





## REVIEW ARTICLE

# Physical activity as a tool for preventing and treating depression: Lessons learned from the COVID-19 pandemic

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## Funding information

Medical Research Council,  
Grant/Award Number: DPhil Studentship;  
NIHR Oxford Biomedical Research Centre,  
Grant/Award Number: Depression  
therapeutics

## Abstract

Physical activity (PA) is understood to be important for the prevention and treatment of depression, however, less is known about the effects of withdrawal from PA on mood. Here we consider evidence published since the outbreak of the SARS-CoV-2 virus to assess the impact of the COVID-19 pandemic on PA patterns and to evaluate whether engagement in PA in the context of the pandemic had an impact on depression vulnerability. During the initial stages of the pandemic and consequent lockdowns, there were global decreases in PA, with women, ethnic minorities, lower-education, lower-income, younger, and elderly people displaying more marked reductions in PA. Less PA was associated with a higher risk of experiencing moderate-to-severe depression symptoms, particularly for those who decreased their PA levels compared to pre-pandemic. Both PA and sedentary behavior were independently associated with depression, such that low activity and high amounts of sitting both increased the likelihood of clinically significant symptoms. We also consider the role social connection during movement; while both in-person and online PA can foster a sense of belonging, there is some evidence that socially distant, pandemic-safe movement might disincentivise certain groups such as older adults and experienced exercisers from participating in PA. We conclude with several implications for prospective public health communications regarding PA, especially in the event of another global pandemic.

## KEYWORDS

covid-19, exercise, major depressive disorder, mood disorders, physical activity

## 1 | INTRODUCTION

During the SARS-CoV-2 pandemic, many countries imposed lifestyle restrictions in an effort to curb its spread (Mallah et al., 2021). Stay-at-home orders, closure of indoor facilities, and cancellation of public events were all implemented to reduce social contact and transmission. During periods of lockdown or self-isolation, physical activity

(PA) was key to public health messaging that aimed to promote behaviors that were likely to have a protective effect on physical and mental well-being. The World Health Organisation (WHO) published guidance on how to remain active at home and recommended at least 150 min of moderate-intensity PA (World Health Organisation, 2020a). Some governments, including the UK government, gave exercise "special status," meaning that people continued to be

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allowed to leave their homes to exercise outdoors, even during the strictest periods of lockdown (International Sport and Culture Association, 2020; Prime Minister's Office, 10 Downing Street & The Rt Hon Boris Johnson, 2020). By promoting PA during the pandemic, governments hoped to mitigate both the physical and mental health risks associated with reduced movement, consistent with the current knowledge about the benefits of PA for overall health and resilience to mood disorders.

There is compelling evidence from prospective cohort studies that PA may be important in *preventing* future depression. Large systematic reviews have consistently shown that high levels of PA are associated with lower likelihood of future depression across age, gender, and geographical region, compared to light or no PA (Dishman et al., 2021; Schuch et al., 2018). While the causal direction of this association is difficult to establish, there is some evidence to suggest the relationship is bidirectional, with PA alleviating depressive symptoms across the lifespan, and depressive symptoms acting as a barrier to PA particularly in early adulthood (Pinto Pereira et al., 2014).

PA, and intentional PA, that is, exercise in particular, is also an effective *treatment* for depression. Evidence from meta-analyses of randomized controlled trials indicates moderate-to-large antidepressant effects of PA compared to nonexercising control groups in both adolescents (Bailey et al., 2018; Recchia et al., 2023) and adults (Heissel et al., 2023; Morres et al., 2019), and equivalent effect sizes compared to pharmacotherapy or psychotherapy (Cooney et al., 2013). Indeed, exercise may be an effective treatment adjunct to both pharmacotherapy and psychotherapy compared to treatment as usual, especially for those experiencing more severe forms of depression (Lee, Gierc, et al., 2021). Exercise interventions might help address specific symptoms of depression, such as amotivation and anhedonia (Sun et al., 2022; Toups et al., 2017), which are not well treated using conventional antidepressant medication (Uher et al., 2012) or cognitive therapy (Dunn et al., 2020). In children, certain forms of PA such as martial arts have been shown to promote cognitive and affective self-regulation, both of which are important precursors to positive mental health (Lakes & Hoyt, 2004).

Less is known about the effects of *withdrawing* from PA on mood, which might be particularly relevant in the context of the COVID-19 pandemic. Two small prepandemic studies used experimental manipulations in which previously active participants were instructed to replace any daily structured or unstructured form of PA with being sedentary (Edwards & Loprinzi, 2016; Endrighi et al., 2016). In both these studies, spending as little as 1 or 2 weeks in the sedentary condition compared to usual levels of activity resulted in increases in self-reported negative mood. Importantly, the increase in sedentary time was significantly associated with participants' negative mood score, and this association persisted after controlling for changes in PA (Endrighi et al., 2016). This suggests that PA and sedentary behavior may be independently associated with negative mood and depression. It also suggests that changes in PA patterns, in addition to the amount of PA per se, may play an important role in mitigating depression vulnerability.

The unique circumstances of the COVID-19 pandemic offer an unprecedented opportunity to examine unanswered questions about the relationship between PA and depression risk, and in particular the effects of changes to and withdrawal of usual PA patterns. In many ways, the pandemic can be thought of as a naturally occurring intervention that changed people's PA behaviors globally. This happened through the implementation of lockdowns and the closure of indoor sporting facilities, but also the explicit public health endorsement of pandemic-safe indoor and outdoor exercise, and the later lifting of restrictions. Investigating such changes in PA patterns has utility for understanding the direction of causality in the relationship between PA and mood, which is difficult to establish from observational studies.

The pandemic was also a time of increased depression risk, with sharp increases in people seeking help with their mental health (Holland et al., 2021; Türközer & Öngür, 2020). During the pandemic, individuals across the globe were exposed to a range of psychosocial risk factors for poor mental health including loneliness (Groarke et al., 2020; Killgore et al., 2020), financial uncertainty (ElTohamy et al., 2022), health anxiety (Heinen et al., 2022; Santabábara et al., 2021), and bereavement (ElTohamy et al., 2022; Wang et al., 2022). It is estimated that an additional 53.2 million cases of major depressive disorder occurred globally because of COVID-19 in 2020 alone (Santomauro et al., 2021). Given this context, there is an opportunity to examine whether factors such as PA can serve as protective 'buffers' amid such heightened risk.

Indeed, the need to synthesize the evidence base of lessons learned from the pandemic, including understanding the facilitators and barriers for activities that promote good mental health, was highlighted as a key research priority by the UK Academy of Medical Sciences and the mental health research charity, MQ: Transforming Mental Health (Holmes et al., 2020). It is hoped that this will facilitate tailored recommendations and more effective public health messaging in the future.

Thus, the aims of this narrative review are twofold: (1) to examine the ways in which the pandemic has affected PA patterns and highlight factors that influenced engagement in PA; and (2) to evaluate whether engaging in PA during the pandemic, a period marked by heightened depression risk, has had an impact on individuals' susceptibility to depression. Information Box 1.

### INFORMATION BOX 1 Search strategy

We conducted a comprehensive literature search from 2020 to 2023 using PubMed and Google Scholar. Our search included cross-sectional, longitudinal, and experimental studies, meta-analyses, and systematic reviews relating to PA, and the relationship between PA and depression, during the COVID-19 pandemic. We exclusively considered articles involving human participants and published in English, though we did not limit our search to English-speaking countries regarding geographical region.

We queried two strings, as follows, to address the two aims of the paper:

1. (coronavirus) OR (covid) OR (covid-19) OR (2019nCoV) OR (SARS-CoV-2) AND (physical activity) OR (exercise)
2. (coronavirus) OR (covid) OR (covid-19) OR (2019nCoV) OR (SARS-CoV-2) AND (depression) OR (depress\*) OR (depressive disorder) OR (low mood) OR (mood) OR (mood disorder) OR (dysthymi\*) AND (physical activity) OR (exercise)

Review of titles and abstracts was performed by AR, AG, and JYP. All authors contributed to contextualizing the research.

## INFORMATION BOX 2 Definition and types of PA included in the review

Throughout the review, we adopt the WHO definition of PA as “all movement including during leisure time, for transport to get to and from places, or as part of a person's work” (World Health Organisation, 2022). This includes, but is not limited to, physical exercise, which is typically defined as “physical activity that is planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness” (Caspersen et al., 1985). This broad definition captures the many ways in which PA is operationalized in the literature and allows us to compare findings across multiple study types, populations, and geographical regions.

The following types of PA were most referenced in the research cited:

- exercise and fitness activities, for example, running, cycling, weightlifting, exercise classes taken online or in-person,
- team and individual sports, for example, football, tennis,
- mindfulness-related PA, for example, yoga, Pilates, online or in-person,
- walking and cycling for commuting and leisure, including step count,
- dance, for example, modern, ballet, jazz, online or in-person,
- martial arts, for example, tai-chi,
- household-related PA, for example, gardening, yard work, house repairs, caring for others,
- informal play, for example, games at home.

We refer to “exercise” where structured PA was explicitly studied, and to PA more generally otherwise.

Although considerable variation exists in how PA was quantified in the literature, we found that, most commonly, researchers chose one of the following:

- A dichotomous variable (was/was not physically active during period of interest).
- Number of days physically active during period of interest.
- Time spent in moderate and vigorous PA (MVPA) during period of interest, as measured using the International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003). In the context of the IPAQ, moderate PA is defined as “activities which make one breathe somewhat harder than normal and may include carrying light loads, cycling at a regular pace, or doubles tennis” and vigorous PA is defined as “activities which make one breathe much harder than normal or break into a sweat and may include heavy lifting, digging, aerobics or fast cycling” (Craig et al., 2003).
- Metabolic Equivalent of Task (MET) minutes/week, where one MET corresponds to the energy expenditure while sitting still, per minute, of an average person weighing approximately 70 kg (Jetté et al., 1990). An activity with a MET value of 4, such as walking, means one expends four times the energy compared to sitting still. MET minutes/week are calculated by multiplying the MET value of each type of PA of interest (e.g., walking, cycling, playing sports) by its weekly duration, and then summing up the resulting values. The MET minutes/week measure allows researchers to discern not only an individual's overall PA level but also the specific contribution of different activity types, while accounting for their varying energy demands.

## 2 | THE IMPACT OF THE PANDEMIC ON GLOBAL EXERCISE PATTERNS

On December 31, 2019, the first cases of COVID-19 were reported in Wuhan, China. As more cases emerged in the weeks that followed, the WHO declared COVID-19 a global pandemic on the 11th of March 2020, meaning the virus had spread worldwide (World Health Organisation, 2020b). Governments all over the globe implemented strict measures to curb the spread of the virus which became known as “lockdowns,” and involved stay-at-home orders, border closures, and business shutdowns, limiting outdoor access for nonessential reasons (Kantis, n.d.; Prime Minister's Office, 10 Downing Street & The Rt Hon Boris Johnson, 2020). Throughout 2020 and 2021 many countries locked down, often repeatedly, with restrictions easing as promising vaccine candidates became available. Hence, the initial lockdown measures, followed by the subsequent easing of

restrictions could have substantially impacted movement and potentially led to significant changes in PA patterns.

Several cross-sectional studies conducted across multiple countries reported that there was a decrease in both the frequency and duration of PA in adults during the early stages of the pandemic, from around January 2020 to May 2021, compared to prepandemic (Ammar et al., 2020; Epidemiology & Disease Control Division, Ministry of Health, Republic of Singapore, 2020; Faulkner et al., 2021; Giuntella et al., 2021; McCarthy et al., 2021; Sport England, 2020a; Strain et al., 2022; Tison et al., 2020). Findings were similar across studies whether PA was measured subjectively through self-report (Ammar et al., 2020; Epidemiology & Disease Control Division, Ministry of Health, Republic of Singapore, 2020; Faulkner et al., 2021; Sport England, 2020a; Strain et al., 2022) or objectively via smartphone-app data and step counts (Giuntella et al., 2021; McCarthy et al., 2021; Tison et al., 2020), although significantly fewer studies employed objective measures of PA. One study conducted in the UK examined a substantial data set comprising 74,430 participants from the Active Lives Survey (Strain et al., 2022). The study compared data collected from mid-April to mid-May 2020 with data from the corresponding periods between 2016 and 2019. PA was measured by calculating the average weekly duration (in minutes) of moderate-to-vigorous activities over a 4-week recall period. This study reported that the odds of reporting any PA in 2020 was 30% lower than in previous years and that the overall duration of PA was lowest in 2020 at 882 min per week, compared to 904–929 min per week in 2016 to 2019. There was also a significantly lower duration of moderate intensity PA at 682 min per week in 2020 compared to 754–765 min per week in the years before (Strain et al., 2022).

There are a range of possible reasons why people did not maintain their previous levels of PA, including the lack of access to indoor exercise facilities such as gyms, sports centres, and pools, and not being allowed to exercise outdoors in some countries (Stockwell et al., 2021; Strain et al., 2022). Moreover, early pandemic lockdowns could have induced barriers to PA outside direct closure of exercise facilities, such increased housework and childcare duties (Carlson et al., 2022; Del Boca et al., 2020; Kenny & Yang, 2021) and reduced need for travel to work (Ishibashi & Taniguchi, 2022; Loef et al., 2022). Others might not have had access to spaces suitable for PA, such as gardens, balconies, or parks (Davies & Sanesi, 2022; Office for National Statistics, 2020).

In contrast to the general trend of a decline in PA at the beginning of the pandemic, a secondary analysis of data from a multinational study of 18 countries found that levels of exercise in fact remained similar, but that more people had switched from playing sports to endurance type activities such as running (Benzing et al., 2021). Moreover, two cross-sectional studies carried out in the United Kingdom (Bailey et al., 2022) and Spain (Romero-Blanco et al., 2020) found an increase in the total duration of PA early in the pandemic between April and May 2020. In the UK study, the increase in the total amount of weekly PA was largely explained by an increase in walking, which accounted for 241 MET minutes/week out of a

total increase of 302 MET minutes/week (Bailey et al., 2022) (for a more comprehensive definition of the MET minutes/week measure, please see Information Box 2). While the results here are in line with research that has documented an increase in walking for leisure during the pandemic (Brown & Marsden, 2022; Kass et al., 2021), it is important to note that other studies may not have captured a similar increase because walking is not always included in PA assessments (Shephard, 2003; Troiano et al., 2020).

Interestingly, some studies found that changes in PA at the onset of the pandemic were related to prepandemic levels of PA. Specifically, those who were highly active before the pandemic showed the largest decrease in PA at the start of the pandemic (Constandt et al., 2020; Elliott et al., 2022; Epidemiology & Disease Control Division, Ministry of Health, Republic of Singapore, 2020; Tison et al., 2020). This could be because highly active people were more likely to be reliant on structured exercise classes or facilities such as sports clubs or gyms and were more likely to take part in group-based sports activities regularly in a social context (Raza et al., 2022; Stevens et al., 2019). In those who were less active before the pandemic, the findings are more mixed; while several large studies found that previously inactive individuals became more active or exhibited a lesser decrease in PA during the early stages of lockdown (Constandt et al., 2020; Faulkner et al., 2021; McCarthy et al., 2021), including a study of older adults in the United Kingdom (Elliott et al., 2022), two studies found that this group were also less likely to exercise frequently during the pandemic (Krist et al., 2021; Romero-Blanco et al., 2020). It should be noted, however, that both of the studies reporting a decrease in PA in those who were less active prepandemic did not use previously validated measures of PA and that they examined smaller sample sizes (818 and 106 participants, respectively) compared to studies reporting the opposite finding of increased PA in those who were less active before the pandemic (sample sizes ranging from 3660 to 13,515 participants) (Constandt et al., 2020; Elliott et al., 2022; Faulkner et al., 2021; McCarthy et al., 2021).

As the pandemic continued, several countries across the world began to progressively relax restriction measures (Han et al., 2020) while implementing vaccination programs from around late 2020 to mid-late 2021. This reduction in restrictions including reopening some exercise facilities such as gyms, recreational facilities, and fitness centres, as well as the relaxation of regulations around exercising outdoors (Han et al., 2020). Longitudinal studies are useful in this context to examine how differences in levels of restrictions throughout the pandemic influenced patterns in PA. Two relatively large longitudinal studies carried out in the United States ( $n = 6540$ ) and across the Austrian, German, and Italian Alps ( $n = 2975$ ) reported an increase in duration and frequency of PA as the pandemic progressed (Schöttl et al., 2022; Wijngaards et al., 2022). Interestingly, the US study also measured the stringency of COVID-19 measures across states in the form of a Standardized Stringency Index and examined if there were any associations with the frequency of exercise (Wijngaards et al., 2022). During the initial lockdown period (April 2020 to January 2021), when the stringency

of COVID-19 measures was comparatively high, it was found that state-level stringency of COVID-19 measures was inversely associated with the frequency of exercise ( $p < 0.01$ ), highlighting the direct impact of lockdown measures on levels of PA. However, it is notable that in both studies, the increase in PA coincided with the summer period, and the findings could therefore partly reflect seasonal patterns in exercise behavior as there tends to be higher PA observed in warmer months (Tucker & Gilliland, 2007). More recently, a large survey of 177,551 UK adults conducted between November 2021 and November 2022 reported that PA levels as well as participation in team sports increased postlockdown and have since returned to pre-pandemic levels (Sport England, 2023a). However, walking for leisure, which increased earlier in the pandemic, decreased, and other fitness activities such as going to the gym and attending structured fitness classes are yet to see the same uptake as pre-COVID (Sport England, 2023a).

There were differences across age groups in the impact that the pandemic had on levels of PA, with young people and older adults affected to a greater extent. A systematic review and meta-analysis of 22 studies found that the duration of PA in children and adolescents decreased by 20% during periods of lockdown, and the time spent engaging in moderate-to-vigorous intensity PA also decreased significantly (Neville et al., 2022). For some children, a lack of active travel to school (Nguyen et al., 2021), a lack of access to outdoor areas which could be used for exercise and play (Okely et al., 2021), and increased parental stress and exhaustion (Okely et al., 2021) could explain the trend towards reduced PA. Several cross-sectional studies also found that adolescents and young adults below the age of 35 were less physically active than before the pandemic compared to older age groups throughout the pandemic (Bu et al., 2021; Faulkner et al., 2021; McCarthy et al., 2021). One reason for this could be a higher reliance on indoor facilities, school-based PA, and a higher likelihood of participating in team sports in these age groups (Do et al., 2022; Koski et al., 2022), all of which were heavily affected by lockdown restrictions. While PA levels in young people have improved now compared to during the pandemic, these improvements were not uniform, and there was a greater recovery in PA levels in older children between the ages of 11 and 16 (Sport England, 2023a). A very recent Korean study of 1143 adolescents reported that the frequency and duration of PA increased after the easing of all COVID-19 restrictions in 2023 compared to during the pandemic (Yun & Lee, 2023), however, it is unclear whether participants have returned to pre-COVID PA levels as the study did not have pre-pandemic baseline data for comparison. Another recent UK study reported that there are still half a million fewer young people between the ages of 16 and 34 who achieve the recommended 150 min of PA per week today compared to 6 years ago (Sport England, 2023a). There was also a significant drop in PA in older adults aged 60 and above, according to a systematic review of 25 studies (Oliveira et al., 2022). This is of particular concern given the health risks that inactivity poses to this population, such as loss of mobility, balance, cardiorespiratory endurance, and increased frailty syndrome (Battaglia et al., 2014; Bellafiore et al., 2011; Cesari et al.,

2015; Vigorito & Giallauria, 2014). Fortunately, however, in contrast to young people, PA levels in older adults are increasing and have reached levels higher than before the pandemic (Sport England, 2023a). It is noteworthy that a study of older adults in German-speaking parts of Europe found that increased feelings of self-efficacy and positive outcome expectancies regarding the health benefits of PA significantly predicted participants' intention to remain active postlockdown (Bösch & Inauen, 2023). Another potential reason for the increase in PA in older adults could be due to public health messaging campaigns around the importance of keeping active for those at increased risk of cognitive decline and physical health issues.

There were also gender differences in the impact of the pandemic on PA patterns. Multiple large-scale studies using well-validated self-report measures of PA found that women were less physically active than men during this time (Kuzmik et al., 2022; Nienhuis & Lesser, 2020; Puccinelli et al., 2021; Sport England, 2020a). While a lack of enjoyment and self-consciousness were reported to contribute to lower levels of PA in women pre-pandemic (Hickey & Mason, 2017; Moreno & Johnston, 2014), women may have also faced pandemic-specific barriers to PA engagement, such as time constraints due to increased childcare and home-schooling (Carli, 2020; Petts et al., 2021). In contrast, two studies reported that women were more physically active than men during the pandemic (Faulkner et al., 2021; Schöttl et al., 2022), although it should be noted that the questionnaire used to measure PA was not validated in one of these studies (Schöttl et al., 2022). One possible explanation for the contradictory findings could lie in differing definitions of what constitutes PA, and whether activities other than those of medium- and high-intensity are considered: for example, one study reported that while women engaged in less high-intensity PA such as running, cycling or resistance training than men, they were more likely than men to engage in low-intensity activities such as yoga and Pilates (Faulkner et al., 2021) which may have been easier to perform at home. The recent Active Lives Survey 2021–2022 (Sport England, 2023a) reported that, while men initially showed larger decreases in PA levels at the start of the pandemic, their PA levels have since returned to prepandemic levels. However, although women had a slightly smaller initial decrease in PA, their PA levels have yet to return to pre-pandemic levels; this is important as it suggests that the pandemic might have widened a pre-existing gender gap in PA (Azevedo et al., 2007; Sport England, 2020b; The Lancet Public Health, 2019).

In countries with a majority white population, several large studies (Bann et al., 2021; Dunton et al., 2020; Robinson et al., 2021; Sher & Wu, 2021; Sport England, 2020a, 2023b; Strain et al., 2022) have reported that Black, Asian and people belonging to mixed or multiple minority ethnic groups (Dunton et al., 2020; Sport England, 2020a) had a greater reduction in PA compared with white participants. This may be partly explained by reduced access to outdoor or green space suitable for PA; a British survey found that during the pandemic, ethnic minorities identifying as Black, Asian, or mixed were less likely to have access to a private outdoor



space inside their homes compared to white respondents (Office for National Statistics, 2020). Moreover, in the United Kingdom, 40% of people from ethnic minority backgrounds live in the most green-space-deprived areas, compared to only 20% of the white population (Friends of the Earth, 2020). Ethnic minorities are also less likely to report good walking routes near to where they live, which might also be a barrier to PA engagement (Natural England, 2019).

Additionally, a recent narrative review of 10 studies found that outside of the pandemic, ethnic minorities were less likely than white people to access green spaces due to concerns about neighborhood safety (Robinson et al., 2023). It is likely that these concerns persisted during the pandemic (Gao et al., 2023) and could be one explanation for the disproportionately lower levels of PA observed in ethnic minorities. For example, a US study found that being an Asian college student was associated with performing significantly lesser PA compared to white college students after the stay-at-home order was issued, which the authors believe might have been prompted by an increase in xenophobic attitudes and unprovoked assaults towards Asians at the time (Coughenour et al., 2021).

Socioeconomic factors such as lower levels of education (Bailey et al., 2022) and lower income (Petts et al., 2021; Wijngaards et al., 2022) were also associated with decreased levels of PA in the context of the pandemic. This could be in part due to limited access to PA equipment (Dubey et al., 2022) and outdoor spaces such as gardens or parks (Burnett et al., 2021). Furthermore, individuals with lower socioeconomic status are more likely to live in smaller homes and in larger households (Patel et al., 2020; Shur et al., 2020), which could restrict the space available for PA.

Aside from changes in PA, there were also changes in sedentary behavior reported throughout the pandemic. Across several cross-sectional studies, it was found that sedentary behavior increased during the pandemic, with more people engaging in high amounts of sitting (Ammar et al., 2020; Bailey et al., 2022; Constandt et al., 2020; Karageorghis et al., 2021; Krist et al., 2021; Meyer et al., 2020; Zheng et al., 2020). This could be due to an increase in the amount of time spent at home due to remote working arrangements and having more time to engage in sedentary activities such as watching television shows, playing video games, and reading (Bailey et al., 2022).

Increases in sedentary behavior such as television viewing and smartphone use were also observed in preschoolers (Okely et al., 2021) and children aged 5–12 years old (Gilbert et al., 2021). A systematic review found that inactive lifestyles in older adults likewise rose significantly during the pandemic, with more elderly engaging in higher amounts of sitting (Oliveira et al., 2022). Nevertheless, in this older age group, a recent longitudinal study found that while sitting time increased during the first 3 months of the pandemic, it returned to pre-pandemic levels a year later (Lefferts et al., 2022). There appear to be no studies in adults and adolescents examining sedentary behavior post-COVID, and it is therefore unclear whether it has returned to pre-pandemic levels in younger people.

In summary, while PA levels largely declined at the beginning of the pandemic, there was a subsequent increase in PA uptake as the pandemic progressed and COVID-19-related restriction measures

were eased. The pandemic impacted not only PA patterns but also the amount of time spent sedentary, with an increase in the amount of time sitting. Certain sociodemographic groups were disproportionately affected by the pandemic, with women, ethnic minorities, lower-education, lower-income, younger, and elderly people displaying more markedly reduced PA during this time. Research suggests that PA levels may have returned to, or even exceeded, pre-pandemic levels in men and older adults; however, women and young people continue to be affected by lower levels of PA compared to before the start of the COVID pandemic.

### 3 | THE IMPACT OF PA ON DEPRESSION VULNERABILITY DURING THE PANDEMIC

The pandemic provides a unique opportunity to examine the effects of PA, and withdrawal of PA, on depression risk. In the context of a shared global stressor, it is important to consider whether any amount of PA, and indeed maintaining similar prelockdown levels of PA, was protective against mood disturbance. The pandemic also provides the opportunity to consider the effects of PA withdrawal on depression vulnerability. By understanding these pandemic-specific dynamics, we can gain insights into the importance of promoting PA as a means to enhance psychological resilience during times of increased risk.

Numerous cross-sectional studies conducted in adult populations found negative associations between the amount of PA performed and depression symptoms (Ding, Yang, Chin, Sullivan, Durstine, et al., 2021; Fu et al., 2020; Jacob et al., 2020; Planchuelo-Gómez et al., 2020; Schuch et al., 2020; Silva Moreira et al., 2021). A large British study of 903 adults showed that the duration of moderate-to-vigorous PA per day was negatively associated with depression, such that less PA was associated with a higher risk of experiencing moderate-to-severe self-reported symptoms of depression (Jacob et al., 2020). Similar associations were reported in studies of Chinese, Spanish, Brazilian, and Portuguese adults (Fu et al., 2020; Planchuelo-Gómez et al., 2020; Schuch et al., 2020; Silva Moreira et al., 2021), as well as in a multinational study of 11 countries (Ding, Yang, Chin, Sullivan, Durstine, et al., 2021), irrespective of how PA was quantified. Notably, anxiety and stress, which are often comorbid with depression, were also associated with lower levels of PA in these studies. A meta-analysis of 21, mostly cross-sectional, studies by Wolf et al. (2021) reported that those who spent a higher total time engaged in moderate to vigorous PA had 12%–32% lower likelihood of experiencing moderate-to-severe depression and 15%–34% lower chances of experiencing moderate-to-severe anxiety (Wolf et al., 2021).

A similar inverse relationship between the amount of PA and depression symptoms was observed in cross-sectional studies conducted in children (Zheng et al., 2022), adolescents (Chen et al., 2020; Lu et al., 2020), and young adult populations (Deng et al., 2020; Khan et al., 2020). One study of 965 Chinese adolescents (Lu et al., 2020) examined the relationships between PA time, sitting time, and the presence of

depression symptoms; they found that both PA time and sitting time were independently associated with depression symptoms, albeit in opposite directions: participants with high PA time were less likely to report experiencing depression symptoms, while those with high sitting time were more likely to report feeling depressed. Participants who exhibited both low PA and high sitting time had the highest likelihood of experiencing clinically significant symptoms of depression, highlighting the importance of understanding how exercise interacts with other behaviors to promote resilience in the face of high-stress situations. Studies of older adults further suggested that greater levels of PA were associated with lower levels of depression symptomatology (Callow et al., 2020; Carriedo et al., 2020). When the intensity of PA was included in analyses, greater levels of light and strenuous activity, but not moderate activity, predicted lower depression symptoms (Callow et al., 2020), although light and moderate-intensity activity scores were correlated ( $r = 0.50$ ).

It is important to note that some studies did not find a significant relationship between levels of PA and depression (Fullana et al., 2020; Lebel et al., 2020). Indeed, one Canadian study of 1987 pregnant women reported that the likelihood of experiencing clinically elevated symptoms of anxiety were lower if participants reported more PA, but the association only reached trend-level for depression (Lebel et al., 2020). While the specific effects of pregnancy on the relationship between PA and depression are not known, a similar study conducted in the United States did not support a lack of association between PA levels and depression during the pandemic (Gildner et al., 2020). It remains to be ascertained whether pregnancy can influence the relationship between PA and depression, and whether any observed effects are pandemic-specific; this is particularly important given that women were less physically active in general over the pandemic. Another large study of 5545 Spanish adults found no relationship between exercising (assessed using a binary yes/no measure) and severity of self-reported depression symptoms (Fullana et al., 2020). In this study, following a healthy diet, having a routine, not reading updates about COVID-19, pursuing hobbies, and time spent outdoors were the best predictors of lower levels of depression symptoms. Importantly, hobbies involving movement and spending time outdoors are included in the measure of light intensity PA in some studies (Callow et al., 2020), which could explain the different results.

A number of studies investigated the relationship between changes in PA patterns and presence of depression/depressive symptoms. This is interesting because, while causation cannot usually be inferred from cross-sectional designs, studying a change from the norm (vs. no change) is more akin to an experimental manipulation from which an order of events could be established. Many of these studies reported that individuals who decreased their PA during lockdown compared to prepandemic levels reported more negative mood (Coughenour et al., 2021; Faulkner et al., 2021; Meyer et al., 2020; Stanton et al., 2020) and had increased likelihood of experiencing moderate-to-severe depression (Kua et al., 2022). Conversely, an increase in PA duration or frequency relative to pre-pandemic was found to be protective in some studies (Faulkner et al., 2021; Kua et al., 2022; Markofski et al., 2022), but not all

(Puccinelli et al., 2021; Rösel et al., 2022). A survey of 4268 German adults (Rösel et al., 2022) found that a change towards less exercise was associated with more self-reported depression symptoms, but a change towards more exercise was not significantly associated with an improvement in depression. Another comprehensive study of 2140 Brazilian adults (Puccinelli et al., 2021) only reported benefits of maintaining the same level of PA as pre-pandemic but not of increasing it, although over 90% of the sample was classed as active or very active before restrictions and only 6.4% increased their PA levels during the lockdown. Thus, it seems that preventing people from performing the amount of PA they are accustomed to might be a risk factor for depression in the context of the COVID-19 pandemic.

Fewer longitudinal studies examined the relationship between changes in PA and depression. One UK study of 3281 adults over the age of 50 reported that the differences in depression and anxiety scores between physically active and inactive people were on average 15% and 20% higher in 2020 than in previous years. Those who reported a pandemic-related decrease in PA in 2020 scored approximately one point higher on the Patient Health Questionnaire-9 (PHQ-9) than those who did not, whereas in previous years inactive participants would have only scored approximately 0.5 points higher (Creese et al., 2021). A second, comparatively smaller study of 110 adults in France and Switzerland found that an increase in PA from Weeks 2 to 4 of the first pandemic lockdown was associated with improved physical health but had no effect on self-reported depression (Cheval et al., 2021). However, an increase in sedentary behavior from Weeks 2 to 4 of the same lockdown was associated with poorer self-reported mood and ability to think. This, again, points to an important distinction between PA and being sedentary, and the roles these separate factors played in promoting risk and resilience to depression during the pandemic.

In terms of optimal patterns of being active, a small longitudinal study of 66 college students found a U-shaped relationship between amount of PA and self-reported depression symptoms; the PA level associated with the lowest burden of depression symptoms corresponded to 108 min of light, 80 min of moderate, or 45 min of vigorous PA every day (Zhang et al., 2020). Both inadequate and excessive amounts of PA worsened negative emotions. This is partly in line with the findings of a cross-sectional study of 937 Brazilian adults reported above (Schuch et al., 2020). In this study, those performing  $\geq 30$  min/day of moderate to vigorous PA or  $\geq 15$  min/day of vigorous PA had lower odds of experiencing prevalent depression symptoms (defined as a score of  $\geq 10$  on the Beck Depression Inventory), although a ceiling after which exercise became detrimental was not found.

Randomized controlled trials investigating the effectiveness of PA interventions for depression over the period of the pandemic are scarce; restrictions on leaving one's home, limited access to research facilities, and inability to meet face-to-face with study participants likely played a role in preventing such research. Nevertheless, there were two intervention studies that targeted inactive older adults who might experience motor learning difficulties as a result of isolation (Beauchamp et al., 2021; Solianik et al., 2021). In a small study

conducted in Lithuania, 30 participants over the age of 60 were randomized to either a 10-week program of tai-chi or a waitlist control group. The tai-chi intervention consisted of biweekly 60-min sessions conducted in an in-person group setting, with the same instructor, during the summer of 2020 when individuals were not required to socially isolate. By the end of the 10 weeks, tai-chi was found to significantly decrease depression and perceived stress relative to the waitlist control, and also improved reaction times and accuracy on a number of cognitive tasks (Solianik et al., 2021). A comparatively larger Canadian study of 241 older adults using online exercise classes found no effect of either group-based or personal exercise on self-reported depression symptoms after a 12-week trial, although it is important to note that the intended sample size was not reached (Beauchamp et al., 2021).

In summary, large studies conducted across multiple countries consistently demonstrated that less PA was associated with a higher risk of experiencing moderate-to-severe depression symptoms during the COVID pandemic. Additionally, a high amount of time spent sedentary was independently associated with more negative self-reported mood and increased likelihood of clinically significant depression. Decreased PA compared to pre-pandemic levels was also linked to more negative mood and increased likelihood of experiencing depression. Conversely, maintaining prepandemic PA levels seemed to be protective. Although limited due to pandemic restrictions, one small intervention study suggested that an in-person PA program focused on martial arts was beneficial in reducing depression and perceived stress among older adults.

#### 4 | THE IMPORTANCE OF ENJOYMENT AND SOCIAL CONNECTEDNESS IN PA DURING THE PANDEMIC

A further consideration, both within and outside of the context of the pandemic, is the role enjoyment and social connectedness play in the positive effects of PA. Despite the provisions made by many governments to allow people to continue to be active, some forms of PA, such as group workouts, team sports, and fitness classes remained inaccessible for large periods during the pandemic. Many structured, group-based PA classes, ranging from traditional exercise activities to other more creative forms of movement such as dance, moved online at the start of the pandemic, and many remained online or hybrid for an extended period. The resulting limited opportunities for socialization during PA may have resulted in decreased motivation, reduced enjoyment, and an overall decline in mental well-being among individuals who thrive on the social connections fostered through movement (Lowe et al., 2023; Shepherd et al., 2021).

Enjoyment of movement-based activity has been suggested to moderate individuals' propensity to continue with PA regimens (Jekauc, 2015). For instance, Foley et al. (2019) reported that in a sample of 1190 otherwise physically inactive women who attended "No Lights, No Lyrca" dance across Australia (which involves free-form dance with dim lighting for 60 min within a nonjudgmental

community space built around inclusivity and without the presence of drugs or alcohol), women reported that the main reason they participated was because they found the activity to be fun (Foley et al., 2019).

Furthermore, it is increasingly understood that the social connectedness aspect of PA may be important for both enjoyment and clinical benefit, especially in older adults (Miller et al., 2019; Stevens et al., 2021). For example, out of two RCTs that studied the effects of a PA intervention on depression in adults over the age of 60 during the pandemic, only the one conducted in an in-person, group setting was found to be effective in improving depression in this population (Solianik et al., 2021). In another study looking at the effects of a dance program specifically targeted at mental health and motor function in individuals with Parkinson's disease, the researchers moved the dance classes to an online format following the onset of the pandemic. While they found significant reductions in depressive symptoms and improvements in affect following participation in the online classes, 13 out of the 21 participants indicated that they preferred in-person classes to the online format because of the social interactions that happen during in-person sessions, which suggests that social interactions may play an important role in the moderation of enjoyment of PA (Ghanai et al., 2021). These findings are perhaps unsurprising, given that low mood in individuals over 50 is intimately tied to feelings of loneliness and isolation (Lee, Pearce, et al., 2021). Online PA interventions may not provide the same sense of community, especially in older adults who might not be used to relying on technology to fulfill social needs.

However, there is some evidence to suggest that it is possible to foster a sense of social connectedness, even when PA classes are delivered online. For example, in a US study of online dance exercise classes during the pandemic, modern, ballet, and jazz dance classes were all associated with improvements in affective state and social connection in adult participants. The participants who experienced the largest self-esteem increases and decreases in negative affect also demonstrated the most gains in social connectivity (Humphries et al., 2023). While the direction of this effect is unclear, it does suggest that social connection during movement exercises may be an important factor in the relationship between PA and mental health in the context of the pandemic, and that social connectedness is possible even with an online format. Indeed, social connectedness may be especially valued in the context of a global event, such as the pandemic, where feelings of solidarity and unity may be particularly important for mental well-being (Bowe et al., 2022).

Interestingly, in another study from the same group using a similar data set (online beginner-level Zoom modern, ballet, and jazz classes), when including dance experience as a covariate, researchers found that the more experienced a dancer, the less positive affect change they experienced from the class (Rugh et al., 2022). It may be that individuals who had more experience attending dance classes in person felt the lack of in-person interactions more acutely, and this resulted in less enjoyment and less positive affect change. In another study of habitual exercisers, it was reported that those who were more active before the pandemic experienced a notable absence of



the competitive aspect of exercising and were hence less likely to engage in PA at the start of lockdown (Constandt et al., 2020). They were also more likely to have been taking part in team sports, which were particularly affected by COVID restrictions (Strain et al., 2022). Collectively, these studies suggest that PA experience could potentially moderate enjoyment in pandemic-safe movement and may interact with social aspects of PA such as social connectedness and competition to promote or hinder participation.

In summary, social connection may be an important aspect of the mental health benefits of PA. Online formats may not fully replicate this important aspect of PA, particularly for older individuals and those with more experience of being active. Future research should continue to examine the individual, interpersonal, and communal contributors to the engagement with, and effects of, PA.

## 5 | LIMITATIONS OF THE EXISTING EVIDENCE BASE

There are several limitations to the studies reviewed here that should be considered. First, most of the research investigating PA during the COVID pandemic and/or its relationship with depression is cross-sectional in nature. This means it is difficult to establish the direction of causality and say, with certainty, that the pandemic caused changes in PA patterns and that those in turn impacted mood or depression risk. Nevertheless, the relationship between worldwide lockdowns and the reported initial decrease in PA is likely to be causal, driven by the closure of gyms and indoor sport facilities in the incipient stages of the pandemic. In terms of the relationship between PA and depression, it is likely the association is bidirectional, with lower levels of PA contributing to higher depression symptoms and vice-versa. An emerging finding from research conducted during the pandemic is that a change towards less PA compared to pre-pandemic levels is particularly associated with depression in several studies (Coughenour et al., 2021; Faulkner et al., 2021; Kua et al., 2022; Meyer et al., 2020; Rösel et al., 2022; Stanton et al., 2020), which points to a potential causal role of altered PA regimes as a risk factor for mood disorders.

Second, there is lack of uniformity across studies in the method used to measure PA levels, with few studies using previously validated tools. Of the studies reported, only a few used the International Physical Activity Questionnaire (IPAQ) to formally quantify exercise, which incorporates measures of intensity, duration, and frequency (Craig et al., 2003). Other studies used PA trends (whether participants were subjectively more or less active than before the pandemic, or whether they were active at all), duration, frequency, or a combination of the above. Few of the studies included in this review specified any exclusion criteria for PA, and some acknowledge they were prone to overestimating people's levels of PA, especially where daily activities such as walking and gardening were included in the measure of total PA performed (Stanton et al., 2020). Moreover, most studies used self-report measures of PA, which are vulnerable to recall bias regardless of whether they

employed a simple yes/no measure of PA or assessed PA patterns in greater depth. Only three studies used an objective smartphone data measure of PA (Giuntella et al., 2021; McCarthy et al., 2021; Tison et al., 2020), which corroborated the decline in PA at the start of the pandemic reported by many other studies using self-report data (Ammar et al., 2020; Epidemiology & Disease Control Division, Ministry of Health, Republic of Singapore, 2020; Faulkner et al., 2021; Sport England, 2020a; Strain et al., 2022).

Regardless of how PA was quantified, there was consistency across most studies assessing its association with depression that there was a significant inverse relationship between the amount of PA performed and level of depression symptoms. This is consistent with prepandemic research, including the suggestion that there is a ceiling past which exercise becomes less beneficial (Chekroud et al., 2018), although this is less clear in the pandemic data.

Third, seasonal patterns in PA behavior could be a confounding factor which was not always accounted for in the research cited. A recent scoping review observed that the total amount of moderate-to-vigorous PA is higher in the summer months compared to winter (Turrise et al., 2021). The initial periods of lockdown, during which a greater decline in PA and increase in sedentary behavior was observed, coincided with winter in Europe and the United States, which means that it is difficult to fully disentangle the effects of seasonal variations from the effect of the pandemic on PA. However, a repeated study across 5 years (2016–2020) which had seasonally matched participants still found a decline in PA at the start of the pandemic (Strain et al., 2022).

Fourth, it is important to highlight that the majority of studies included in this review had female-majority samples. Although gender was used as a covariate and controlled for in many of the reported analyses, few studies focused on gender differences as an outcome and it remains unclear whether the same conclusions can be freely generalized across both male and female populations. There is an apparent lack of consensus about whether men or women were more physically active during the pandemic, although this could be dependent on the specific type of PA studied (Faulkner et al., 2021). One study reported that women had significantly lower levels of PA than men and that these were significantly influenced by the perceived difficulty of being physically active, whereas this association was not significant for men (Nienhuis & Lesser, 2020). The same study found that women who experienced increased childcare demands reported increased difficulty and decreased confidence in being physically active, even though there was no significant difference in the number of men and women in this sample who saw changes to childcare provision. This suggests women may require targeted opportunities and support to remain physically active, particularly during stay-at-home scenarios such as a global pandemic. Furthermore, we identified no studies examining how the COVID pandemic influenced the relationships between exercise and depression in gender nonbinary or nonconforming individuals.

Highly physically active and highly educated individuals are over-represented across the research reviewed, whilst ethnic minorities, individuals with lower education levels, and lower household income

are underrepresented (Bailey et al., 2022; Faulkner et al., 2021). Given that existing health inequalities may exacerbate the effect of the pandemic on physical and mental health, it is vital for further research to (re)examine specific barriers and facilitators for PA in disadvantaged populations, as well as their relationship with depression risk.

A detailed consideration of the interactions between changes in PA and other risk factors for depression exacerbated by the pandemic was beyond the scope of this review. However, as the COVID pandemic altered daily routines, sleep and nutrition were also among the aspects that suffered notable changes (Huber et al., 2021; Morin et al., 2021); the relationships between PA, sleep, nutrition, and mood are highly complex, more so within the context of the pandemic, but would benefit from closer inspection in future research. Nevertheless, the evidence base reviewed here revealed an interesting relationship between low PA and sedentary behavior, with the combination of the two making the highest contribution to depression risk.

Lastly, there were varying forms of social restrictions imposed by different governments, though a multi-country comparison study found that such country-level factors were weakly associated with depressive symptoms (Ding, Yang, Chin, Sullivan, Demirhan, et al., 2021). However, this still somewhat limits our ability to draw common conclusions across studies and populations.

## 6 | CONCLUSIONS AND RECOMMENDATIONS

In this narrative review, we sought to (1) examine the ways in which the pandemic has affected PA patterns and highlight factors that influenced engagement in PA and (2) to evaluate whether engaging in PA during the pandemic, a period marked by heightened depression risk, has had an impact on individuals' susceptibility to depression.

As governments across the globe took drastic measures to contain the spread of the virus, there was a general reduction in PA, particularly at the start of the COVID-19 pandemic. Furthermore, studies suggested that lower levels of PA (duration, frequency, or intensity) were negatively associated with depressive symptoms. Those who decreased their levels of PA compared to pre-pandemic may have been particularly at-risk of developing depressive symptoms, whereas an uptake in PA was not always associated with decreased mental health burden. Several demographic and lifestyle factors seemed to modulate changes in PA patterns during the pandemic, although more research is needed in this area. Being young, female, or from a disadvantaged background was associated with becoming less active, with current PA levels continuing to be lower than pre-pandemic in women and young people.

In addition to structural inequalities, it is important to consider that on an individual level, differences in motivation may impact upon engagement in PA. Consistent with this, a Malaysian study reported that those with negative mood found it challenging to fully integrate exercise into their lives (Yew et al., 2022). Given that motivational

dysfunction can be present in depression, PA might be best stipulated within the context of psychological interventions such as behavioral activation therapy, which specifically address amotivation and anhedonia (Hird et al., 2024). Beyond PA levels, time spent in sedentary behavior was independently associated with depression during the pandemic. Requiring people to isolate in their own homes brings about changes not only in PA patterns, but also in the amount of time spent sitting or physically inactive, which tends to increase—for example, during long periods of remote working where previously the job demanded travel to the office (Fukushima et al., 2021). The studies included in this review suggest that increases in sitting time are associated with increased depression-like symptomatology (Cheval et al., 2021), and that those who report both becoming less active and more sedentary have the worst mental health outcomes (Lu et al., 2020). Notably, these changes in behavior do not need to be long-term to potentially have a detrimental effect; one longitudinal study found that even a 2 weeks increase in sedentary behavior was significantly associated with decreased mood and ability to think (Cheval et al., 2021). Conversely, there were no significant relationships between changes in PA and participants' mental health across the same 2 weeks, suggesting that the effects of PA and sedentary behavior might operate independently, under different timelines. It is therefore important for public health messaging to not only cover the benefits of staying active, but also the risks of sedentary behavior particularly in situations where individuals are home-bound.

Finally, we briefly considered the enjoyment and social aspects of PA. Social connection during movement was associated with better mental health outcomes; while both in-person and online PA can foster a sense of belonging, there is some evidence that socially distant, pandemic-safe movement might disincentivise certain groups such as older adults and experienced exercisers from participating in PA. Understanding social connection and enjoyment as potential motivating factors could assist in encouraging individuals to undertake PA even in the most challenging contexts.

It is important to acknowledge that the cross-sectional nature of many studies limits drawing clear causal conclusion. More longitudinal data are required to further understand the association between PA and mood during the pandemic and beyond.

This review highlights important implications for the future use of PA and exercise-related public health messaging during pandemics. These implications may vary across countries and contexts but hold the potential to enhance the effectiveness of such public health messaging. First, leveraging social media information campaigns more extensively could be one way of reaching younger audiences, who may be particularly vulnerable to inactivity. It could also be important for the messages crafted to not only promote PA but also discourage prolonged periods of sedentary behavior to support overall well-being. Moreover, establishing support mechanisms for individuals accustomed to an active lifestyle could prove crucial to mitigate the potential risk of developing depression symptoms due to disruptions to routines. Collaborative program development through community consultation could be of great value here, as it would increase understanding of the barriers to staying active faced by historically

marginalized populations. Lastly, promoting PA that fosters social connectivity, when safe to do so, could preserve the mental health benefits associated with social interactions during PA.

## ACKNOWLEDGMENTS

We thank our colleagues at Psychopharmacology and Emotion Research Laboratory (PERL), Department of Psychiatry, University of Oxford, for providing insight and expertise into this research. This review was supported by the NIHR Oxford Health Biomedical Research Centre. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health. Miss Raslescu is additionally supported through a Medical Research Council (MRC) studentship.

## CONFLICT OF INTEREST STATEMENT

Prof. Susannah Murphy is a guest editor for the special issue on "Transdiagnostic protective factors across mood disorders" in *Mental Health Science*, as well as a senior author on our manuscript. To the best of their knowledge, none of the other authors report a conflict of interest, financial or otherwise.

## DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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## PEER REVIEW

The peer review history for this article is available at <https://www.webofscience.com/api/gateway/wos/peer-review/10.1002/mhs2.57>.

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**How to cite this article:** Raslescu, A., Guru, A., Delattre, B., Park, J.-Y., Harmer, C. J., & Murphy, S. E. (2024). Physical activity as a tool for preventing and treating depression: Lessons learned from the COVID-19 pandemic. *Mental Health Science*, e57. <https://doi.org/10.1002/mhs2.57>