Can physical activity protect against depression and anxiety during the COVID-19 pandemic? A rapid systematic review

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Abstract

The Covid-19 pandemic is affecting the entire world population. During the first spread, most governments have implemented quarantine and strict social distancing procedures. Similar measures during recent pandemics resulted in an increase in post-traumatic stress, anxiety and depression symptoms. The development of novel interventions to mitigate the mental health burden are of outmost importance. In this rapid review, we aimed to provide a systematic overview of the literature with regard to associations between physical activity (PA) and depression and anxiety during the COVID-19 pandemic. We searched major databases (PubMed, EMBASE, Sportdiscus, Web of Science) and preprint servers (MedRxivs, SportRxiv, ResearchGate and Google scholar), for relevant papers up to 25/07/2020. We identified a total of 21 observational studies (4 longitudinal, one cross-sectional with retrospective analysis and 16 cross-sectional), including information of 42,293 (age range = 6-70 years, median female = 68%) participants from 5 continents. The early evidence suggests that people who performed PA on a regular basis with higher volume and frequency and kept the PA routines stable, showed less symptoms of depression and anxiety. For instance, those reporting a higher total time spent in moderate to vigorous PA had 12% to 32% lower chances of presenting depressive symptoms and 15% to 34% of presenting anxiety. In order to maintain PA routines during Covid-19, specific volitional and motivational skills might be paramount to overcome Covid-19 specific barriers. Particularly, web-based technologies could be an accessible way to increase motivation and volition for PA and maintain daily PA routines.

Key Points

- The Covid-19 pandemic increased symptoms of anxiety and depression symptoms. Those reporting a higher total time spent in moderate to vigorous physical activity, had 12% to 32% lower chances of presenting depressive symptoms and 15% to 34% of presenting anxiety.
- The promotion of physical activity habits and routines might be a cost-effective and comprehensive worldwide applicable strategy to overcome the severe gap between people in need and people receiving mental health care, especially in low-income countries with even non-existing mental health supplies.
- Web-based technologies might be promising tools to increase motivation and volition for PA and maintain daily physical activity routines even under pandemic-specific barriers. However, there is a clear need for more systematic research for effectively and safely usable apps or web-based programs to prevent psychiatric disorders through physical activity.

Introduction

With 23,057,288 confirmed cases all over the world (up to August 23th, 2020) [1], COVID-19 is a global public health emergency. The World Health Organization (WHO) has issued recommendations to implement social distancing measures for the general public as well as quarantining procedures, for people infected with the COVID-19.

Quarantine and social distancing measures had already been enforced during earlier pandemics, such as the 2003 outbreak of SARS and the 2014 outbreak of Ebola [2]. Studies on the effects of these measures have

reported increased symptoms of anxiety, post-traumatic-stress, and depressive disorders, as well as a 30% increase in suicide rates in populations impacted by these measures [3, 4]. These findings are being replicated during the Covid-19 pandemic with multiple studies reporting an increased prevalence of depression and anxiety [e.g. 5, 6-9].

Notably psychiatric disorders result in a considerable burden of disease, accounting for 6.7% of overall disability-adjusted life years [10] and being attributable to 14.3% of death worldwide [11]. Despite the high burden of psychiatric disorders, there is a severe gap between people in need and people receiving mental health care [12]. This general treatment gap is especially severe in low- and middle-income countries, where 76% to 85% of people with mental disorders do not receive any treatment [13]. The latest WHO "mental health Atlas" indicates that only 95,6 out of 100 000 depressed cases worldwide receive any professional mental health care, whereas the treatment prevalence in high-income countries is 16-times higher compared to low-income countries [14]. Although there is no current global data available, the treatment gap is assumed to be much higher during or after the Covid-19 pandemic. Access to general mental health care might be restricted for several reasons, including supply priorities that being focused on Covid-19 infections, medication shortages, prohibition of face-to-face psychotherapeutic sessions of psychological treatment, closing of inpatient facilities to mention only some reasons.

To mitigate the negative mental health consequences of pandemics, evidence suggests that policymakers should ensure quarantine measures to be as short as possible, to provide adequate general supplies for basic needs, give people as much information as possible and strengthen social support and communication among people affected by the pandemic [2]. A recently published position paper on research priorities for mental health science regarding COVID-19 [15] demands the interdisciplinary development of novel interventions to protect mental wellbeing by mechanistically based approaches to strengthen altruism and prosocial behavior. Among others, physical activity (PA) interventions are highlighted as a promising approach. PA is defined as any bodily movement produced by skeletal muscles that results in energy expenditure and exercise is defined as PA, that is planned, structured, and repetitive, with the primary aim to improve or maintain physical fitness [16]. International PA guidelines recommend 150 minutes of moderate or 75 minutes of vigorous intensity PA per week for optimal physical and mental health benefits [17]. Indeed, in pre-pandemic times PA has been identified as a protective factor against incident depression [18] and anxiety [19]. However decreased levels of PA were observed in the general population in multiple countries during the pandemic [e.g. 20, 21, 9]. This rapid systematic review aims to outline current evidence regarding the associations of PA and exercise with depression and anxiety during the Covid-19 pandemic.

Methods

In this rapid review, we sought for observational studies examining the associations of PA and depression and anxiety during the COVID-19 pandemic. inclusion criteria were: 1) Observational studies in any population, including cross-sectional and longitudinal designs. Longitudinal studies could be either prospective or retrospective; 2) Studies have tested the association, of PA with depression or anxiety, using linear or logistic regressions; 3) depression and anxiety were assessed using validated screening or diagnostic tools. We excluded opinion pieces, systematic reviews, and studies addressing other viruses.

We searched the electronic databases PubMed, EMBASE, Sportdiscus, and Web of Science using the following strategy: (physical activity OR exercise OR sport) AND (coronavirus OR sars-cov-2 OR COVID* OR severe acute respiratory syndrome OR pandemic) AND (depression OR anxiety OR mental health). Preprints were searched in MedRxiv, SportRxiv, and Scielo preprints using the following strategy: "(physical activity OR exercise) AND (coronavirus OR sars-cov-2 OR COVID* OR severe acute respiratory syndrome OR pandemic)". Additional hand searches were performed on COVID-19 platform on ResearchGate and Google scholar. Searches were made by an experienced reviewer (FS) on 29th July, 2020. Study selection was conducted in three steps: 1) duplicates removal; 2) screening at the title and abstract level; and 3) assessment based on full-text. The selection was made by one reviewer (FS). Data extraction of selected studies was then performed by three researchers (FS, BS, SW). Data extracted were: Author and year, country of the included sample, study design, sample size, age group of the sample included, when possible, mean or range of age sample, % of women, instrument/question used to assess PA levels, instruments used to assess depression and anxiety, publication type and statistical outcomes (regression standardized beta coefficients and odd's ratios). If they were indicated in the report, fully adjusted coefficients and odd's ratios were extracted. As studies included in this review used very heterogeneous statistical approaches, a meta-analysis could not be conducted. Instead, we summarized the evidence and presented effect sizes (betas and odds ratios (OR)) with confidence intervals and indicated significant associations between PA and depression or anxiety, separately (see table 2). In case the study just reported the unstandardized betas, we requested the standardized betas by email. If standardized effects could not be obtained, unstandardized effects were presented and indicated. The risk of bias of individual studies was assessed using the National Institutes of Health (NIH) study quality assessment tool for observational cohort and cross-sectional studies [22]. The NIH tool assessment is composed by 14 questions the risk of potential selection bias, information bias measurement bias or confounding bias. There are 3 options (yes, no, other) for each question. Each "no" or "other" is suggestive of the presence of some risk of bias. Questions #6 (exposure prior outcome), #7 (sufficient time to see an effect), #10 (repeated exposure assessment), and #13 (follow-up rate) were disregarded for cross-sectional studies. Due to the self-reported nature of the assessments, question #12 (blinding of outcome assessors) was also disregarded for all studies.

Results

Searches on PubMed, EMBASE, Sportdiscus, and Web of science resulted in 592 potentially relevant studies. Preprint databases identified additional 572 potentially relevant studies. A flow-chart of the selection process is provided in figure 1. Of the identified studies, 21 studies meet the criteria [9, 23-34, 5, 35-37, 6, 38-40]. Four studies had a prospective longitudinal design [26, 29, 39, 36], one was a cross-sectional study with a retrospective measure of the exposure factor (henceforth treated as retrospective) [5], and 16 were cross-sectional studies [9, 23-25, 27, 29-35, 37, 6, 38, 40, 28, 41]. A total of 7 studies were conducted in Asia [24, 25, 27, 30, 33, 39, 40], 6 in Europe [9, 26, 31, 32, 35, 36], 3 in South America [28, 29, 6], 3 in North America [23, 34, 5], one in Oceania [38] and one study included a multinational sample [37].

Data form a total of 42,293 (median = 68% of women) participants were included. Only one study was exclusively composed by older adults (over 50 years), 4 were in children, adolescents, or young adults, while 13 studies were in adults (over 18). Only 7 studies used validated measures to assess PA levels. A wide

range of scales to measure depression or anxiety were used, the most used scales being the Beck Depression and Anxiety inventory and the DASS-21. Most studies (n=14) were not per-reviewed (pre-prints). A summary of studies is provided in Table 1.

Results are summarized and presented in table 2. Out of 9 studies reporting analyses on the association between the overall volume of PA and depression, 6 studies showed that more PA is significantly associated with less depression symptoms [23, 25, 32, 33, 35, 37], and 3 out of 8 studies investigating the association between the overall volume of PA and anxiety symptoms showed that more PA is significantly associated with less anxiety symptoms [25, 32, 35]. 3 out of 5 studies reported higher frequencies of PA to be significantly associated with less depression [27, 29, 36] and 2 out of 4 studies to be significantly associated with less anxiety [27, 29]. One study showed that vigorous but not moderate PA is significantly associated with less depression and anxiety symptoms [6] and another study indicated that light and vigorous PA is significantly correlated with less depression, but moderate intensity was not [23]. Out of 5 studies assessing an association between regular and guideline-consistent PA less depression and anxiety symptoms, two studies demonstrate that regular PA (compared to not regular) is significantly associated with less depression and anxiety symptoms [27, 30] and 1 study demonstrated that guideline conforming moderate to vigorous PA is associated with lower odds of depression and anxiety [6]. 5 out of 6 studies showed that a decreasing PA during the pandemic was significantly associated with more depression symptoms [9, 27, 5, 38, 40] and 3 out of 6 studies showed that a decrease in PA was significantly associated with more anxiety symptoms [9, 27, 38]. 1 study reported that an increase in PA was associated with less depressive symptoms [39].

The risk of bias of individual studies is presented in table 2. All studies clearly defined their research questions and used valid tools to assess main outcomes. Among the cross-sectional studies, 11 (68.75%) studies did not report the participation rate or included less than 50% of eligible participants, and 13 (81.25%) did not use valid tools to assess the exposure measure. A total of 3 out of 5 (60%) longitudinal studies are in risk of bias in the evaluating the definition of the study population, the participation rate, the validity of the exposure measure and in the retention of the sample.

Discussion

The present study is, to the best of our knowledge, the first study to summarize the evidence on the associations of PA with depression and anxiety during the COVID-19 pandemic. The majority of studies included in the present review showed that those who performed PA on a regular basis with higher volume and frequency and kept the PA routines stable, showed less symptoms of depression and anxiety. There was consistent evidence that those who could not keep their PA routine stable during the pandemic showed more depression and anxiety symptoms [9, 27, 5, 38-40]. However, the association was more consistent regarding depressive compared to anxiety symptoms. Those reporting a higher total time spent in moderate to vigorous PA had 12% to 32% lower chances of presenting depressive symptoms and 15% to 34% of presenting anxiety. These findings are in line with results of recent meta-analyses showing that those with higher PA levels were 17% less likely of developing depression [18] and 26% less likely to develop anxiety [19], independently of the the COVID-19 pandemic.

Indeed, the found reduction of PA behavior during COVID-19 specific conditions is highly expected. For example, due to social distancing, exercising in a group setting was limited or completely prohibited. However high social support is associated with more engagement in PA [42]. Indeed, social support was one of the strongest factors associated with adherence to PA in effective exercise interventions [43]. Furthermore, the COVID-19 pandemic impaired opportunities to be physically active due to the closure of sports clubs, gyms, or common indoor and outdoor places for PA. While some people were still allowed to do exercises like jogging on the streets, others were not [44]. In general, a lack of sporting opportunities seems to be associated with reduced PA [45]. Further negative consequences of the pandemic such as financial insecurities might have caused stress in individuals and stress, in turn, may differentially impact individuals' level of PA. Whereas habitually active individuals might even increase their level of PA, those who had not yet integrated exercise as a part of daily life, reduce their level of PA [46]. Thus, habitually active individuals might have built PA-related health competence and learned to utilize PA as a strategy to cope with negative feelings, such as stress, that may arise with sudden adaptions [47, 48]. Therefore, in order to prevent an increase in psychiatric disorders during the current or further pandemics, factors that facilitate the integration of PA into daily life routines, such as motivational and volitional skills, need to be identified and encouraged [49, 50]. One of the best ways to promote motivation and volition is the application of behavior change techniques (BCTs) [51]. During the COVID-19 pandemic, some BCTs appear to be particularly important for the maintenance of regular PA. For instance, the knowledge about the benefits of PA on symptoms that accompany lock-down procedures, such as lowered mood or anxiety [2-4]. Furthermore, individuals need the strong ability of coping planning to anticipate barriers that could discourage them to engage in PA (e.g., closed facilities) and find strategies to overcome them (e.g., engage in home training).

A web-based tool, e.g. a smartphone application could be a low-threshold and cost-effective option to train, supervise, apply, and adopt such BCTs, especially in terms of COVID-19. First empirical evidence showed preliminary efficacy of apps in promoting PA. Users of such apps are more likely to meet recommendations on PA than non-users [52-54]. Furthermore, a meta-analysis showed that Internet-delivered interventions, which are able to use different BCTs, were effective in increasing PA [55]. A major advantage of such web-based tools is the possibility to overcome some of the COVID-19 specific barriers. For instance, it is possible to become physically active online with friends or a virtual community, which might work against the lack of social support. In addition, limited sporting opportunities may be expanded through fitness technology and the provision of structured programs, as they can be used both indoors (e.g. through fitness videos) and outdoors (e.g. through running apps) and therefore be adapted to the specific situation.

Limitations

Most of the studies included in this review used cross-sectional research designs. A causal nature of these associations therefore remains unclear. There are notably differences in effect sizes which point at a high heterogeneity of the effects. Several studies further showed methodological shortcomings, e.g. not reporting the participation rate, including less than 50% of eligible participants, no validated tools to assess PA and failure to report standardized coefficients. Heterogeneity in research designs and statistical analyses hindered meta-analytic approaches, which would have provided a more sophisticated overall effect

estimate. Finally, several included studies were published as preprints and are currently in review processes for final publications. It is therefore planned to update this review in the future.

Conclusions, Future Research Directions And Implications

This rapid review shows promising evidence that higher volume and frequency of PA and the keeping of regular PA habits during the Covid-19 pandemic is associated with less symptoms of depression and anxiety. For instance, those reporting a higher total time spent in moderate to vigorous PA had 12% to 32% lower chances of presenting depressive symptoms and 15% to 34% of presenting anxiety. Thus, the promotion of PA habits and routines might be a cost-effective and comprehensive worldwide applicable strategy to overcome the severe gap between people in need and people receiving mental health care, especially in low-income countries with even non-existing mental health supplies. Particularly, web-based technologies, could be an easily accessible way to increase motivation and volition for PA and maintain daily PA routines even under pandemic-specific barriers. However only very few apps or websites have been tested in RCTs with high methodological standards [56]. Thus, there is a clear need for more systematic research for effectively and safely usable apps or web-based programs to prevent psychiatric disorders through PA.

Declarations

References

1. World Health Organization. WHO Coronavirus Disease (COVID-19) Dashboard. 2020. https://covid19.who.int/. Accessed 19.06.2020.
2. Brooks SK, Webster RK, Smith LE, Woodland L, Wessely S, Greenberg N et al. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. Lancet. 2020;395(10227):912-20. doi:10.1016/S0140-6736(20)30460-8.
3. Lee AM, Wong JG, McAlonan GM, Cheung V, Cheung C, Sham PC et al. Stress and psychological distress among SARS survivors 1 year after the outbreak. Canadian journal of psychiatry Revue canadienne de psychiatrie. 2007;52(4):233-40. doi:10.1177/070674370705200405.
4. Yip PS, Cheung YT, Chau PH, Law YW. The impact of epidemic outbreak: the case of severe acute respiratory syndrome (SARS) and suicide among older adults in Hong Kong. Crisis. 2010;31(2):86-92. doi:10.1027/0227-5910/a000015.

5. Meyer J, McDowell C, Lansing J, Brower C, Smith L, Tully M et al. Changes in physical activity and sedentary behaviour due to the COVID-19 outbreak and associations with mental health in 3,052 US adults. Cambridge Open Engage. 2020. doi:10.33774/coe-2020-h0b8g.

6. Schuch FB, Bulzing RA, Meyer J, Vancampfort D, Firth J, Stubbs B et al. Associations of moderate to vigorous physical activity and sedentary behavior with depressive and anxiety symptoms in self-isolating people during the COVID-19 pandemic: A cross-sectional survey in Brazil. Psychiatry Res. 2020;292:113339. doi:10.1016/j.psychres.2020.113339.

7. Cao W, Fang Z, Hou G, Han M, Xu X, Dong J et al. The psychological impact of the COVID-19 epidemic on college students in China. Psychiatry Res. 2020;287:112934. doi:10.1016/j.psychres.2020.112934.

8. Liu CH, Zhang E, Wong GTF, Hyun S, Hahm HC. Factors associated with depression, anxiety, and PTSD symptomatology during the COVID-19 pandemic: Clinical implications for U.S. young adult mental health. Psychiatry Res. 2020;290:113172. doi:10.1016/j.psychres.2020.113172.

9. Bauer LL, Seiffer B, Deinhart C, Atrott B, Sudeck G, Hautzinger M et al. Associations of exercise and social support with mental health during quarantine and social-distancing measures during the COVID-19 pandemic: A cross-sectional survey in Germany. medRxiv. 2020:2020.07.01.20144105. doi:10.1101/2020.07.01.20144105.

10. Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME); 2018.

11. Walker ER, McGee RE, Druss BG. Mortality in mental disorders and global disease burden implications: a systematic review and meta-analysis. JAMA Psychiatry. 2015;72(4):334-41. doi:10.1001/jamapsychiatry.2014.2502.

12. Patel V. Global mental health: from science to action. Harv Rev Psychiatry. 2012;20(1):6-12. doi:10.3109/10673229.2012.649108.

13. Thornicroft G, Chatterji S, Evans-Lacko S, Gruber M, Sampson N, Aguilar-Gaxiola S et al. Undertreatment of people with major depressive disorder in 21 countries. British Journal of Psychiatry. 2017;210(2):119-24. doi:10.1192/bjp.bp.116.188078.

14. WHO. Mental Health ATLAS 2017. 2017.

15. Holmes EA, O'Connor RC, Perry VH, Tracey I, Wessely S, Arseneault L et al. Multidisciplinary research priorities for the COVID-19 pandemic: a call for action for mental health science. Lancet Psychiatry. 2020;7(6):547-60. doi:10.1016/S2215-0366(20)30168-1.

16. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep. 1985;100(2):126-31.

17. WHO. Physical Activity. 2018. https://www.who.int/news-room/fact-sheets/detail/physical-activity.

18. Schuch FB, Vancampfort D, Firth J, Rosenbaum S, Ward PB, Silva ES et al. Physical Activity and Incident Depression: A Meta-Analysis of Prospective Cohort Studies. Am J Psychiatry. 2018;175(7):631-48. doi:10.1176/appi.ajp.2018.17111194.

19. Schuch FB, Stubbs B, Meyer J, Heissel A, Zech P, Vancampfort D et al. Physical activity protects from incident anxiety: A meta-analysis of prospective cohort studies. Depress Anxiety. 2019;36(9):846-58. doi:10.1002/da.22915.

20. Schuch F, Bulzing R, Meyer J, Lopez-Sanchez G, Grabovac I, Willeit P et al. Moderate to vigorous physical activity and sedentary behavior change in self-isolating adults during the COVID-19 pandemic in Brazil: A cross-sectional survey exploring correlates. medRxiv. 2020:2020.07.15.20154559. doi:10.1101/2020.07.15.20154559.

21. Mattioli AV, Sciomer S, Cocchi C, Maffei S, Gallina S. Quarantine during COVID-19 outbreak: Changes in diet and physical activity increase the risk of cardiovascular disease. Nutr Metab Cardiovasc Dis. 2020;30(9):1409-17. doi:10.1016/j.numecd.2020.05.020.

22. National Institutes of Health (NIH). Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. 2014. https://www.nhlbi.nih.gov/health-pro/guidelines/in-develop/cardiovascular-risk-reduction/tools/cohort Accessed 15.07.2020.

23. Callow DD, Arnold-Nedimala NA, Jordan LS, Pena GS, Won J, Woodard JL et al. The Mental Health Benefits of Physical Activity in Older Adults Survive the COVID-19 Pandemic. The American journal of geriatric psychiatry : official journal of the American Association for Geriatric Psychiatry. 2020. doi:10.1016/j.jagp.2020.06.024.

24. Chen F, Zheng D, Liu J, Gong Y, Guan Z, Lou D. Depression and anxiety among adolescents during COVID-19: A cross-sectional study. Brain Behav Immun. 2020;88:36-8. doi:10.1016/j.bbi.2020.05.061.

25. Chen J, Zhang SX, Wang Y, Afshar Jahanshahi A, Mokhtari Dinani M, Nazarian Madavani A et al. The curvilinear relationship between the age of adults and their mental health in Iran after its peak of COVID-19 cases. medRxiv. 2020:2020.06.11.20128132. doi:10.1101/2020.06.11.20128132.

26. Cheval B, Sivaramakrishnan H, Maltagliati S, Fessler L, Forestier C, Sarrazin P et al. Relationships Between Changes in Self-Reported Physical Activity, Sedentary Behaviours and Health During the Coronavirus (COVID-19) Pandemic in France and Switzerland. SportRxiv Preprints. 2020. doi:10.31236/osf.io/ydv84.

27. Deng C-H, Wang J-Q, Zhu L-M, Liu H-W, Guo Y, Peng X-H et al. Online Physical Education and the Relationship with Mental Health of College Students during the Outbreak of COVID-19: Online Survey Study in Wuhan (Preprint). JMIR Preprints. 2020. doi:10.2196/preprints.21301.

28. Filgueiras A, Stults-Kolehmainen M. The Relationship Between Behavioural and Psychosocial Factors Among Brazilians in Quarantine Due to COVID-19. SSRN Electronic Journal. 2020. doi:10.2139/ssrn.3566245.

29. Filgueiras A, Stults-Kolehmainen M. Factors linked to changes in mental health outcomes among Brazilians in quarantine due to COVID-19. medRxiv. 2020:2020.05.12.20099374. doi:10.1101/2020.05.12.20099374.

30. Fu W, Wang C, Zou L, Guo Y, Lu Z, Yan S et al. Psychological health, sleep quality, and coping styles to stress facing the COVID-19 in Wuhan, China. Transl Psychiatry. 2020;10(1):225. doi:10.1038/s41398-020-00913-3.

31. Fullana MA, Hidalgo-Mazzei D, Vieta E, Radua J. Coping behaviors associated with decreased anxiety and depressive symptoms during the COVID-19 pandemic and lockdown. Journal of Affective Disorders. 2020;275:80-1. doi:10.1016/j.jad.2020.06.027.

32. Jacob L, Tully MA, Barnett Y, Lopez-Sanchez GF, Butler L, Schuch F et al. The Relationship between Physical Activity and Mental Health in a Sample of the UK Public: A Cross-Sectional Study During the Implementation of COVID-19 Social Distancing Measures. in press.

33. Khan AH, Sultana MS, Hossain S, Hasan MT, Ahmed HU, Sikder MT. The impact of COVID-19 pandemic on mental health & wellbeing among home-quarantined Bangladeshi students: A cross-sectional pilot study. 2020.

34. Lebel C, MacKinnon A, Bagshawe M, Tomfohr-Madsen L, Giesbrecht G. Elevated depression and anxiety symptoms among pregnant individuals during the COVID-19 pandemic. Journal of Affective Disorders. 2020;277:5-13. doi:10.1016/j.jad.2020.07.126.

35. Moreira PS, Ferreira S, Couto B, Machado-Sousa M, Fernandez M, Raposo-Lima C et al. Protective elements of mental health status during the COVID-19 outbreak in the Portuguese population. medRxiv. 2020:2020.04.28.20080671. doi:10.1101/2020.04.28.20080671.

36. Planchuelo-Gómez Á, Odriozola-González P, Irurtia MJ, de Luis-García R. Longitudinal evaluation of the psychological impact of the COVID-19 crisis in Spain. 2020.

37. Plomecka MB, Gobbi S, Neckels R, Radziński P, Skórko B, Lazerri S et al. Mental Health Impact of COVID-19: A global study of risk and resilience factors. medRxiv. 2020.

38. Stanton R, To QG, Khalesi S, Williams SL, Alley SJ, Thwaite TL et al. Depression, Anxiety and Stress during COVID-19: Associations with Changes in Physical Activity, Sleep, Tobacco and Alcohol Use in Australian Adults. Int J Environ Res Public Health. 2020;17(11). doi:10.3390/ijerph17114065.

39. Zhang Y, Zhang H, Ma X, Di Q. Mental Health Problems during the COVID-19 Pandemics and the Mitigation Effects of Exercise: A Longitudinal Study of College Students in China. Int J Environ Res Public Health. 2020;17(10):3722. doi:10.3390/ijerph17103722.

40. Zheng Y, Li J, Zhang M, Jin B, Li X, Cao Z et al. A survey of the psychological status of primary school students who were quarantined at home during the coronavirus disease 2019 epidemic in Hangzhou China. medRxiv. 2020:2020.05.28.20115311. doi:10.1101/2020.05.28.20115311.

41. Lopez-Bueno R, Calatayud J, Ezzatvar Y, Casajus JA, Smith L, Andersen LL et al. Association Between Current Physical Activity and Current Perceived Anxiety and Mood in the Initial Phase of COVID-19 Confinement. Frontiers in psychiatry. 2020;11:729. doi:10.3389/fpsyt.2020.00729.

42. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJF, Martin BW. Correlates of physical activity: why are some people physically active and others not? The Lancet. 2012;380(9838):258-71. doi:10.1016/s0140-6736(12)60735-1.

43. Meade LB, Bearne LM, Sweeney LH, Alageel SH, Godfrey EL. Behaviour change techniques associated with adherence to prescribed exercise in patients with persistent musculoskeletal pain: Systematic review. Br J Health Psychol. 2019;24(1):10-30. doi:10.1111/bjhp.12324.

44. Sallis JF, Adlakha D, Oyeyemi A, Salvo D. An international physical activity and public health research agenda to inform COVID-19 policies and practices. J sport health sci. 2020.

45. Burke SM, Carron AV, Eys MA. Physical activity context and university student's propensity to meet the guidelines Centers for Disease Control and Prevention/American College of Sports Medicine. Med Sci Monitor. 2005;11(4):CR171-CR6.

46. Stults-Kolehmainen MA, Sinha R. The effects of stress on physical activity and exercise. Sports Med. 2014;44(1):81-121. doi:10.1007/s40279-013-0090-5.

47. Buman MP, Tuccitto DE, Giacobbi PR. Predicting daily reports of leisure-time exercise from stress appraisals and coping using a multilevel modeling approach. J Sport Exercise Psy. 2007;29:S150-S.

48. Sudeck G, Pfeifer K. Physical activity-related health competence as an integrative objective in exercise therapy and health sports - conception and validation of a short questionnaire. German Journal of Exercise and Sport Research. 2016;46(2):74-87. doi:10.1007/s12662-016-0405-4.

49. Zhang C-Q, Zhang R, Schwarzer R, Hagger MS. A meta-analysis of the health action process approach. Health Psychology. 2019;38:623-37. doi:10.1037/hea0000728.

50. Milne S, Orbell S, Sheeran P. Combining motivational and volitional interventions to promote exercise participation: protection motivation theory and implementation intentions. Br J Health Psychol. 2002;7(Pt 2):163-84. doi:10.1348/135910702169420.

51. Abraham C, Kelly MP, West R, Michie S. The UK National Institute for Health and Clinical Excellence public health guidance on behaviour change: a brief introduction. Psychology, Health and Medicine. 2009;14(1):1-8. doi:10.1080/13548500802537903.

52. Coughlin SS, Whitehead M, Sheats JQ, Mastromonico J, Smith S. A Review of Smartphone Applications for Promoting Physical Activity. Jacobs J Community Med. 2016;2(1).

53. Carroll JK, Moorhead A, Bond R, LeBlanc WG, Petrella RJ, Fiscella K. Who uses mobile phone health apps and does use matter? A secondary data analytics approach. J med internet res. 2017;19(4):e125.

54. Gal R, May AM, van Overmeeren EJ, Simons M, Monninkhof EM. The Effect of Physical Activity Interventions Comprising Wearables and Smartphone Applications on Physical Activity: a Systematic Review and Meta-analysis. Sports Med Open. 2018;4(1):42. doi:10.1186/s40798-018-0157-9.

55. Davies CA, Spence JC, Vandelanotte C, Caperchione CM, Mummery WK. Meta-analysis of internet-delivered interventions to increase physical activity levels. The international journal of behavioral nutrition and physical activity. 2012;9(1):52. doi:10.1186/1479-5868-9-52.

56. Direito A, Dale LP, Shields E, Dobson R, Whittaker R, Maddison R. Do physical activity and dietary smartphone applications incorporate evidence-based behaviour change techniques? BMC public health. 2014;14(1):646.

Tables

Table 1. Characteristics of included studies

Author	Country	Design	Type	N	age group (years)	% females	PA assessment	MH assessment
Bauer et al., 2020	Germany	Cross-sectional	pre-print	3,700	adults (M = 33.13)	78.6	BSA-F	PHQ-9; GAD-7
Callow et al., 2020	US	Cross-sectional	peer-reviewed	1,046	older adults (< 50)	80	PASE	GDS; GAS
Chen et al., 2020a	China	Cross-sectional	peer-reviewed	1,036	children/ adolescents (R = 6-15)	48.7	NR	DSRS-C; SCARED
Chen et al., 2020b	Iran	Cross-sectional	pre-print	474	adults (R = 20-70)	51.3	Single item (hours/day)	PHQ-2; GAD-2
Cheval et al., 2020	France, Switzerland	Longitudinal (retrospective and prospective)	pre-print	110	adults (M = 43)	68	IPAQ	PROMIS (adapted questions for depression and anxiety)
Deng et al., 2020	China	Cross-sectional	pre-print	1,607	adolescents/ young adults (NR)	35.2	Multiple items (duration, frequency)	DASS-21
Filgueiras & Stultz-Kolehmainen, 2020a	Brazil	Cross-sectional	pre-print	1,460	adults (M = 32.9)	72.87	Single item (frequency)	FDI; SSTAI
Filgueiras & Stultz-Kolehmainen 2020b	Brazil	Longitudinal (prospective)	pre-print	360	adults (M = 37.9)	68.8	Multiple items (frequency, type)	FDI; SSTAI
Fu et al., 2020	China	Cross-sectional	peer-reviewed	1,242	adults (NR)	69.7	NR	PHQ-9; GAD-7
Fullana et al., 2020	Spain	Cross-sectional	Peer-reviewed	5,545	adults (M = 47)	73	NR	PHQ-9; GAD-7
Jacob et al., 2020	UK	Cross-sectional	peer-reviewed	902	adults (NR)	63.8	Multiple items (duration/day, intensity)	BDI; BAI
Khan et al., 2020	Bangladesh	Cross-sectional	pre-print	505	adolescents/ young adults	37.3	NR	DASS-21
Lebel et al., 2020	Canada	Cross-sectional	pre-print	1,987	adults (M = 32.4)	100	Multiple items (duration/week, intensity)	EPDS; PROMIS anxiety
Meyer et al., 2020	US	Longitudinal (retrospective)	pre-print	3,052	adults (NR)	62	Multiple items (duration/day, intensity)	BDI; BAI
Moreira et al., 2020	Portugal	Cross-sectional	pre-print	1,280	adults (M = 37.1)	79.8	Single item (duration/day, intensity)	DASS-21
Planchuelo-Gómez et al., 2020	Spain	Cross-Sectional	pre-print	1,056	adults (M = 32.1)	67.6	NR	DASS-21
Plomecka et	Multiple (12	Cross-	pre-print	12,817	adults (NR)	72.3	NR	BDI

al., 2020	countries)	sectional					
Schuch et al., 2020	Brazil	Cross-sectional	Peer-reviewed	937	adults (NR)	72.3	Multiple items (duration/day, intensity)	BDI; BAI
Stanton et al., 2020	Australia	Cross-sectional	peer-reviewed	1,491	adults (M = 50.5)	67	AAS	DASS-21
Zhang et al., 2020	China	Longitudinal (prospective)	peer-reviewed	66	adolescents/adults (M = 20.7)	62.1	IPAQ	DASS-21
Zheng et al., 2020	China	Cross-sectional	pre-print	1,620	children/ adolescents (M = 10.1)	47.8	Single item (decrease since Covid)	DSRSC; SASC

Abbreviations: AAS = Active Australia Survey; BASF-F = The Physical Activity Exercise, and Sport Questionnaire; DASS-21 = Depression and anxiety scale 21 items; DSRS-C = Depression Self-Rating Scale for Children; EPDS = Edinburgh Depression Scale; FDI = Filgueira depression inventory; GAD-7 = Generalized Anxiety Screener 7; GAS = geriatric anxiety scale; GDS = geriatric depression scale; IPAQ = International physical activity questionnaire; M = Mean; MH = mental health; n = number of participants; NR = not reported; PA = physical activity; PAVS = physical activity vital sign; PASE = Physical activity scale for the eldery; PHQ-9 = patient health questionnaire 9; PROMIS = Patient-Reported Outcomes Measurement Information System; R = Range; SASC = Social Anxiety Scale for Children; SCARED = Screen for Child Anxiety Related Disorders; SSTAI = The Spielberg State and Trait Anxiety Inventory

Table 2. Main results of multiple linear and logistic regressions analyzing the association of physical activity or exercise with symptoms of depression or anxiety in the included studies

Author	Predictor	Depressive Symptoms		Anxiety Symptoms	
		Beta (95% CI)	OR (95% CI)	Beta (95% CI)	OR (95% CI)
Volume					
Bauer et al., 2020	EX (minutes/week)	0.00# (NR; NR)		0.01# (NR; NR)	
Callow et al., 2020	PA (PASE score)	-0.22*** (NR; NR)		-0.02 (NR; NR)	
Chen et al., 2020b	EX (hours/day)		0.68* (0.47; 0.97)		0.66* (0.45; 0.96)
Cheval et al., 2020	PA (minutes/day)	NR# (NR; NR)		NR# (NR; NR)	
Jacob et al., 2020	EX (minutes/day)		0.88° (0.8; 0.97)		0.85° (0.79; 0.97)
Khan et al., 2020	EX (any amount; Ref.: No EX)	-2.1* (-4.02; -0.17)[1]		-0.55 (-1.92; 0.82)[1]	
Moreira et al., 2020	EX (hours)	-1.17° (NR; NR)[1]		-0.81° (NR; NR)[1]	
Plomencka et al., 2020	EX (> 15 min/day; Ref.: ≤ 15 min/day, <60 min/day)	-0.13*** (NR; NR)	NR# (NR; NR)		
	EX (≥60 min/day; Ref.: ≤ 15 min/day)	-0.15*** (-0.18; -0.12)	NR# (NR; NR)		
Schuch et al., 2020	PA (minutes/day; per 10 minutes increase)	-0.03 (-0.1; 0.03)		-0.05 (-0.13; 0.02)	
Frequency					
Deng et al., 2020	EX (> 1 to 2 times/week; Ref: < 1x/week)	-0.11*** (NR; NR)		-0.09** (NR; NR)	
Filgueiras & Stultz-Kolehmainen 2020a	EX (frequency/week)	-2.68** (NR; NR)[1]		-1.64*** (NR; NR)[1]	
Fullana et al., 2020	EX (Unclear)		0.93 (NR; NR)		0.95 (NR; NR)
Planchuelo-Gómez et al., 2020	EX (1-2 times/week; Ref.: No EX)	-0.17 (NR; NR)[1]			
	EX (3-5 times/week; Ref.: No EX)	-0.85* (NR; NR)[1]			
	EX (6-7 times/week; Ref.: No EX)	-1.29*** (NR; NR)[1]			
Filgueiras & Stultz-Kolehmainen 2020b	EX (frequency/week)	NR# (NR; NR)		NR# (NR; NR)	
Intensity					
Callow et al., 2020	light PA (PASE score)	0.12** (NR; NR)			

Study	Measure	Col 1	Col 2	Col 3	Col 4
	moderate PA (PASE score)	-0.01 (NR; NR)			
	vigorous PA (PASE score)	0.09* (NR; NR)			
Schuch et al., 2020	vigorous PA (minutes/day)	-0.19* (-0.34; -0.04)	0.6** (0.44; 0.83)	-0.22* (-0.4; -0.03)	0.71** (0.52; 0.96)
	moderate PA (minutes/day)	0.00 (-0.09; 0.09)	0.77 (0.57; 1.02)	-0.03 (-0.14; 0.08)	0.75 (0.58; 1)

Regular/Guideline Conforming

Study	Measure	Col 1	Col 2	Col 3	Col 4
Chen et al.,2020a	EX (regular; Ref.: not regular)		0.37 (NR; NR)[2]		0.43 (NR; NR)[2]
Deng et al., 2020	EX (regular; Ref.: not regular)	-0.2*** (NR; NR)		-0.14*** (NR; NR)	
Fu et al., 2020	EX (not regular; Ref.: regular)		1.71*** (1.28; 2.29)		1.45* (1.08; 1.93)
Lebel et al., 2020	EX (guideline conforming; Ref.: not guideline conforming)		0.87 (0.67; 1.12)		0.81 (0.64; 1.03)
Schuch et al., 2020	PA (≥ 30 minutes/day; Ref.: < 30 minutes/day)		0.72* (0.54; 0.96)		0.72* (0.54; 0.96)

Change

Study	Measure	Col 1	Col 2	Col 3	Col 4
Bauer et al., 2020	EX (less; equal; more)[3]	-0.08*** (NR; NR)		-0.05*** (NR; NR)	
Deng et al., 2020	EX (no change; Ref.: large change)	-0.27*** (NR; NR)		-0.21*** (NR; NR)	
	EX (little change; Ref.: large change)	-0.22*** (NR; NR)		-0.17*** (NR; NR)	
Filgueiras et al., 2020b	EX (none, increase, decrease)	NR# (NR; NR)		NR# (NR; NR)	
Meyer et al., 2020	PA (increased; Ref.: maintained high)	-0.01 (-0.05; 0.02)		0.00 (-0.03; 0.04)	
	PA (decreased; Ref.: maintained high)	0.09*** (0.05; 0.13)		0.03 (-0.01; 0.07)	
	PA (maintained low; Ref.: maintained high)	0.04 (0.00; 0.07)		0.02 (-0.02; 0.05)	
Stanton et al., 2020	PA (negative change; Ref.: no change/positive change)		1.08*** (1.06; 1.11)		1.09*** (1.05; 1.13)
Zhang et al., 2020	PA (per 100 MET increase)	-0.04* (-0.08; 0)		-0.03 (-0.07; 0)	

			2.07**	1.24 (NR;
Zheng et al., 2020	PA (decrease vs. no change/increase)		(NR; NR)	NR)

Table 3. Risk of bias assessment (NIHM tool for observational studies)

| Items	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cross-sectional studies														
Bauer et al., 2020	Y	Y	Y	Y	Y	-	-	Y	Y	-	Y	-	-	Y
Callow et al., 2020	Y	Y	Y	Y	Y	-	-	Y	Y	-	Y	-	-	Y
Chen et al., 2020a	Y	N	NR	N	Y	-	-	N	N	-	Y	-	-	N
Chen et al., 2020b	Y	Y	N	N	Y	-	-	Y	N	-	Y	-	-	Y
Deng et al., 2020	Y	Y	Y	Y	N	-	-	Y	N	-	Y	-	-	N
Filgueiras & Stultz-Kolehmainen, 2020a	Y	N	NR	Y	Y	-	-	Y	N	-	Y	-	-	Y
Fu et al., 2020	Y	Y	NR	Y	Y	-	-	N	N	-	Y	-	-	Y
Fullana et al., 2020	Y	Y	NR	Y	N	-	-	N	N	-	Y	-	-	Y
Jacob et al., 2020	Y	Y	NR	Y	Y	-	-	Y	N	-	Y	-	-	Y
Khan et al., 2020	Y	N	NR	Y	Y	-	-	N	N	-	Y	-	-	Y
Lebel et al., 2020	Y	Y	NR	Y	Y	-	-	N	N	-	Y	-	-	Y
Moreira et al,. 2020	Y	Y	NR	Y	Y	-	-	N	N	-	Y	-	-	Y
Plomecka et al., 2020	Y	Y	Y	Y	Y	-	-	Y	N		Y			Y
Schuch et al., 2020	Y	Y	NR	Y	Y			Y	N	-	Y	-	-	Y
Stanton et al., 2020	Y	Y	NR	Y	Y	-	-	N	Y	-	Y	-	-	Y
Zheng et al., 2020	Y	Y	Y	Y	N	-	-	N	N	-	Y	-	-	Y
Longitudinal studies														
Cheval et al., 2020	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	-	Y	NR
Filgueiras & Stultz-Kolehmainen, 2020B	Y	N	NR	Y	Y	Y	Y	Y	N	Y	Y	-	N	Y
Meyer et al., 2020	Y	Y	Y	Y	Y	N	Y	Y	N	N	Y	-	NA	Y
Planchuelo-Gómez et al., 2020	Y	Y	NR	Y	N	Y	Y	Y	NR	Y	Y	-	N	Y
Zhang et al., 2020	Y	N	NR	Y	Y	Y	Y	Y	Y	Y	Y	-	Y	NR

Figures
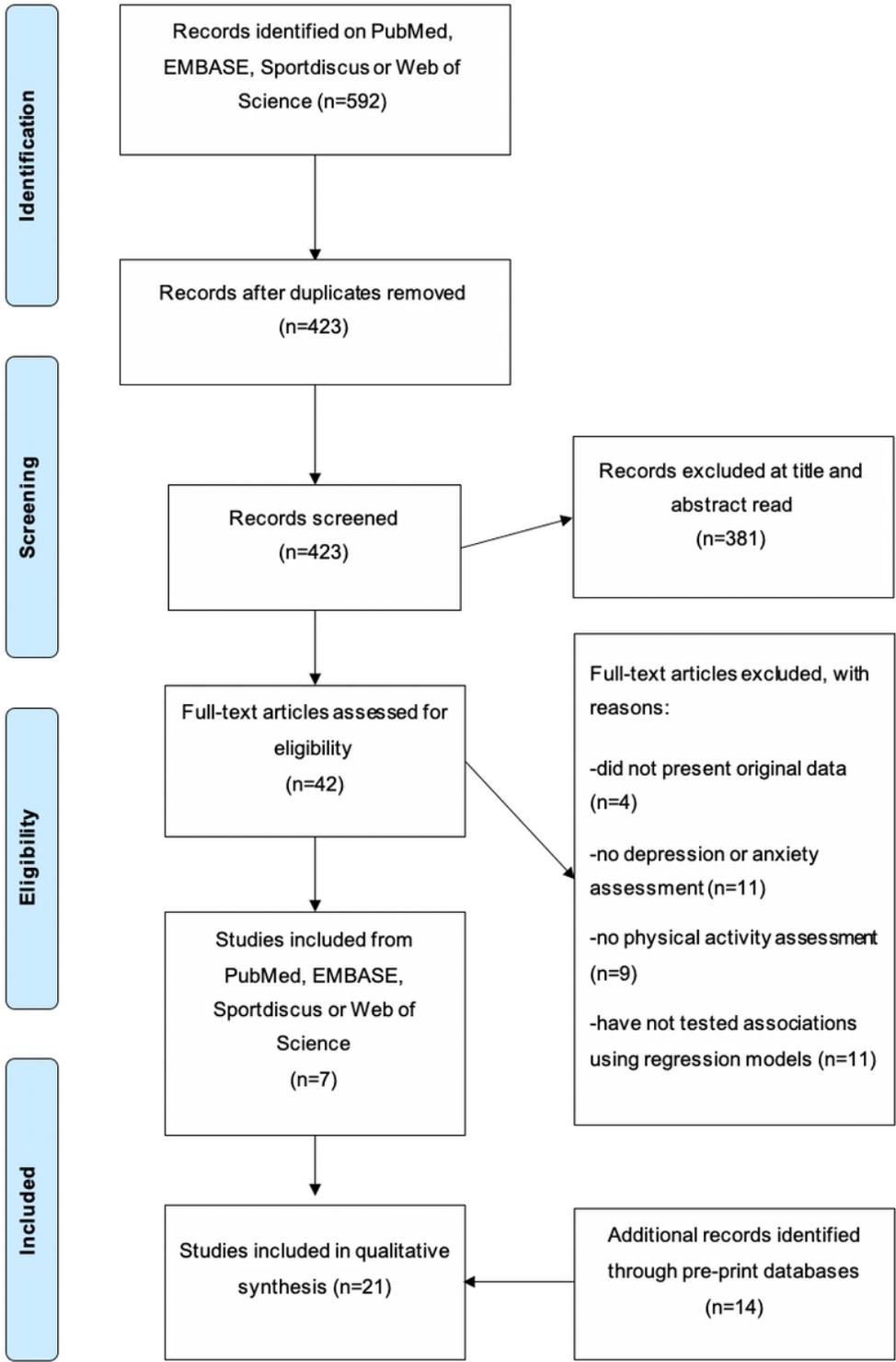
Figure 1

PRISMA flow-chart of the screening and selection of studies.