261 than participants with low fitness (Table 3). This finding was consistent in those with and
262 without baseline stress (-2.1 [-3.4 to -0.9]) (Table 4). In binary logistic regression, compared to
263 those who were categorized as low fitness, participants with excellent muscular fitness had less
264 than half risk of the presence of depression during the pandemic (OR [95% CI], 0.47 [0.31 to
265 0.72]), and combined participants with moderate, high or excellent muscular fitness also showed
266 a much lower risk 0.66 [0.57 to 0.75]) (Figure 1).

267

268 **DISCUSSION**

269 This study is the first to examine the relationship between physical fitness across multiple
270 domains and the presence of depressive symptoms during the COVID-19 pandemic. Our data
271 showed that 13.9% of young men and 15.0% of women had BDI scores that qualified them for
272 the diagnosis of depression, which is unexpectedly similar to the level of depression reported
273 previously in older adult populations (16.5%). (Wang et al. 2020) Findings that are particularly
274 implicative as both depression and low physical fitness are risk factors for future CVD and
275 diabetes. (Moulton et al. 2015; Myers et al. 2015; Pedersen et al. 2019) This study further
276 explored the association between previous levels of explosive, anaerobic, flexibility, and
277 pulmonary domains of fitness, with depression. Our data demonstrate that apart from flexibility
278 and pulmonary fitness, all of these fitness parameters were independently inversely associated
279 with depression in young adults free from chronic diseases.

280

281 Depression and depressive symptom severity vary in individuals, and at different periods, at
282 times, it may impact functional capabilities, whose effects are deleterious on individuals'
283 physical and psychological wellbeing. While the etiology of depression remains largely
284 unknown, the onset of depression may come in various forms, ranging from physiological
285 factors, psychological factors, and those coming from an individual's environment. Both chronic
286 and acute stresses are believed to play an integral part in the development of depression. Chronic

287 stress, encompassing long-term negative environmental circumstances, such as financial
288 difficulties; conflictual relationships with family, friends, or romantic partners (Hammen et al.
289 2009), acute stresses coming from episodes of stress such as those environmental or from
290 personal loss. The COVID-19 pandemic and lockdowns have led to a surge in negative emotions
291 and increased depression(Choi et al. 2020; Lei et al. 2020).
292
293 Recent research has shown that anaerobic training to be inversely associated with depression
294 severity independent of aerobic activity. (Cangin et al. 2018) Our research showed for the first
295 time that anaerobic fitness was the greatest predictor of a lower BDI-II score among the fitness
296 parameters. After stratification of baseline stress, increasing levels of fitness were significantly
297 correlated with lower BDI-II scores in a near dose-response fashion, with those with the highest
298 fitness being less likely to be depressed (Table 4). Furthermore, in conjunction with previous
299 research,(Harvey et al. 2018; Kerling et al. 2015) our findings showed that aerobic fitness was
300 independently associated with lower depression scores. A number of studies have found that
301 aerobic exercise is an effective therapy for moderate forms of depression while also showing it
302 may be equally effective compared to other traditional methods of psychotherapy. The
303 association of aerobic fitness with lower levels of depression is not limited to young adults as
304 longitudinal studies have similar results in reducing depression in middle-aged and older
305 individuals and younger adults. (Jaworska et al. 2019)
306

Muscular fitness was measured through two strength tests to best evaluate for muscular strength and endurance, given the variability of muscular fitness across sexes. Muscular fitness and its inverse association with depressive symptoms have been previously investigated(Marques et al. 2020). This association was also shown in this study after multivariable analysis, showing that participants in the highest subset of muscular fitness demonstrated a BDI-II score lower than participants with low scores. These findings are consistent with those found during pre-pandemic conditions, where increased handgrip strength as well as comprehensive muscular fitness appears to act as a buffer against depressive symptoms and are associated with improvements in depression. (Krogh et al. 2009; Suija et al. 2013) Previous large-scale observational studies suggested that muscular fitness may even have greater effects than those associated with aerobic fitness in the reduction of depression. (Bennie et al. 2019) Our findings extend those of others, in that we found muscular fitness to be associated with lower depression scores during the COVID-19 pandemic. Moreover, Explosive fitness, utilizing the phosphocreatine system (Baker et al. 2010), was found to be independently and inversely associated with depressive symptoms, with the highest level of explosive fitness being associated with a lower BDI-II score. Furthermore, individuals in the highest explosive fitness level had less than half the associated risk of depression than individuals in the lowest levels. This is a particularly interesting finding as it appears to suggest that different types of fitness than those reported elsewhere (Ren et al. 2020) may have an effect of protection from depressive symptoms. Future prospective cohort or

intervention studies are required to better elucidate the relationships between explosive fitness and the risk of depressive symptoms.

Physical fitness and its inverse relationship with depression could be brought about through increased physical activity and exercise. Accumulating evidence suggests that exercise could be associated with primary monoamines, whereby higher amounts of exercise have a positive impact on neurotransmitter systems that regulate primary monoamines, dopamine, noradrenaline, and serotonin. (Dishman 1997; Poulton & Muir 2005) As well as having a positive effect on physiological states, regular exercise and higher fitness could impact psychological states. Mental resilience may be improved through exercise and attainability of higher fitness,(Childs & de Wit 2014) as persons who feel or believe themselves to be healthier may be less inclined to fear the COVID-19 pandemic or at least feel more resilient against it. This has been demonstrated as those with higher mental resilience were less likely to be depressed, (Kirby et al. 2017) as participation in regular exercise can usually distract individuals from noxious stimuli, thereby improving depression. Furthermore, since exercise is often extrinsic, increased self-efficacy and self-esteem, garnered from higher muscle mass and fitness could lead to improved mental health. (Blumenthal et al. 2007)

While this study provides certain insights into the associations through which higher physical fitness levels in several parameters of fitness is related to a decreased risk of depressive

346 symptoms, the causation between fitness parameters and depressive symptoms could not be
347 established due to the cross-sectional study design. Associations between fitness measures and
348 depressive symptoms in young adults may be bidirectional. Studies have indicated that previous
349 depression could be a factor in the cessation of exercise, and the development of a sedentary
350 lifestyle since those with depression may have lower self-worth, and confidence, increased self-
351 criticism, and unwarranted guilt. (Faulkner et al. 2014; Ren et al. 2020) Future prospective
352 cohort or intervention studies are required to better elucidate the relationships between fitness,
353 particularly anaerobic and explosive fitness, and the risk of depressive symptoms.
354
355 Furthermore, the sample was selected through convenience sampling and therefore may be
356 subject to a degree of information bias, may not be representative of the whole population, and
357 variations within individuals exist. As is with all cross-sectional studies, our data demonstrate an
358 association between physical fitness and prevalence of rather than incidence of depression during
359 the COVID-19 pandemic, although baseline stress status was included as a covariate in all
360 multivariable analyses, and baseline stress-stratified multivariable analysis was performed, with
361 consistent findings. The present study only comprised university-educated Chinese young adults,
362 which potentially limits the generalizability of the findings. However, our findings were
363 consistent among sexes, and with multivariable adjustment of age, baseline stress, geographic
364 attribute, socio-economic level, and smoking, alcohol, living status, changes in weight, and
365 exercise volume during the pandemic. In addition, all findings were consistent in both

multivariable linear and binary logistic regressions. It seems plausible that the biologic effects of many factors would be qualitatively similar in other populations.

CONCLUSION

Multiple physical fitness parameters are inversely associated with the prevalence of depression in young adults during the COVID-19 pandemic. These associations were independent of other potential confounders, such as sex, age, baseline stress, dwelling location, socio-economic level, and smoking, alcohol, living status, weight changes, and exercise volume during the pandemic. These findings along with previous research suggest that that techniques and lifestyle management that lead to improved comprehensive fitness including a wider range of muscle groups and energy systems may be considered as a possible approach to help prevent and/or reverse depression during the pandemic.

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Author Contributions SXL, YSD and JWR conceived the study. SXL and YSD were involved in securing funding for the study. NJZ, WLZ, YCD, MJC, ZHH, JL and QXL coordinated the study conduct and data collection. YSD did the study analyses, supervised by SXL. YSD and JWR wrote the article, with assistance from RJT, TPO, QXL and SXL. All authors approved the final version of the manuscript. SXL had full access to all the data in the study and had final responsibility for the decision to submit for publication.

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Table 1(on next page)

Demographics and characteristics of participants pre- and during the COVID-19 pandemic

CI, confidence interval; COVID-19, coronavirus disease-19. Data were expressed as mean ± standard deviation or number (percent) accordingly. † Socio-economic level data was obtained based on residence place of participants and 2019 Chinese Family Income data. A family earning less than ¥14,360 per year was considered a lower-income family; between ¥14,360 and ¥36,470 per year was considered a middle-income family; more than ¥36,470 per year was considered a upper-income family. * Mean difference (95% CI) and *P* value are for the comparison between men and women. ‡ Mean difference (95% CI) in percent.

Table 1. Demographics and characteristics of participants pre- and during the COVID-19 pandemic

	Men (N = 2,549)	Women (N = 10,340)	Total (N = 12,889)	Mean diff. (95% CI) *	*P* value*
Age, yr	20 ± 1	19 ± 1	20 ± 1	0.2 (0.2 to 0.3)	<0.001
Weight, kg	63.4 ± 10.3	52.0 ± 7.7	54.3 ± 9.5	11.4 (11.0 to 11.8)	<0.001
Body mass index, kg/m^2	21.2 ± 3.2	20.2 ± 2.7	20.4 ± 2.8	1.0 (0.8 to 1.1)	<0.001
Socio-economic status†					0.002
Lower-income	288 (11.3)	1,282 (12.4)	1,570 (12.2)	NA	
Middle-income	1,621 (63.6)	6,183 (59.8)	7,804 (60.6)	NA	
Upper-income	640 (25.1)	2,875 (27.8)	3,514 (27.3)	NA	
Baseline stress, yes, n (%)	1,026 (40.3)	4,458 (43.1)	5,484 (42.5)	NA	0.009
Exercise volume, MET-hr/wk	13.9 ±12.3	8.8 ± 8.3	9.8 ± 9.4	5.2(4.7 to 5.7)	<0.001
Physical fitness					
Anaerobic fitness, 50-m sprint, s	7.5 ± 0.5	9.2 ± 0.6	8.9 ± 0.9	-1.7 (-1.7 to -1.7)	<0.001
Anaerobic fitness score	78 ± 10	70 ± 9	71 ± 10	8.4 (7.9 to 8.4)	<0.001
Aerobic fitness, 800-m/1000-m run, s	237 ± 22	247 ± 27	NA	NA	NA
Aerobic fitness score	67 ± 13	73 ± 11	72 ± 12	-5.8 (-6.3 to -5.2)	<0.001
Explosive fitness, standing jump, meters	2.2 ± 0.2	1.7 ± 0.1	1.8 ± 0.3	0.5 (0.4 to 0.6)	<0.001
Explosive fitness score	67 ± 14	71 ± 12	70 ± 13	-3.6 (-4.3 to -3.0)	<0.001
Muscular fitness, timed sit-ups/pull-ups	34 ± 8	8 ± 5	NA	NA	NA
Muscular fitness score	53 ± 27	67 ± 11	65 ± 15	-13.7 (-15.0 to -12.4)	<0.001
Flexibility fitness, sit and reach, cm	14 ± 6	17 ± 5	17 ± 6	-3.7 (-3.9 to -3.4)	<0.001
Flexibility fitness score	73 ± 13	78 ± 11	77 ± 12	-4.7 (-5.3 to -4.2)	<0.001
Pulmonary fitness, vital capacity, L	4.1 ± 0.7	2.8 ± 0.4	3.1 ± 0.7	1.3 (1.3 to 1.3)	<0.001
Pulmonary fitness score	75 ± 13	76 ± 11	76 ± 11	-0.5 (-1.0 to 0.1)	0.100

Depression score during COVID-19 pandemic	5 ± 8	6 ± 8	6 ± 8	-0.6 (-0.9 to -0.2)	0.001
Without depression	2,195 (86.1)	8,789 (85.0)	10,984 (85.2)	NA	0.151
With depression	354 (13.9)	1,551 (15.0)	1,905 (14.8)	NA	
Mild depression	155 (6.1)	672 (6.5)	827 (6.4)	NA	
Moderate depression	138 (5.4)	579 (5.6)	717 (5.6)	NA	0.650
Severe depression	61 (2.4)	300 (2.9)	361 (2.8)	NA	
Geographic attribute					<0.001
Rural area	1,007 (39.5)	3,557 (34.4)	4,564 (35.4)	NA	
Urban-rural junction area	1,037 (40.7)	4,426 (42.8)	5,463 (42.4)	NA	
Urban area	505 (19.8)	2,358 (22.8)	2,862 (22.2)	NA	
Living status during COVID-19 pandemic					<0.001
Living alone	1,207 (47.4)	4,081 (39.5)	5,288 (41.0)	NA	
Living with family/friends	1,342 (52.6)	6,259 (60.5)	7,601 (59.0)	NA	
Smoking, n (%)					<0.001
Never smoke	1932 (75.8)	10,107 (97.7)	12,039 (93.4)	NA	
Former smoker	227 (8.9)	147 (1.4)	374 (2.9)	NA	
Currently smoking	390 (15.3)	86 (0.9)	476 (3.7)	NA	
<10 cigarettes/day	297 (11.7)	73 (0.7)	370 (2.9)	NA	
10-15 cigarettes/day	57 (2.2)	9 (0.09)	66 (0.5)	NA	
>15 cigarettes/day	36 (1.4)	4 (0.03)	40 (0.3)	NA	
Alcohol, drinks/wk	1.8 ± 2.9	0.7 ± 1.6	0.9 ± 2.0	1.2 (0.1 to 1.3)	<0.001
Change in weight, kg	2.6 ± 3.9	2.1 ± 3.6	2.2 ± 3.7	0.5 (0.3 to 0.6)	<0.001
Change in exercise volume, MET-hr/wk	-0.6 ± 13.0	2.5 ± 10.1	1.9 ± 10.8	-3.1 (-3.6 to -2.5)	<0.001

3 CI, confidence interval; COVID-19, coronavirus disease-19. Data were expressed as mean ±

4 standard deviation or number (percent) accordingly.

† Socio-economic level data was obtained based on residence place of participants and 2019 Chinese Family Income data. A family earning less than ￥14,360 per year was considered a lower-income family; between ￥14,360 and ￥36,470 per year was considered a middle-income family; more than ￥36,470 per year was considered a upper-income family.

* Mean difference was calculated as women subtracted by men, and expressed as mean difference (95% CI). *P* values are for the comparison between men and women.

Table 2(on next page)

Univariate linear regression for the relationships between prior physical fitness and depression during the COVID-19 pandemic.

CI, confidence interval; COVID-19, coronavirus disease-19; BDI-II, Becks' Depression Inventory-II. The first level of the ordered categorical variables were used as reference. Data are expressed as BDI-II score change related to each variable.

1

2 Table 2. Univariate linear regression for the associations between each prior physical fitness and
3 BDI-II depression score during the COVID-19 pandemic.

	Men (N = 2,549)		Women (N = 10,340)		Total (N = 12,889)	
	Coefficients	*P* Value	Coefficients	*P* Value	Coefficients	*P* Value
Age, yr	-0.100	0.432	-0.038	0.574	-0.064	0.287
Change in weight, kg	0.147	<0.001	0.127	<0.001	0.128	<0.001
Change in exercise volume, MET-hr/wk	-0.010	0.411	-0.021	0.010	-0.015	0.025
Baseline stress, yes						
No	Reference		Reference		Reference	
Yes	0.467	0.005	0.283	<0.001	0.324	<0.001
Prior physical fitness						
Anaerobic fitness						
Low	Reference		Reference		Reference	
Moderate	-3.471	0.084	-1.504	0.001	-1.635	<0.001
High	-3.929	0.054	-1.504	0.010	-1.816	<0.001
Excellent	-4.547	0.023	-2.680	0.014	-2.964	<0.001
Aerobic fitness						
Low	Reference		Reference		Reference	
Moderate	-1.123	0.033	-1.497	<0.001	-1.120	<0.001
High	-0.978	0.340	-1.548	<0.001	-1.176	<0.001
Excellent	-2.648	0.015	-2.017	<0.001	-1.794	<0.001
Explosive fitness						
Low	Reference		Reference		Reference	
Moderate	-1.236	0.046	-0.652	0.100	-0.745	0.017

High	-1.020	0.276	-0.720	0.132	-0.759	0.052
Excellent	-2.486	0.028	-1.531	0.001	-1.605	<0.001
Muscular fitness						
Low	Reference		Reference		Reference	
Moderate	0.434	0.263	-1.410	<0.001	-0.139	0.824
High	0.152	0.860	-2.438	<0.001	-1.044	0.008
Excellent	-1.610	0.018	-2.152	0.016	-1.482	0.003
Flexibility fitness						
Low	Reference		Reference		Reference	
Moderate	0.253	0.946	-0.479	0.627	0.061	0.994
High	-0.759	0.572	-0.804	0.358	-0.304	0.726
Excellent	0.549	0.772	-0.763	0.389	-0.088	0.984
Pulmonary fitness						
Low	Reference		Reference		Reference	
Moderate	-0.769	0.520	0.783	0.248	0.380	0.580
High	-1.196	0.272	0.599	0.448	0.089	0.985
Excellent	-0.749	0.596	0.177	0.942	-0.118	0.970
Geographic attribute						
Rural area	Reference		Reference		Reference	
Urban-rural junction area	-0.941	0.147	0.063	0.948	-0.115	0.813
Urban area	-1.232	0.056	-0.202	0.605	-0.378	0.164
Socio-economic status						
Lower-income	Reference		Reference		Reference	
Middle-income	-0.488	0.631	-0.279	0.482	-0.310	0.362
Upper-income	-0.261	0.886	-1.163	<0.001	-1.001	0.001
Alcohol, drinks/wk	0.422	<0.001	0.766	<0.001	0.554	<0.001

Living status						
Living alone	Reference		Reference		Reference	
Living with family/friends	0.222	0.171	0.068	0.419	0.114	0.126
Smoking						
Never smoke	Reference		Reference		Reference	
Former smoker	2.270	<0.001	6.787	<0.001	3.610	<0.001
Currently smoking						
<10 cigarettes/day	1.238	0.027	9.185	<0.001	2.196	<0.001
10-15 cigarettes/day	5.327	<0.001	9.669	<0.001	5.246	<0.001
>15 cigarettes/day	5.989	<0.001	12.835	0.002	6.029	<0.001

CI, confidence interval; COVID-19, coronavirus disease-19; BDI-II, Becks' Depression Inventory-II. The first level of the ordered categorical variables were used as reference.

Table 3(on next page)

Multivariate linear regression for the relationships between prior physical fitness and depression during the COVID-19 pandemic.

CI, confidence interval; COVID-19, coronavirus disease-19; BDI-II, Becks' Depression Inventory-II. Multivariate models were adjusted for age, baseline stress, dwelling location, socio-economic level, and smoking, alcohol, living status, changes in weight and exercise volume during COVID-19 pandemic. The low fitness level of each physical fitness variable were used as reference. Data are expressed as BDI-II score change related to each variable.

Table 3. Multivariable linear regression for the relationships between prior physical fitness and depression during the COVID-19 pandemic.

	Men (N = 2,549)		Women (N = 10,340)		Total (N = 12,889)	
	BDI-II score change Mean (95% CI)	*P* Value	BDI-II score change Mean (95% CI)	*P* Value	BDI-II score change Mean (95% CI)	*P* Value
Anaerobic fitness						
Low	Reference		Reference		Reference	
Moderate	-1.6 (-6.5 to 1.2)	0.292	-1.5 (-2.6 to -0.5)	0.003	-1.6 (-2.7 to -0.6)	0.001
High	-2.3 (-7.4 to 0.5)	0.390	-1.6 (-2.9 to -0.2)	0.016	-2.0 (-3.2 to -0.7)	<0.001
Excellent	-2.6 (-7.9 to -0.1)	0.325	-2.7 (-5.2 to -0.2)	0.028	-3.3 (-4.8 to -1.8)	<0.001
Aerobic fitness						
Low	Reference		Reference		Reference	
Moderate	-0.9 (-2.3 to 0.5)	0.279	-1.4 (-2.4 to -0.5)	0.001	-1.1 (-1.9 to -0.4)	<0.002
High	-0.9 (3.0 to 1.1)	0.605	-1.4 (-2.5 to -0.4)	0.003	-1.1 (-1.9 to -0.2)	<0.011
Excellent	-2.2 (-5.1 to 0.8)	0.211	-1.8 (-3.0 to -0.6)	0.002	-1.5 (-2.6 to -0.5)	0.003
Explosive fitness						
Low	Reference		Reference		Reference	
Moderate	-1.8 (-3.3 to -0.3)	0.016	-0.7 (-1.5 to 0.2)	0.127	-0.9 (-1.6 to -0.1)	0.019
High	-1.4 (-3.3 to 0.6)	0.250	-0.9 (-1.8 to 0.1)	0.100	-0.9 (-1.8 to -0.1)	0.036
Excellent	-3.1 (-6.4 to 0.2)	0.067	-1.6 (-2.7 to -0.4)	0.004	-1.6 (-2.7 to -0.6)	<0.001
Muscular fitness						
Low	Reference		Reference		Reference	
Moderate	-0.8 (-1.9 to 0.4)	0.277	-1.6 (-2.4 to -0.8)	<0.001	-0.5 (1.0 to 0.1)	0.088
High	-1.4 (-3.6 to 0.7)	0.310	-2.3 (-3.5 to -1.2)	<0.001	-1.4 (-2.3 to -0.4)	0.002
Excellent	-2.2 (-4.2 to -0.1)	0.033	-2.1 (-3.7 to -0.5)	0.006	-1.7 (-3.0 to -0.5)	0.003

CI, confidence interval; COVID-19, coronavirus disease-19; BDI-II, Becks' Depression Inventory-II. Multivariate models were adjusted for age, baseline stress, dwelling location, socio-economic level, and smoking, alcohol, living status, changes in weight and exercise volume during COVID-19 pandemic. The low fitness level of each physical fitness variable were used as reference. Data are expressed as BDI-II score change related to each variable.

Table 4(on next page)

Baseline stress-stratified multivariate linear regression for the relationships between prior physical fitness and depression during the COVID-19 pandemic.

CI, confidence interval; COVID-19, coronavirus disease-19; BDI-II, Becks' Depression Inventory-II. Multivariate models were adjusted for sex, age, dwelling location, socio-economic level, and smoking, alcohol, living status, changes in weight and exercise volume during COVID-19 pandemic. The low fitness level of each physical fitness variable were used as reference. Data are expressed as BDI-II score change related to each variable.

Table 4. Baseline stress-stratified multivariable linear regression for the relationships between prior physical fitness and depression during the COVID-19 pandemic.

	Baseline stress (N = 2,549)		No baseline stress (N = 10,340)		Total (N = 12,889)	
	BDI-II score change Mean (95% CI)	*P* Value	BDI-II score change Mean (95% CI)	*P* Value	BDI-II score change Mean (95% CI)	*P* Value
Anaerobic fitness						
Low	Reference		Reference		Reference	
Moderate	-1.5 (-2.8 to -0.2)	0.025	-1.6 (-3.3 to 0.1)	0.065	-1.5 (-2.6 to -0.5)	0.002
High	-2.1 (-3.7 to -0.5)	0.006	-1.5 (-3.4 to 0.75)	0.172	-1.8 (-3.0 to -0.5)	0.003
Excellent	-2.6 (-4.5 to -0.7)	0.004	-2.8 (-5.3 to -0.3)	0.021	-2.7 (-4.2 to -1.2)	<0.001
Aerobic fitness						
Low	Reference		Reference		Reference	
Moderate	-1.0 (-2.0 to -0.1)	0.029	-2.0 (-3.3 to -0.7)	0.001	-1.3 (-2.1 to -0.6)	<0.001
High	-1.3 (-2.3 to -0.2)	0.018	-1.7 (-3.2 to -0.2)	0.018	-1.3 (-2.2 to -0.5)	0.001
Excellent	-1.5 (-2.9 to -0.2)	0.019	-2.4 (-4.1 to -0.6)	0.004	-1.8 (-2.8 to -0.7)	<0.001
Explosive fitness						
Low	Reference		Reference		Reference	
Moderate	-0.8 (-1.8 to 0.1)	0.084	-1.1 (-2.4 to 0.0)	0.052	-1.0 (-1.7 to -0.2)	0.006
High	-0.5 (-1.6 to 0.6)	0.538	-1.8 (-3.2 to -0.36)	0.010	-1.0 (-1.9 to -0.2)	0.016
Excellent	-1.4 (-2.8 to -0.1)	0.027	-2.5 (-4.1 to -0.9)	0.002	-1.8 (-2.9 to -0.8)	<0.001
Muscular fitness						
Low	Reference		Reference		Reference	
Moderate	-1.1 (-1.9 to -0.3)	0.003	-0.6 (-1.3 to 0.1)	0.09	-1.4 (-2.0 to -0.8)	<0.001
High	-1.6 (-2.8 to -0.4)	0.006	-1.2 (-2.3 to -0.2)	<0.02	-2.1 (-3.1 to -1.1)	<0.001
Excellent	-2.3 (-4.0 to -0.8)	<0.001	-2.0 (-3.4 to -0.7)	0.001	-2.1 (-3.4 to -0.9)	<0.001

CI, confidence interval; COVID-19, coronavirus disease-19; BDI-II, Becks' Depression Inventory-II. Multivariate models were adjusted for sex, age, dwelling location, socio-economic level, and smoking, alcohol, living status, changes in weight and exercise volume during COVID-19 pandemic. The low fitness level of each physical fitness variable were used as reference. Data are expressed as BDI-II score change related to each variable.

Figure 1

Binary logistic regression for the relationships between prior physical fitness and depression during the COVID-19 pandemic.

Figure 1. OR, odds ratio; CI, confidence interval; COVID-19, coronavirus disease-19. The low fitness was used as reference for each physical fitness variable. Multivariate models were adjusted for sex, age, prior perceived stress, dwelling location, socio-economic level, and smoking, alcohol, living status, changes in weight and exercise volume during the COVID-19 pandemic. * Overall equates to the participants that were graded as pass, good and excellent.

Figure 1. Binary logistic regression for the relationships between prior physical fitness and depression during the COVID-19 pandemic.

	Crude OR (95% CI) (N = 12,899)	*P* Value	Adjusted OR (95% CI) (N = 12,899)	Odds Ratios	*P* Value
Anaerobic fitness					
Low	Reference		Reference		
Moderate	0.71 (0.55 to 0.91)	0.006	0.73 (0.55 to 0.97)		0.033
High	0.71 (0.53 to 0.96)	0.024	0.71 (0.51 to 0.99)		0.049
Excellent	0.52 (0.36 to 0.75)	<0.001	0.58 (0.37 to 0.90)		0.015
Overall	0.64 (0.53 to 0.76)		0.68 (0.55 to 0.82)		
Aerobic fitness					
Low	Reference		Reference		
Moderate	0.77 (0.65 to 0.92)	0.004	0.80 (0.64 to 0.99)		0.041
High	0.82 (0.67 to 1.01)	0.059	0.82 (0.64 to 1.05)		0.122
Excellent	0.69 (0.52 to 0.90)	0.006	0.76 (0.56 to 1.04)		0.089
Overall	0.77 (0.68 to 0.86)		0.80 (0.68 to 0.91)		
Explosive fitness					
Low	Reference		Reference		
Moderate	0.83 (0.69 to 0.99)	0.034	0.77 (0.63 to 0.95)		0.013
High	0.79 (0.64 to 0.98)	0.034	0.73 (0.57 to 0.94)		0.014
Excellent	0.67 (0.51 to 0.87)	0.003	0.62 (0.46 to 0.85)		0.003
Overall	0.77 (0.68 to 0.89)		0.72 (0.61 to 0.82)		
Muscular fitness					
Low	Reference		Reference		
Moderate	0.93 (0.83 to 1.06)	0.278	0.72 (0.61 to 0.85)		<0.001
High	0.79 (0.62 to 1.00)	0.054	0.67 (0.50 to 0.90)		0.007
Excellent	0.49 (0.33 to 0.71)	<0.001	0.47 (0.31 to 0.72)		<0.001
Overall	0.81 (0.72 to 0.90)		0.66 (0.57 to 0.75)