



## INTRODUCTION

The transition from further education to higher education is often synonymous with heightened academic demands and societal pressures (Lowe & Cook, 2003), as well as declines in outcomes of mental health (Andrews & Wilding, 2004). Indeed, reports from the academic year of 2018/19 indicate rates as high as 37.2% for depression and 45.7% for anxiety among female UK university students, and 16.7% for both conditions in males (Jenkins et al., 2021). The emergence of the coronavirus pandemic (COVID-19) in 2019 caused further concern surrounding students' mental health due to unprecedented disruption to daily living, working, and social arrangements, culminating in reduced access to university support services, reduced availability of campus and leisure facilities, and the loss of in-person contact with tutors and peers (Appleby et al., 2022; Tasso et al., 2021). Consequently, literature has demonstrated that outcomes of mental health were substantially impaired during this period, with mental well-being declining by 6.7% (Savage et al., 2021) and the prevalence of clinical depression increasing by 20.5% in UK university students (Evans et al., 2021). Given the concerning context of university students' mental health prior to the pandemic, it is alarming that the prevalence of poor mental health remains elevated despite the removal of COVID-19-related restrictions (Emmerton et al., 2024; Liverpool et al., 2023).

Previously, a positive relationship between mental health and physical activity (PA) has been well-established in university students (Adams et al., 2007; Bhoohibhoya et al., 2020; Bray & Kwan, 2006; Grasdalsmoen et al., 2020; Tyson et al., 2010). The evidence from intervention-based research supports a causal relationship, indicating that an increase in PA directly contributes to improved mental health in both students (Gondoh et al., 2009; Hemat-Far et al., 2012; Herbert et al., 2020) and the general adult population (Atlantis et al., 2004; Dunn et al., 2005; Pilu et al., 2007). Accordingly, during the COVID-19 pandemic, the World Health Organization (WHO) suggested that people "exercise regularly" to mitigate against impaired mental health outcomes (WHO, 2020). Despite this, data throughout this period suggests that weekly moderate to vigorous physical activity (MVPA) declined by approximately one-fifth among university students from the UK (Savage et al., 2021), Italy (Gallè et al., 2020), and Canada (Bertrand et al., 2021), which could have contributed to the observed decline in mental health (Bennett et al., 2022). However, mixed findings on the relationship between PA and mental health in students have been reported during the COVID-19 pandemic. Studies in the US of mainly white and female students, with an average age of 20–25 years, have reported a strong positive (Giuntella et al., 2021), weak positive (Coughenour et al., 2021), and no discernible relationship (Wilson et al., 2021) between PA levels and mental health during periods of social restrictions (sample sizes approximately 700, 200, and 1000 participants respectively). Furthermore, results from European countries measuring the relationship between PA and mental health in students (56–81% female; average age of 20–28 years; sample sizes approximately 200–2500 participants) found either a weak positive connection (Coakley et al., 2021; Lukács, 2021; Maugeri et al., 2020; Rogowska et al., 2020; Schlichtiger et al., 2020) or no relationship during social restrictions (Savage et al., 2021; Savage et al., 2020; Talapko et al., 2021). These contrasting findings suggest that societal factors associated with the pandemic might have altered the traditionally positive correlation between PA and mental health in students (Adams et al., 2007; Bhoohibhoya et al., 2020; Bray & Kwan, 2006; Grasdalsmoen et al., 2020; Tyson et al., 2010). For example, the introduction of social isolation measures inhibited the opportunity for social interactions whilst conducting exercise, which may have resulted in a less enjoyable exercise experience; ultimately reducing the overall positive impact of PA on student mental health during the pandemic (Fox et al., 2000; Mandolesi et al., 2018; Raedeke, 2007).

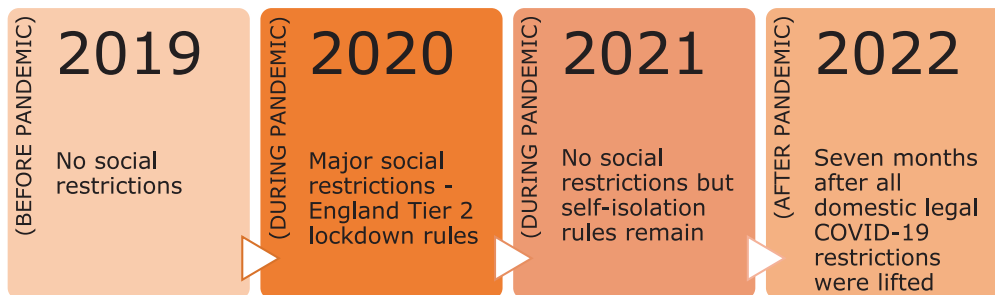
The prevalence of mental health problems among students is a significant concern post-pandemic (Emmerton et al., 2024; Liverpool et al., 2023). Poor mental health extends beyond emotional distress by impairing academic performance (Andrews & Wilding, 2004), social interactions (Martin et al., 2010), and physical health (Markoulakis & Kirsh, 2013). Thus, implementing effective strategies to improve student well-being remains paramount. Whilst increasing PA participation appears promising from pre-pandemic research (Gondoh et al., 2009; Hemat-Far et al., 2012; Herbert et al., 2020), conflicting findings regarding the presence of a relationship between PA levels and student mental health during COVID-19 social restrictions

suggests the beneficial effects of PA could possibly have been impeded (Coughenour et al., 2021; Giuntella et al., 2021; Wilson et al., 2021). However, there is limited data surrounding the nature of this relationship following the removal of COVID-19-related restrictions. It is imperative that research establishes the nature of this relationship in the current context of societal ‘normality’ to provide insight into developing mental health provisions following the pandemic. Therefore, the aim of the current study was to explore the relationship between PA and mental health in UK university students across the phases of the COVID-19 pandemic: pre, during, and post. A distinctive feature of this study was the incorporation of data from late 2022 to examine whether any lingering effects persist as COVID-19 transitions to an endemic state. The outcomes have the potential to inform university policies and influence decision-making regarding interventions aimed at improving student mental health. Specifically, the results could guide decisions about whether promoting PA should be prioritised to support student mental health, or if the pandemic has created an increased necessity for alternative support measures.

## METHODS

### PARTICIPANTS AND STUDY DESIGN

Participants were students from an English university in the East Midlands that were enrolled in a longitudinal cohort study aiming to explore university students’ health and well-being. Students were invited by email to complete an online survey administered in the first term of four successive academic years (2019–2022) to form a pre/during/post-COVID-19 pandemic timeline (Figure 1). A total of 6,250 unique participants contributed to the study over these years. Prior to beginning the online survey, participants were briefed on the study’s purpose and informed consent was obtained. The study pseudo-anonymised all data to maintain confidentiality and stored the data on a password-protected hard drive. Ethical approval for the study was granted by The Nottingham Trent University School of Science and Technology Non-invasive Ethics Committee.



**Figure 1** Flow diagram detailing the status of social restrictions across the timeline of the study and at the points of data collection.

### OUTCOMES

Three demographic questions were included in the survey. The Physical Activity Vital Sign (PAVS) questionnaire (Coleman et al., 2012) was deployed to assess MVPA for the first year (2019), while The International Physical Activity Questionnaire-short form (IPAQ-SF) (Craig et al., 2017) was utilised for the following years (2020, 2021 and 2022). Both questionnaires have previously demonstrated criterion validity and test-retest reliability (Dinger et al., 2006; Murphy et al., 2017). A calculation of MVPA was conducted by multiplying the number of days per week engaged in moderate to vigorous PA by the minutes per day completed at this exercise intensity (Savage et al., 2021).

Mental well-being was evaluated using the Short Warwick-Edinburgh Mental Well-being Scale (SWEMWBS), which is a validated instrument for assessing mental well-being in UK adult populations (Ng Fat et al., 2017). The scale measures positive mental well-being through seven Likert-style items that are positively phrased (e.g., ‘I’ve been dealing with problems well’). Participants respond based on the previous two weeks and answer by selecting one of five categories, ranging from ‘None of the time’ to ‘All of the time’. The outcome score ranges from 7 to 35, with higher values indicating better mental well-being.

Pearson’s Product Moment Correlation tests were employed to determine the correlation between MVPA and mental well-being for each individual year. Subsequent analyses focused on stratification by gender, whereby differences in the strength of the association were assessed using a Z-test approach (Eid et al., 2011). Primary correlation analyses were conducted using SPSS v.29.0 (IBM, Chicago, IL, USA), and secondary analyses were conducted using an online calculator (Lenhard & Lenhard, 2014). Statistical significance was set at  $p < 0.05$ .

## RESULTS

### DEMOGRAPHICS

The demographic characteristics of the participants are presented in Table 1. Across all years, the majority of the sample were female (66.9%) and white (74.3%).

DEMOGRAPHIC CHARACTERISTICS	PERIOD				TOTAL
	BEFORE (2019)	DURING (2020)	DURING (2021)	AFTER (2022)	
<b>Total participants</b>	1316	2274	1354	1976	6920
<b>Gender</b>					
Female	833 (63.3)	1516 (66.7)	894 (66.0)	1388 (70.2)	4631 (66.9)
Male	467 (35.5)	722 (31.8)	415 (30.6)	530 (26.8)	2134 (30.8)
Neither of the above/other	11 (0.8)	16 (0.7)	45 (3.3)	58 (2.9)	130 (1.9)
Prefer not to say	5 (0.4)	20 (0.9)	0 (0)	0 (0)	25 (0.4)
<b>Age (y)</b>					
18	172 (13.1)	308 (13.5)	126 (9.3)	214 (10.8)	820 (11.8)
19	274 (20.8)	392 (17.2)	223 (16.5)	314 (15.9)	1203 (17.4)
20	299 (22.7)	423 (18.6)	289 (21.3)	386 (19.5)	1397 (20.2)
21	197 (15.0)	390 (17.2)	226 (16.7)	335 (17.0)	1148 (16.6)
22–25	236 (17.9)	438 (19.3)	274 (20.2)	359 (18.2)	1307 (18.9)
26–35	93 (7.1)	206 (9.1)	148 (10.9)	245 (12.4)	692 (10.0)
35+	44 (3.3)	117 (5.1)	68 (5.0)	123 (6.2)	352 (5.1)
Prefer not to say	1 (0.1)	0 (0)	0 (0)	0 (0)	1 (0.0)
<b>Ethnicity</b>					
Asian	126 (9.6)	214 (9.4)	183 (13.5)	308 (15.6)	831 (12.0)
Black	73 (5.5)	140 (6.2)	76 (5.6)	165 (8.4)	454 (6.6)
Mixed	36 (2.7)	92 (4.0)	59 (4.4)	83 (4.2)	270 (3.9)
White	1032 (78.4)	1766 (77.7)	986 (72.8)	1357 (68.7)	5141 (74.3)
Other	32 (2.4)	37 (1.6)	30 (2.2)	48 (2.4)	147 (2.1)
Prefer not to say	17 (1.3)	25 (1.1)	20 (1.5)	15 (0.8)	77 (1.1)

**Table 1** Participant information. Displayed as numerical value for number of participants and percentage of total (%).

### CORRELATION ANALYSIS

Pearson’s Product Moment Correlation tests revealed a weak positive relationship between MVPA and mental well-being for each year when analysing all participants, females, and males (Table 2). This relationship was statistically stronger for males compared to females in 2020 ( $Z = 1.02, p < 0.01$ ) and 2022 ( $Z = 3.56, p < 0.001$ ), but without statistical significance in 2019 ( $Z = 0.35, p = 0.36$ ) and 2021 ( $Z = 1.02, p = 0.15$ ).

VARIABLE	BEFORE (2019)			DURING (2020)			DURING (2021)			AFTER (2022)		
	<i>M</i>	<i>SD</i>	<i>r</i>	<i>M</i>	<i>SD</i>	<i>r</i>	<i>M</i>	<i>SD</i>	<i>r</i>	<i>M</i>	<i>SD</i>	<i>r</i>
<b>All participants</b>												
MVPA (mins/week)	233	234	0.17***	197	304	0.17***	178	301	0.14***	224	346	0.19***
Mental well-being	20.8	3.6		20.3	3.6		20.3	3.8		20.7	3.8	
<b>Females</b>												
MVPA (mins/week)	214	222	0.15***	167	267	0.09***	145	255	0.09**	185	316	0.14***
Mental well-being	20.5	3.5		20.0	3.3		19.9	3.6		20.5	3.7	
<b>Males</b>												
MVPA (mins/week)	269	250	0.17***	265	364	0.22***	259	375	0.15**	329	399	0.23***
Mental well-being	21.4	3.8		21.1	3.9		21.6	4.1		21.6	3.8	

## DISCUSSION

The present study explored the relationship between MVPA and mental well-being in students before, during and after the COVID-19 pandemic. A weak positive correlation between MVPA and mental well-being was observed across the four-year timeline of the pandemic, suggesting that the positive benefits of exercise on mental health persisted even in the face of social isolation measures and lockdowns. As such, the results underscore the enduring association between PA and student mental health, emphasising the potential significance of promoting increased PA levels as a means to improve student well-being. These findings suggest that further attention should be directed towards exploring the role of enhanced PA in fostering improved mental health outcomes in students, both in periods characterised by societal ‘normality’ and during times of unprecedented stress.

In line with a plethora of previous literature, the current study identified a positive association between PA and student mental health prior to the onset of the COVID-19 pandemic (Adams et al., 2007; Bhoohibhoya et al., 2020; Bray & Kwan, 2006; Grasdalsmoen et al., 2020; Tyson et al., 2010). This relationship was observed throughout the duration of the pandemic, which aligns with other cross-sectional studies that examined the relationship during social restrictions in their respective nations (Coakley et al., 2021; Lukács, 2021; Maugeri et al., 2020; Rogowska et al., 2020; Schlichtiger et al., 2020) and provides further evidence that higher PA levels may safeguard against declines in outcomes of mental health during periods of significant stress in students. Indeed, during the early stages of the pandemic, studies suggested that university students undertaking less PA tended to exhibit poorer mental health (Coughenour et al., 2021; Maher et al., 2021), while those who maintained their PA levels experienced sustained mental health (Petersen et al., 2023). Furthermore, previous studies indicate that the advantages of PA may persist even during the examination season by reducing emotional stress reactivity (von Haaren et al., 2015), decreasing test anxiety (Zhang et al., 2022), and mitigating declines in affective well-being (Hachenberger et al., 2023). Thus, the results of this study demonstrate the value of PA for mental health of university students across both ordinary and extraordinary stressors.

The current study also provides evidence that the relationship between PA and mental health remains consistent following the removal of COVID-19-related restrictions. This suggests that promoting higher PA after the pandemic may support mental health outcomes toward and beyond pre-pandemic levels. Although causality cannot be inferred from the current study, there is strong evidence to suggest that exercise can boost feelings of vigour and ease negative mood states (McDonald & Hodgdon, 1991), enhance positive emotions (Reed & Ones, 2006), decrease acute and chronic anxiety (Wipfli et al., 2008), and reduce depressive symptoms (Herring et al., 2012). However, current incentives to improve PA participation in UK universities are sub-optimal (Malagodi et al., 2023), and mental well-being scores in the present study were below values for the general adult population in England (Ng Fat et al., 2017). As such, it is now imperative that universities focus on enhancing existing PA provision and developing new initiatives to improve student mental health and well-being following the pandemic.

**Table 2** The relationship between PA and mental health across the study timeline among all participants and participants categorised by gender.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Interestingly, the association between mental well-being and MVPA was significantly stronger in 2020 and 2022 in males compared to females. The presence of major social restrictions in 2020 may have had differential effects on the relationship between PA and student mental health outcomes among men and women. Indeed, males may have relied more heavily on MVPA as a coping strategy in response to the pandemic-related stressors, which may have helped better protect their mental health compared to females (Talapko et al., 2021). However, the presence of variations in the strength of the relationship between MVPA and student mental well-being across years raises questions about the stability of gender differences over time. Male students may generally be more likely to perform PA for enjoyment, which is associated with greater positive feelings and emotions (Raedeke, 2007), in comparison to female students who are more likely to report weight management and appearance as a higher motivation for PA participation (Roberts et al., 2015). Furthermore, the optimal intensity of PA for mental health benefits may be high for males and low for females (Asztalos et al., 2010). Indeed, the association between subjective health and walking is stronger in females, whereas the association with jogging is stronger in males (Ransford & Palisi, 1996). This corresponds with evidence that depressive symptoms are negatively associated with light and moderate intensity PA in females but not vigorous PA (Poole et al., 2011). Students with a preference for higher intensity PA gain more enjoyment and positive feelings from moderate to vigorous PA compared to their counterparts with a preference for lower intensity PA (Box & Petruzzello, 2020). Therefore, female students may receive fewer benefits to mental health from moderate to vigorous PA than their male counterparts. Further research is warranted on gender differences in PA intensity preferences to inform university strategies when devising exercise interventions for mental health.

A key strength of the present study lies in the prospective study design. This approach enhances data reliability by minimising recall bias associated with participants' memory of previous states (Cohen et al., 2018). Additionally, the current study included data from across the entire timeline of the pandemic. These results can therefore be utilised to protect against declines in students' mental health during both periods of societal 'normality' and elevated stress, such as examination periods. However, variations in lockdown restrictions among countries complicate cross-country comparisons as social isolation measures remained dynamic worldwide until the COVID-19 pandemic became endemic, rendering generalisations for all students at any given time point unfeasible. In addition, it is important to note that the duration for which populations would face restrictions became clear only once COVID-19 became endemic. Consequently, the prolonged uncertainty may have had a significant impact on populations for extended periods, which cannot be fully accounted for in studies of this nature.

Although the study employed a between-subjects design, the demographic characteristics remained highly similar throughout, which mitigates concerns about substantial demographic shifts influencing the observed trends. Additionally, using self-reported questionnaires has been shown to overestimate MVPA in comparison to device-based measures (Downs et al., 2014). However, the current study used validated scales and data were in line with previous literature that used self-report measures in student populations (Bertrand et al., 2021; Gallè et al., 2020; Maher et al., 2021). Furthermore, the use of the PAVS for 2019 and IPAQ-SF for 2020–2022 to measure PA introduces a potential impediment to cross-year comparisons. The IPAQ-SF is known to overestimate MVPA (Lee et al., 2011), whilst the PAVS can be conservative in its estimates (Kuntz et al., 2021). An additional complicating factor arises from individuals possibly being more inclined to report zero minutes of MVPA on the IPAQ-SF due to the option of reporting light PA levels, whereas the PAVS solely measures MVPA. This relates to a social-desirability bias, whereby the tendency to under-report undesirable behaviour might be lower with the IPAQ-SF due to the opportunity to compensate with the question of light PA levels. Whilst research on the concurrent validity of these two measurement tools is clearly necessary, data included in the current study demonstrates reasonably good agreement between the two scales (Supplementary data 1).

## CONCLUSION

In summary, the present study investigated the correlation between MVPA and mental well-being among students before, during, and after the COVID-19 pandemic. Despite the challenges posed by social restrictions and lockdowns, the present study found a consistent weak positive correlation between MVPA and mental well-being throughout the pandemic.









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