The association between prior physical fitness and depression in young adults during the COVID-19 pandemic – a cross-sectional 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 young adults 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 multivariate linear and binary logistics 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:** showed 13.9% and 15.0% of men and women sampled qualified for a diagnosis of depression. After multivariable adjustment, anaerobic (mean change [95% CI], -3.9 [-5.1 to -2.7]), aerobic (-1.5 [-2.4 to -0.6]), explosive (-1.4 [-2.3 to -0.5]) and muscular (-1.3 [-2.4 to -0.2]) fitness were independently and inversely associated with depression across sexes. These remained consistent after sex- and baseline stress-stratification. In binary logistic regression, the fittest individuals had a much lower risk of depression during the pandemic than the least fit ($P \leq 0.002$ for each fitness). **Conclusions:** These findings suggest that prior physical fitness may be inversely associated with depression in young adults during a pandemic and that improving physical fitness may represent an effective approach to help prevent/reverse depression.

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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 young adults 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 multivariate linear and binary logistics 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: showed 13.9% and 15.0% of men and women sampled qualified for a diagnosis of depression. After multivariable adjustment, anaerobic (mean change [95% CI], -3.9 [-5.1 to -2.7]), aerobic (-1.5 [-2.4 to -0.6]), explosive (-1.4 [-2.3 to -0.5]) and muscular (-1.3 [-2.4 to -0.2]) fitness were independently and inversely associated with depression across sexes. These remained consistent after sex- and baseline stress-stratification. In binary logistic regression, the fittest individuals had a much lower risk of depression during the pandemic than the least fit ($P \leq 0.002$ for each fitness).

Conclusions: These findings suggest that prior physical fitness may be inversely associated with depression in young adults during a pandemic and that improving physical fitness may represent an effective approach to help prevent/reverse depression.

Keywords: Depression; Physical fitness; COVID-19.

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). With a concern that such a surge may lead to an increased rate of suicides,(Reger et al. 2020) domestic abuse, economic, and somatic health issues, where depression can lead to increased weight and obesity prevalence and is a risk factor to CVD and diabetes, (Moulton et al. 2015) evidence-based research is needed to address the rise in depression as a result of COVID-19.

Physical fitness and exercise capacity have repeatedly been shown to be negatively associated with future CVD and diabetes risk (Myers et al. 2015; Pedersen et al. 2019) as well has having a positive relationship with mental health in multiple populations.(Baumeister et al. 2017; Cho et al. 2019; Kerling et al. 2015) However, these studies are largely limited by the tendency to analyze single physical fitness factors and outcomes with a main focus being on cardiorespiratory fitness rather than any other fitness parameters.(Willis et al. 2018) Studies have been published on the association between COVID-19 and adverse effects on mental health, but to our knowledge none have explored the possible association between prior multiple physical fitness and pandemic-related depression.

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) 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). This study was evaluated and approved by the Review Board of Xiangya Hospital Central South University (approval No. 202005126). Written informed consent

was documented. 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 reliability across all assessments employed were a intraclass correlation coefficient (ICC) > 0.90. The details about performing CNSPFS have been described previously.(Yi et al. 2019; Zhu et al. 2017)

Baseline stress and depression during the COVID-19 pandemic

Baseline stress was assessed concurrently with the CNSPFS test through a modified question as described previously.(Frazier et al. 2014) Beck's Depression Inventory, second edition (BDI-II)

149 was also administered.(Yang & Stewart 2020) The BDI-II is a 21-item self-report questionnaire
150 validated in young Chinese adults(Yang & Stewart 2020; Zhu et al. 2018) and well correlated
151 with clinical diagnosis of depression,(Moullec et al. 2015) with four response options for each
152 item. The added total Scores of the BDI-II can vary from 0 to 63 and are classified as: 0–13 no
153 depression, 14–19 mild depression, 20–28 moderate depression, and 29–63 severe depression.
154
155 **Covariates**
156 Exercise habits were collected through questions regarding exercise pre- and during lockdown,
157 including frequency, duration, and intensity of aerobic exercise and strength exercise. Smoking
158 status and alcohol intake were assessed as daily and weekly consumption, respectively.
159 Socioeconomic status and dwelling location were retrieved from the university databases. Pre-
160 pandemic body weight was assessed at the time of CNSPFS test, while body weight during the
161 COVID-19 pandemic was obtained via a self-reported questionnaire throughout May,
162 2020.(Ross et al. 2019)
163
164 **Characteristics of Lockdown**
165 The first lockdown order in China was delivered on January 23rd, 2020 by the government of
166 Wuhan, Hubei province, followed by the other provinces across China. The main requirements
167 were: (1) all individuals were ordered to stay home or at their place of residence, except for
168 permitted work, local shopping or other permitted errands, or as otherwise authorized. (2) all

169 schools, sports facilities, entertainment, and recreational venues, personal care and beauty
170 services, and the majority of factories and markets were closed.
171
172 **Statistical methods**
173 The primary outcome of the present study was depression during the COVID-19 pandemic. The
174 predictors were baseline characteristics of physical fitness, stress, socio-economic status,
175 dwelling location, and smoking, alcohol, living status, changes in body weight and exercise
176 volume per week during the pandemic. Continuous and categorical variables were expressed as
177 mean ± standard deviation or number (percent), as appropriate. Independent t-test and Wilcoxon
178 signed-rank tests were used for assessment in mean difference between sexes of continuous and
179 categorical variables, respectively. The independent relationships of prior physical fitness factors
180 and BDI-II depression score or prevalence of depression during the pandemic were assessed
181 using multivariate linear and binary logistics regressions accordingly. Variables including
182 demographics, the predictors mentioned above and potentially associated with depression or
183 those that had a p value <0.20 in the univariate analyses were included in the multivariate linear
184 and binary logistic regression analyses. Potential nonlinear effects of decreases versus increases
185 in each variable were evaluated by modeling changes in indicator categories, with "the lowest
186 level" as the reference. To minimize confounding from baseline psychological status, baseline
187 stress-stratified multivariate linear regression was used. Multicollinearity was tested using the
188 variance inflation factor (VIF) method, with a VIF ≥ 5 indicating the presence of
189 multicollinearity. All the logistic regression models underwent a goodness of fit test. Analyses

190 were carried out with the use of SAS software, version 9.4 (SAS Institute), a two-tailed alpha
191 level of 0.05 was considered significant.
192
193 **RESULTS**
194 **Demographic**
195 Demographics of 12,889 participants are presented in Table 1. Male participants were
196 proportionally a smaller percentage of the population, as a result of the cohort being selected
197 from medical schools largely populated by women. Across sex, there were 12.2%, 60.6% and
198 27.3% of participants that came from lower-income, middle-income and upper-income families,
199 respectively and 35.4%, 42.4% and 22.2% of participants lived in a rural, urban-rural junction,
200 and urban areas, respectively. During the COVID-19 pandemic, 41% and 59% of participants
201 lived alone or with family/friends, respectively.
202
203 **Characteristics of prior physical fitness and prevalence of depression during the COVID-**
204 **19 pandemic**
205 Each of five physical fitness parameters was scored and graded as low fitness (not pass),
206 moderate fitness, good, or excellent according to CNSPFS that was established referring national
207 physical fitness test data while taking age and sex into account. Across multiple physical fitness
208 tests, the mean score ranged from 53 to 78 in men and 67 to 78 in women, there were significant
209 differences in physical fitness score between sexes (P<0.001 for each comparison except
210 pulmonary fitness score). The grade distributions conformed to normal distribution, the majority

211 of participants were graded between moderate and high fitness. Less than 25% participants were
212 graded as low fitness or excellent. The average BDI-II depression scores were 5 for men and 6
213 for women (P<0.001). Men and women who presented depression made up 13.9% and 15.0% of
214 their respective populations, no significance was found between sexes (P=0.14) (More in Table
215 1).
216
217 **Association between anaerobic fitness and depression during the pandemic**
218 After multivariable adjustment, anaerobic fitness was independently and negatively associated
219 with BDI-II score. Across four grades, participants with excellent anaerobic fitness had an
220 average BDI-II score that was 3.9 (95% CI, 2.7 to 5.1) points lower BDI-II score than those with
221 low fitness (Table 2 and 3). This finding showed consistency in men and women, and also across
222 sex in subjects with and without baseline stress (mean diff. [95% CI], 2.9 [1.6 to 4.1]) (Table 4).
223 In binary (participants with depression versus without depression) logistic regression, compared
224 to low fitness participants, participants with an excellent anaerobic fitness had less than half the
225 risk of presence of depression during the pandemic (OR [95% CI], 0.49 [0.33 to 0.73]), and
226 combined participants with moderate, high or excellent anaerobic fitness also showed a much
227 lower risk (0.64 [0.54 to 0.75]) (Figure 1).
228
229 **Association between aerobic fitness and depression during the pandemic**
230 Aerobic fitness showed a similar association with BDI-II score as did anaerobic fitness. Across
231 four grades of aerobic fitness, participants categorized as excellent had an average BDI-II score

232 on average 1.8 (95% CI, 0.9 to 2.7) lower than those with low fitness (Table 2 and 3). This
233 finding was consistent in men and women, and across sex in participants with and without
234 baseline stress (mean diff. [95% CI], 2.0 [1.1 to 2.9]) (Table 4). In binary logistic regression,
235 compared to those who had low fitness scores, those categorized as excellent had a 35% lower
236 risk of the presence of depression during the pandemic (OR [95% CI], 0.65 [0.49 to 0.86]), a
237 lower risk was also seen in comparison to combined participants with moderate, high or
238 excellent aerobic fitness grades (0.74 [0.65 to 0.83]) (Figure 1).
239
240 **Association between explosive fitness and depression during the pandemic**
241 Explosive fitness was inversely correlated with depression during COVID-19 pandemic.
242 Participants with excellent explosive fitness had an average of 1.4 (95% CI, 0.5 to 2.3) lower
243 BDI-II score than participants with low fitness (Table 2 and 3). This finding was consistent in
244 men and women, and in participants with and without baseline stress across sex (mean diff. [95%
245 CI], 1.7 [0.8 to 2.6]) (Table 4). In binary logistic regression, compared to those with low fitness
246 scores, participants with excellent explosive fitness had a 36% lower risk of presence of
247 depression (OR [95% CI], 0.64 [0.49 to 0.85]), and combined participants with moderate, high or
248 excellent explosive fitness scores also showed a lower risk (0.75 [0.65 to 0.83]) (Figure 1).
249
250 **Association between muscular fitness and depression during the pandemic**
251 Muscular fitness was also independently and negatively correlated with depression. Participants
252 with excellent muscular fitness had an average of 1.3 (95% CI, 0.2 to 2.4) lower BDI-II score

253 than participants with low fitness (Table 3). This finding was consistent in men and women, and
254 across sex in those with and without baseline stress (mean diff. [95% CI], 1.7 [0.8 to 2.5]) (Table
255 4). In binary logistic regression, compared to those who were categorized as low fitness,
256 participants with excellent muscular fitness had less than half risk of presence of depression
257 during the pandemic (OR [95% CI], 0.46 [0.33 to 0.67]), and combined participants with
258 moderate, high or excellent muscular fitness also showed a much lower risk (0.69 [0.61 to 0.78])
259 (Figure 1).
260

261 **DISCUSSION**

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

Depression and depressive symptoms are weakening disorders whose effects are deleterious on individuals' physical and psychological wellbeing. While the etiology of depression remains largely unknown. The onset of depression may come in various forms, ranging from physiological factors, psychological and those coming from an individual's environment. Both chronic and acute stresses are believed to play an integral part in the development of depression. Chronic stress, encompassing long term negative environmental circumstances, such as financial difficulties; conflictual relationships with family, friends or romantic partners(Hammen et al. 2009), acute stresses coming from episodes of stress such as those environmental or from personal loss. The COVID-19 pandemic and lockdowns have led to a surge in negative emotions and increased depression.

Recent research has shown that anaerobic training to be inversely associated with depression severity independent from aerobic activity.(Cangin et al. 2018) Our research showed for the first time that anaerobic fitness was the greatest predictor of a lower BDI-II score among the fitness parameters. After stratification of baseline stress, increasing levels of fitness were significantly correlated with lower BDI-II scores in a near dose-response fashion, with those with the highest fitness being less likely to be depressed (Table 4). Furthermore, in conjunction with previous research,(Harvey et al. 2018; Kerling et al. 2015) our findings showed that aerobic fitness was independently associated with lower depression scores. A number of studies have found that aerobic exercise is an effective therapy for moderate forms of depression while also showing it may be equally effective compared to other traditional methods of psychotherapy. The

295 association of aerobic fitness with lower levels of depression is not limited to young adults as
296 longitudinal studies have similar results in reducing depression in middle-aged and older
297 individuals and younger adults.(Jaworska et al. 2019)
298
299 Muscular fitness was measured through two strength tests to best evaluate for muscular strength
300 and endurance, given the variability of muscular fitness across sexes. Decreased Muscular fitness
301 and its association with depressive symptoms is well documented.(Tian et al. 2016) This
302 association was also shown in this study after multivariate analysis, showing that participants in
303 the highest subset of muscular fitness demonstrated a BDI-II score lower than participants with
304 low scores. These findings are consistent with those found during pre-pandemic conditions,
305 where musculoskeletal fitness appears to act as a buffer against depressive symptoms and has
306 been shown to be associated with improvements in depression in those with major
307 depression.(Suija et al. 2013) Previous large-scale observational studies suggested that muscular
308 fitness may even have greater effects than those associated with aerobic fitness in the reduction
309 of depression.(Bennie et al. 2019) Our findings extend those of others, in that we found muscular
310 fitness to be associated with lower depression scores during the COVID-19 pandemic. Moreover,
311 Explosive fitness which utilizes the phosphocreatine system (Baker et al. 2010) in which energy
312 immediately available during an all-out exertion lasting approximately 10-15 seconds when the
313 potential power output is at its greatest. In this study, explosive fitness was found to be
314 independently and inversely associated with depressive symptoms, with the highest level of
315 explosive fitness being associated with a lower BDI-II score. Furthermore, individuals in the

316 highest explosive fitness level had less than half the associated risk of depression than
317 individuals in the lowest levels. This is a particularly interesting finding as it appears to suggest
318 that different types fitness than those reported elsewhere(Ren et al. 2020) may have an effect of
319 protection from depressive symptoms. Future prospective cohort or intervention studies are
320 required to better elucidate the relationships between explosive fitness and the risk of depressive
321 symptoms.
322
323 Physical fitness and its inverse relationship with depression could be brought about through
324 physical activity. Accumulating evidence suggests that physical activity could be associated with
325 primary monoamines, whereby exercise has a positive impact on neurotransmitter systems that
326 regulate primary monoamines, dopamine, noradrenaline, and serotonin.(Dishman 1997; Poulton
327 & Muir 2005) As well as having a positive effect physiological state, regular physical activity
328 and higher fitness could impact psychological states. Mental resilience may be improved through
329 exercise and attainability of higher fitness,(Childs & de Wit 2014) as persons who feel or believe
330 themselves to be healthier may be less inclined to fear the COVID-19 pandemic or at least feel
331 more resilient against it. This has been demonstrated as those with higher mental resilience were
332 less likely to be depressed, (Kirby et al. 2017) as the participation of regular physical activity can
333 usually distract individuals from noxious stimuli, thereby improving depression. Furthermore,
334 since exercise is often extrinsic, increased self-efficacy and self-esteem, garnered from higher
335 muscle mass and fitness could lead to improved mental health.(Blumenthal et al. 2007)
336

337 While this study provides certain insights into the associations through which higher physical
338 fitness levels in several parameters of fitness is related to decreased risk of depressive symptoms,
339 the causation between fitness parameters and depressive symptoms could not be established due
340 to the cross-sectional study design. Associations between fitness measures and depressive
341 symptoms in young adults may be bidirectional. Studies have indicated that previous depression
342 could be a factor in the cessation of exercise, and the development of a sedentary lifestyle since
343 those with depression may have lower self-worth, and confidence, increased self-criticism and
344 unwarranted guilt.(Faulkner et al. 2014; Ren et al. 2020) Future prospective cohort or
345 intervention studies are required to better elucidate the relationships between fitness, particularly
346 anaerobic and explosive fitness and the risk of depressive symptoms.
347
348 Furthermore, the results here represent the average public effect, and variations within
349 individuals exist. As is with all cross-sectional studies, our data demonstrate an association
350 between physical fitness and prevalence of rather than incidence of depression during the
351 COVID-19 pandemic, although baseline stress status was included as a covariate in all
352 multivariate analyses, and baseline stress-stratified multivariate analysis was performed, with
353 consistent findings. The present study only comprised university-educated Chinese young adults,
354 which potentially limits the generalizability of the findings. However, our findings were
355 consistent among sexes, and with multivariable adjustment of age, baseline stress, geographic
356 attribute, socio-economic level, and smoking, alcohol, living status, changes in weight and
357 exercise volume during the pandemic. In addition, all findings were consistent in both

multivariate 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, changes in weight, and exercise volume during the pandemic. These findings suggest that that techniques and lifestyle management that lead to improved comprehensive fitness including a wider range of muscle groups and energy systems should be considered as a possible approach to help prevent and/or reverse depression during the pandemic.

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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.

1 Table 1. Demographics and characteristics of participants pre- and during the COVID-19
2 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)	-11.1 (-18.7 to -2.9) ‡	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)	0.10

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	0.14
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	0.65
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 (95% CI) and *P* value are for the comparison between men and women.

‡ Mean difference (95% CI) in percent.

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 relationships between prior physical fitness and

3 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
Age, yr	-0.1 (-0.4 to 0.2)	0.44	-0.1 (-0.2 to 0.1)	0.58	-0.1 (-0.2 to 0.1)	0.29
Change in weight, kg	0.1 (0.1 to 0.2)	<0.001	0.1 (0.1 to 0.2)	<0.001	0.1 (0.1 to 0.2)	<0.001
Change in exercise volume, MET-hr/wk	-0.1 (-0.1 to 0.1)	0.41	-0.1 (-0.1 to -0.0)	0.01	-0.1 (-0.1 to -0.0)	0.03
Baseline stress, yes						
No	Reference		Reference		Reference	
Yes	0.9 (0.3 to 1.6)	0.004	0.6 (0.2 to 0.9)	<0.001	0.6 (0.4 to 0.9)	<0.001
Prior physical fitness						
Anaerobic fitness						
Low	Reference		Reference		Reference	
Moderate	-3.5 (-7.4 to 0.4)	0.08	-1.5 (-2.5 to -0.5)	0.001	-1.6 (-2.6 to -0.7)	<0.001
High	-3.9 (-7.9 to 0.1)	0.05	-1.5 (-2.7 to -0.3)	0.009	-1.8 (-2.9 to -0.7)	<0.001
Excellent	-4.5 (-8.5 to -0.6)	0.02	-1.6 (-4.9 to -0.4)	0.01	-3.0 (-4.2 to -1.7)	<0.001
Aerobic fitness						
Low	Reference		Reference		Reference	
Moderate	-1.1 (-2.2 to -0.1)	0.03	-1.5 (-2.3 to -0.7)	<0.001	-1.2 (-1.8 to -0.6)	<0.001
High	-1.0 (-2.6 to 0.6)	0.34	-1.5 (-2.5 to -0.6)	<0.001	-1.2 (-1.9 to -0.4)	<0.001
Excellent	-2.6 (-4.9 to -0.4)	0.02	-2.0 (-3.1 to -0.9)	<0.001	-1.8 (-2.7 to -0.9)	<0.001
Explosive fitness						
Low	Reference		Reference		Reference	

Moderate	-1.2 (-2.5 to -0.1)	0.04	-0.7 (-1.4 to 0.1)	0.10	-0.7 (-1.4 to -1.0)	0.02
High	-1.0 (-2.6 to 0.5)	0.28	-0.7 (-1.6 to 0.2)	0.13	-0.8 (-1.5 to 0.0)	0.05
Excellent	-2.5 (-4.8 to -0.2)	0.03	-1.5 (-2.5 to -0.5)	0.001	-1.6 (-2.5 to -0.7)	<0.001
Muscular fitness						
Low	Reference		Reference		Reference	
Moderate	0.4 (-0.3 to 1.2)	0.26	-1.4 (-2.1 to -0.7)	<0.001	-0.1 (-0.6 to 0.3)	0.82
High	0.2 (-1.3 to 1.6)	0.86	-2.4 (-3.5 to -1.4)	<0.001	-1.0 (-1.9 to -0.2)	0.008
Excellent	-1.6 (-3.0 to -0.3)	0.02	-2.2 (-3.6 to -0.7)	0.002	-1.4 (-2.6 to -0.4)	0.003
Flexibility fitness						
Low	Reference		Reference		Reference	
Moderate	0.3 (-1.3 to 1.9)	0.95	-0.5 (-2.0 to 0.6)	0.63	0.1 (-1.0 to 1.2)	0.99
High	-0.8 (-2.6 to 1.1)	0.57	-0.8 (-2.4 to 0.8)	0.36	-0.3 (-1.4 to 0.8)	0.73
Excellent	0.5 (-1.3 to 2.4)	0.77	-0.8 (-2.3 to 0.8)	0.39	-0.1 (-1.2 to 1.0)	0.98
Pulmonary fitness						
Low	Reference		Reference		Reference	
Moderate	-0.8 (-2.6 to 1.0)	0.52	0.8 (-0.4 to 2.0)	0.25	0.4 (-0.6 to 1.4)	0.58
High	-1.2 (-3.1 to 0.7)	0.27	0.6 (-0.7 to 1.9)	0.45	0.1 (-1.0 to 1.2)	0.99
Excellent	-0.7 (-2.7 to 1.2)	0.60	0.2 (-1.1 to 1.5)	0.94	-0.1 (-1.2 to 1.0)	0.97
Geographic attribute						
Rural area	Reference		Reference		Reference	
Urban-rural junction area	-0.9 (-2.1 to 0.3)	0.15	0.1 (-0.5 to 0.6)	0.95	-0.1 (-0.6 to 0.4)	0.81
Urban area	-1.2 (-2.5 to 0.0)	0.06	-0.2 (-0.8 to 0.3)	0.61	-0.4 (-0.9 to 0.1)	0.16
Socio-economic status						
Lower-income	Reference		Reference		Reference	
Middle-income	-0.5 (-1.9 to 1.0)	0.63	-0.3 (-0.9 to 0.4)	0.48	-0.3 (-0.9 to 0.3)	0.36
Upper-income	-0.3 (-1.8 to 1.3)	0.89	-1.1 (-1.9 to -0.5)	<0.001	-1.0 (-1.7 to -0.4)	0.001

Alcohol, drinks/wk	0.4 (0.3 to 0.5)	<0.001	0.8 (0.7 to 0.9)	<0.001	0.5 (0.5 to 0.6)	<0.001
Living status						
Living alone	Reference		Reference		Reference	
Living with family/friends	0.4 (-0.2 to 1.1)	0.17	0.1 (-0.2 to 0.5)	0.42	0.2 (-0.1 to 0.5)	0.13
Smoking						
Never smoke	Reference		Reference		Reference	
Former smoker	2.3 (1.0 to 3.5)	<0.001	6.8 (5.4 to 8.2)	<0.001	3.6 (2.7 to 4.5)	<0.001
Currently smoking						
<10 cigarettes/day	1.2 (0.1 to 2.4)	0.03	9.2 (7.2 to 11.1)	<0.001	2.2 (1.3 to 3.1)	<0.001
10-15 cigarettes/day	5.3 (2.9 to 7.7)	<0.001	9.7 (4.1 to 15.2)	<0.001	5.2 (3.2 to 7.3)	<0.001
>15 cigarettes/day	6.0 (2.9 to 9.1)	<0.001	12.8 (4.5 to 21.1)	0.002	6.0 (3.3 to 8.8)	<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. Data are expressed as BDI-II score change related to each variable.

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. Multivariate 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	-2.7 (-6.5 to 1.2)	0.19	-1.4 (-2.4 to -0.5)	0.002	-1.7 (-2.6 to -0.8)	<0.001
High	-3.5 (-7.4 to 0.5)	0.08	-1.6 (-2.8 to -0.5)	0.003	-2.2 (-3.3 to -1.2)	<0.001
Excellent	-4.0 (-7.9 to -0.1)	0.04	-2.8 (-5.0 to -0.6)	0.008	-3.9 (-5.1 to -2.7)	<0.001
Aerobic fitness						
Low	Reference		Reference		Reference	
Moderate	-1.0 (-2.1 to -0.0)	0.04	-1.4 (-2.2 to -0.6)	<0.001	-1.0 (-1.6 to -0.3)	<0.001
High	-0.9 (-2.5 to 0.6)	0.36	-1.5 (-2.4 to -0.6)	<0.001	-0.9 (-1.6 to -0.1)	<0.01
Excellent	-2.8 (-5.1 to -0.6)	0.008	-2.0 (-3.1 to -0.9)	<0.001	-1.5 (-2.4 to -0.6)	<0.001
Explosive fitness						
Low	Reference		Reference		Reference	
Moderate	-1.3 (-2.5 to -0.1)	0.03	-0.6 (-1.3 to 0.2)	0.15	-0.6 (-1.3 to -0.0)	0.04
High	-1.0 (-2.6 to 0.5)	0.26	-0.7 (-1.6 to 0.1)	0.11	-0.7 (-1.5 to 0.0)	0.07
Excellent	-2.5 (-4.8 to -0.2)	0.03	-1.5 (-2.5 to -0.5)	0.002	-1.4 (-2.3 to -0.5)	<0.001
Muscular fitness						
Low	Reference		Reference		Reference	
Moderate	0.1 (-0.7 to 0.8)	0.93	-1.4 (-2.1 to -0.7)	<0.001	0.3 (-0.1 to 0.8)	0.21
High	-0.2 (-1.6 to 1.2)	0.82	-2.4 (-3.4 to -1.4)	<0.001	-0.7 (-1.5 to 0.1)	0.14
Excellent	-1.8 (-3.1 to -0.4)	0.009	-2.1 (-3.6 to -0.7)	0.001	-1.3 (-2.4 to -0.2)	0.01

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 multivariate 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	-1.7 (-3.2 to -0.3)	0.02	-1.3 (-2.5 to -0.1)	0.02	-1.5 (-2.5 to -0.6)	<0.001
High	-1.7 (-3.4 to -0.1)	0.04	-2.1 (-3.5 to -0.7)	0.002	-1.9 (-3.0 to -0.8)	<0.001
Excellent	-3.1 (-5.2 to -1.1)	0.001	-2.7 (-4.3 to -1.1)	<0.001	-2.9 (-4.1 to -1.6)	<0.001
Aerobic fitness						
Low	Reference		Reference		Reference	
Moderate	-1.6 (-2.7 to -0.5)	0.001	-1.1 (-2.0 to -0.4)	0.001	-1.3 (-2.0 to -0.7)	<0.001
High	-1.5 (-2.7 to -0.3)	0.01	-1.4 (-2.4 to -0.5)	0.001	-1.4 (-2.1 to -0.6)	<0.001
Excellent	-2.0 (-3.5 to -0.6)	0.004	-2.2 (-3.4 to -1.0)	<0.001	-2.0 (-2.9 to -1.1)	<0.001
Explosive fitness						
Low	Reference		Reference		Reference	
Moderate	-1.1 (-2.1 to -0.1)	0.02	-0.5 (-1.3 to 0.3)	0.26	-0.8 (-1.4 to -0.2)	0.008
High	-1.6 (-2.8 to -0.4)	0.006	-0.3 (-1.3 to 0.6)	0.73	-0.9 (-1.6 to -0.1)	0.02
Excellent	-2.4 (-3.8 to -1.0)	<0.001	-1.2 (-2.4 to -0.0)	0.04	-1.7 (-2.6 to -0.8)	<0.001
Muscular fitness						
Low	Reference		Reference		Reference	
Moderate	-1.3 (-2.2 to -0.5)	<0.001	-0.6 (-1.3 to 0.1)	0.09	-0.9 (-1.4 to -0.4)	<0.001
High	-2.3 (-3.7 to -0.9)	<0.001	-1.2 (-2.3 to -0.2)	<0.02	-1.7 (-2.5 to -0.8)	<0.001
Excellent	-1.5 (-3.2 to -0.1)	0.04	-2.0 (-3.4 to -0.7)	0.001	-1.8 (-2.9 to -0.7)	<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	0.72 (0.56 to 0.93)		0.01
High	0.71 (0.53 to 0.96)	0.02	0.68 (0.60 to 0.92)		0.01
Excellent	0.52 (0.37 to 0.75)	<0.001	0.49 (0.33 to 0.73)		<0.001
Overall	0.64 (0.53 to 0.76)		0.64 (0.54 to 0.75)		
Aerobic fitness					
Low	Reference		Reference		
Moderate	0.77 (0.65 to 0.92)	0.04	0.76 (0.63 to 0.91)		0.003
High	0.82 (0.67 to 0.99)	0.05	0.78 (0.63 to 0.97)		0.02
Excellent	0.69 (0.52 to 0.90)	0.006	0.65 (0.49 to 0.86)		0.002
Overall	0.77 (0.68 to 0.86)		0.74 (0.65 to 0.83)		
Explosive fitness					
Low	Reference		Reference		
Moderate	0.83 (0.69 to 0.99)	0.03	0.82 (0.68 to 0.98)		0.03
High	0.79 (0.64 to 0.98)	0.03	0.77 (0.62 to 0.96)		0.02
Excellent	0.67 (0.51 to 0.87)	0.003	0.64 (0.49 to 0.85)		0.002
Overall	0.77 (0.68 to 0.89)		0.75 (0.66 to 0.85)		
Muscular fitness					
Low	Reference		Reference		
High	0.93 (0.83 to 1.06)	0.28	0.80 (0.69 to 0.93)		0.003
Moderate	0.79 (0.62 to 1.00)	0.05	0.69 (0.54 to 0.89)		0.004
Excellent	0.49 (0.33 to 0.71)	<0.001	0.46 (0.31 to 0.67)		<0.001
Overall	0.81 (0.72 to 0.90)		0.69 (0.61 to 0.78)