Swansea University
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The change in children's and adolescents' physical activity levels and well-being during the COVID-19 pandemic in Wales

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1.1 Abstract

Introduction:
Coronavirus disease-2019 (COVID-19)-related lockdowns and restrictions took away children's primary source of structure, routine and physical activity, creating an environment that encouraged sedentary behaviour. The aim of the study was to determine the change in children's and adolescents' physical activity and well-being during the COVID-19 pandemic.

Method:
4,885 children aged 8-18 years old living in Wales answered an online questionnaire over the course of four time-points (January 2021 to March 2022). At each time-point, a sub-sample of 800 participants was randomly selected stratified by age, sex, and socio-economic status to wear an Axivity AX3 accelerometer for seven consecutive days. Linear mixed models were used to assess the influence of PA metrics, time-point, age group, sex, socioeconomic status and well-being.

Results:
All PA metrics significantly increased (MVPA β=20.83, 95% CI:14.18-27.47, P<0.001; LPA β=41.81 CI:26.11-57.50 P<0.001) and sedentary time (β=-73.78, 95% CI:-113.48—34.08 p<0.05) decreased after lockdown (first time-point) whilst well-being significantly increased at the second (2.05 ± 0.72; p=0.005) and third time-point (4.89 ± 1.80; p= 0.007). There was no significant sex difference in moderate-to-vigorous PA during lockdown (p=0.327) but at all other time points boys engaged in significantly more MVPA than their female counterparts (2nd time-point 24.33, p<0.001; 3rd time-point 23.25, p<0.001; 4th time-point 17.66, p<0.001). Furthermore, there was a significant relationship between well-being and MVPA across all time-points (β=0.28; 95% CI:0.01-0.49; p=0.008).

Conclusion:
Despite boys and primary school children having the greatest change in their MVPA during the period of COVID-19 restrictions, girls and secondary school children's PA levels remained concerningly low. As with prior to the COVID-19 pandemic girls and secondary school children should be targeted with interventions to increase their PA levels.

1.2 Declarations and statements

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed Bella Roddis

Date 09/10/2023

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

Signed Bella Roddis

Date 09/10/2023

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

Signed Bella Roddis

Date 09/10/2023

The University's ethical procedures have been followed and, where appropriate, that ethical approval has been granted.

Signed Bella Roddis

Date 09/10/2023

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1.4 Acknowledgments

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1.5 Tables and figures

1.6 List of abbreviations

Abbreviation	Meaning
GCI	Good Childhood Index
HBSC	Health Behaviour in School aged Children
LPA	Light Physical Activity
MVPA	Moderate-to-Vigorous Physical Activity
ONS	Office of National Statistics
PA	Physical Activity
PAQ	Physical Activity Questionnaire
PAQ-A	Physical Activity Questionnaire for Adolescents
PAQ-C	Physical Activity Questionnaire for Older Children
PE	Physical Education
SCWBS	Stirling Children's Well-being Scale
SES	Socio-economic status
SHRN	School Health Research Network
WHO	World Health Organization

2.0 Introduction

Children's and adolescents' physical activity (PA), sedentary behaviour and well-being are a global public health concern, due to the ever decreasing PA and well-being levels and increasing levels of sedentary behaviour (Guthold et al., 2020; Hall et al., 2021). The low PA levels are a global health concern because of the health implications of physical inactivity which put substantial strain on healthcare systems worldwide (Pišot, 2021). The World Health Organization (WHO, 2023) have stated that physical inactivity is one of the leading risk factors for non-communicable diseases and death worldwide. It is essential that these areas are monitored to identify where interventions are required to promote PA and well-being. Children should be targeted with interventions to increase PA and well-being as childhood is a key area for development and forming lifelong habits and behaviours (Guthold et al., 2020; Hayes et al., 2019). PA is defined as "any bodily movement produced by skeletal muscles that requires energy expenditure above resting" (World Health Organization, 2018). Regular PA is associated with numerous physical and mental health benefits in children and adolescents, such as improved self-esteem (Poitras et al., 2016), yet the majority of children and adolescents globally are not sufficiently physically active. Indeed, a study involving 1.6 million 11-17 year olds worldwide found that more than 80% of the world's children and adolescent population is insufficiently physically active (World Health Organization, 2018). Currently, there is limited global data on the PA levels of children aged 11 years and younger. In this thesis those aged 8-11 years old will be referred to as children and 12-18 year olds referred to as adolescents (Kowalski et al., 2004).

Coupled with the low levels of PA, children and adolescents aged 10-17 years spend a significant amount of time being sedentary, particularly in screen-based behaviours (Roman-Viñas et al., 2016; Trinh et al., 2013; Twenge & Campbell, 2018). Sedentary behaviour is defined as "any waking behaviour characterised by an energy expenditure less than 1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture" (Bames et al., 2012,page 540) Sedentary behaviour and PA are two independent but related lifestyle behaviours (Rodriguez-Ayllon et al., 2019); individuals can be active and sedentary (Pearson et al., 2014). There is a large body of evidence highlighting the detrimental effects of

sedentary behaviour on children's health, such as increased depressive symptoms and decreased quality of life (Stiglic & Viner, 2019; Tremblay et al., 2011).

In accord with PA, well-being is a crucial element of overall health, with concerningly low levels being reported worldwide. A global survey including over 2,600 children identified that Wales had the lowest levels of well-being across 35 countries, and that well-being was on a downward trajectory (Marquez & Long, 2021; Gwyther Rees et al., 2020). There is a well-established relationship between PA and well-being. A meta-analysis (Rodriguez-Ayllon et al., 2019) reported that PA was inversely associated with psychological ill-being (e.g. depression) and positively associated psychological well-being (e.g. life satisfaction). Whilst sedentary behaviour was positively associated with depression and there was an inverse association between sedentary behaviour and life satisfaction in adolescents. The meta-analysis suggests that promoting PA and decreasing sedentary behaviour aids in protecting children's and adolescents' well-being (Downward & Dawson, 2016; Landers & Arent, 2007; Rodriguez-Ayllon et al., 2019).

In March 2020, the WHO declared COVID-19 a global pandemic. The COVID-19 pandemic caused dramatic changes to everyone's lives, with the complete shutdown of many societies across the world, including the United Kingdom (UK; World Health Organization, 2020). In the UK, health policy is controlled by the devolved nations, meaning that the devolved nations' governments were able to implement varying restrictions as they considered appropriate for their nation. The Welsh government enforced several national lockdowns throughout the COVID-19 pandemic. These lockdowns involved the closure of all non-essential services, such as schools and sports clubs. This resulted in the removal of children's and adolescents' primary sources of structure, routine and PA, creating an environment that encouraged and facilitated sedentary behaviour. It has been postulated that COVID-19 restrictions disproportionately affected children's and adolescents' health and well-being more than adults because childhood is a key phase of life for development, with the effects potentially being lifelong for some children (Runacres et al., 2021; Shen et al., 2020). For instance, the COVID-19 pandemic created the largest disruption to the education systems in history, with UNESCO reporting that at the peak over 1.6 billion children across more than 190 countries were out of school (UNESCO, 2020).

Research since the outset of the COVID-19 pandemic has been focused on establishing the effects of COVID-19 restrictions on children's and adolescents' PA levels and well-being. Studies during the pandemic have predominantly relied on validated (De Matos et al., 2020; Medrano et al., 2021; Zenic et al., 2020) or unvalidated online questionnaires (López-Bueno, Calatayud, et al., 2020) due to the social distancing requirements and ease of administering questionnaires to large samples (Saint-Maurice et al., 2020). However, this method of assessing PA levels in children is not without limitations, including recall errors and social desirability. Consequently, it is advocated that such questionnaires should be used in conjunction with device-based measures (Dollman et al., 2009).

Current research from the early stages of the COVID-19 pandemic show significant variability in children's and adolescents' PA and well-being levels during the COVID-19 pandemic, with the majority of studies within Wales using a cross-sectional or short longitudinal approach (Ford et al., 2021; James, Marchant, et al., 2021a). Consequently leaving significant questions as to the longer-term impacts of COVID-19 restrictions on children's and adolescents' PA and well-being. These questions have created a need for longitudinal data to gain insight into the long-term effects of COVID-19 restrictions and identify demographic groups that may need further interventions to aid their COVID-19 recovery.

Therefore, the aim of this thesis was to determine the change in children's and adolescents' physical activity and well-being during the COVID-19 pandemic. A secondary aim was to examine the relationship between PA and well-being. It was hypothesised that the COVID-19 pandemic would have a long-term effect on children's and adolescents' PA and well-being, with the strictness of COVID-19 restrictions influencing PA and well-being levels. It was further hypothesised that the positive relationship between PA and overall well-being would still be present at all four time-points during this study, thus meaning children who were more physically active during the pandemic had higher well-being.

3.0 Literature review

3.0 PA health benefits

Physical Activity (PA) is defined as "*any bodily movement produced by skeletal muscles that requires energy expenditure above resting*" (World Health Organization, 2018). There is extensive evidence demonstrating that PA is vital to overall health. Indeed, PA induces an array of health benefits dependent on the frequency, intensity, time, and type of PA undertaken (Gibson-Moore, 2019).

PA elicits beneficial health effects in children and adolescents including improved psychosocial and physiological health (Strong et al., 2005; Tremblay et al., 2016). Psychosocial health is a multidimensional state of well-being with both negative (depression and anxiety) and positive (self-concept) indicators (Dale et al., 2019). A systematic review of the role of PA on children's and adolescents' mental health found PA to be inversely associated with psychological ill-being and positively associated with psychological well-being (life satisfaction, happiness and overall well-being;Rodriguez-Ayllon et al., 2019). Despite decades of research reporting that PA is 'good' for young people's mental health, the understanding of the underlying mechanisms explaining changes in mental health due to PA remains scarce (Biddle et al., 2019). Furthermore, a recent review has noted that national guidelines and previous research has often not recognised that the mental health benefits of PA in young people are dependent on the experience and context of the PA (Biddle et al., 2019). Therefore, future research should focus on investigating the influence of different types of PA, individuals' preferences, social and physical context elicit on mental health benefits (Biddle et al., 2019).

There are also numerous physiological benefits of PA in children and adolescents, with moderate to strong evidence that PA in children and adolescents improves bone health, cardiovascular fitness, muscular fitness and weight status (Health & Services, 2018). Childhood is a key period when children develop lifestyle and activity behaviours which can sustain across the life course, therefore it is key that children are physically active as PA levels track from childhood into adulthood (Hayes et al., 2019). There is a well-established dose-response curve between PA and health benefits, with the biggest impact of increased PA on

health being for the least active (Geidl et al., 2020; Lee, 2007; Sriram et al., 2021). However, in a recent review of reviews, Biddle et al. (2019) reported that, across three mental health outcomes of depression, self-esteem and cognitive functioning, there was no evidence for a dose-response relationship. The association between PA and health benefits could be more complex of a linear, curvilinear or have a threshold than the frequently reported dose-response curve. As research on the dose-response curve often focuses on PA intensity, future research should investigate the duration, type of activity, and overall PA levels to aid understanding of the dose-response relationship for mental health.

PA intensities are defined based on metabolic equivalents (METs), with light PA being any activity <3 METs (e.g. standing), moderate PA (MPA) being 3-<6 METs, such as walking briskly or mowing the lawn, and vigorous PA (VPA) as activity above >6 METs, for example playing singles tennis (MacIntosh et al., 2021). Moderate-to-vigorous PA (MVPA) has been the primary focus of PA research due to the benefits associated with PA being demonstrated to be dose-dependent, with the greater the volume and intensity, the greater the health benefits, up to a certain threshold (Nakagawa et al., 2020). This, coupled with MVPA being significantly easier to accurately measure using self-reported methods because of the typically structured nature of MVPA compared to LPA, means the focus of PA intensity has only shifted from MVPA to other PA intensities as device-based methods (e.g. accelerometers) have developed. PA research has also shown that for healthy individuals there is no absolute threshold for the health benefits, with benefits achieved both above and below the PA guidelines (Gibson-Moore, 2019).

Recently, there has been a shift in focus from MVPA towards the benefits of light physical activity (LPA). LPA has huge potential for increasing total PA and energy expenditure due to being more accessible and feasible to participate in for longer periods of time than MVPA while also providing health benefits (Amagasa et al., 2017; Donahoo et al., 2004; McGregor et al., 2021). Fuezeki et al. (2017b) reported that LPA is favourably associated with health outcomes such as obesity, markers of lips, glucose metabolism and mortality in the general population and in some diseased populations. Similarly, a systematic review found that LPA was inversely associated with all-cause mortality risk, favourably associated with some cardiometabolic risk factors and associated with well-being (Amagasa et al., 2018; Poitras et

al., 2016). As such, Fuezeki et al. (2017b) recommends that LPA should be included in PA guidelines especially for those who are inactive or insufficiently active. However, the majority of these studies assessed the benefits of LPA in adults, with few studies examining the benefits in children and adolescents because of the sporadic nature of their activity (Fuezeki et al., 2017a). Thus, research is required to establish the health benefits of LPA in children and adolescents.

3.1 PA guidelines

Since 2019, there has been a global consensus that children and adolescents aged 5 to 18 years old should participate in an average of 60 minutes of MVPA per day (Bull et al., 2020; Gibson-Moore, 2019; Piercy et al., 2018; Tremblay et al., 2016). The updated 2019 Chief Medical Officers' PA guidelines for children and adolescents says they should engage in a variety of types and intensities of PA across a week to aid development of movement skills, muscular fitness and bone strength (Gibson-Moore, 2019).

3.2 Physical inactivity

Physical inactivity is defined as *"the non-achievement of PA guidelines"* (Thivel et al., 2018). Globally, there are high levels of physical inactivity, with the WHO stating there is a "global epidemic of childhood inactivity" (Guthold et al., 2020). A consequence of the physical inactivity epidemic is that inactivity is the fourth leading cause of mortality globally (England, 2019; Hall et al., 2021; Kohl 3rd et al., 2012). These extraordinary high levels are putting substantial strain on the UK NHS, with physical inactivity estimated to cost the UK £7.4 billion annually (England, 2019) and reported in 2015 to cost NHS Wales £35 million a year (NHS Wales, 2017).

3.2.1 Prevalence of physical inactivity

The majority of children and adolescents within the UK do not meet the current PA guidelines (Gibson-Moore, 2019), with only 44.9% of children and adolescents in England meeting the guidelines (Sport England, 2020). The low levels of PA are particularly prevalent in Wales which was ranked last (out of 30 countries included in the Global Activity Cards) for children's PA levels (Tomkinson et al., 2018; Tomkinson & Olds, 2007) and has an overall physical activity

rating of F prior to the COVID-19 pandemic (Richards et al., 2022). A rating of F means that less than 20% of children and adolescents in Wales met the global PA recommendations of accumulating at least 60 minutes of MVPA on all seven days of the week (Richards et al., 2022). The low levels of physical activity in Wales have continued on a downward trend, despite interventions to try and increase PA such as the Daily Mile Scheme. In Wales 591 schools are signed up to the Daily Mile Scheme which aims to get children out of the classroom for fifteen minutes every day to run or jog, at their own pace with their classmates (The Daily Mile, 2023). Other interventions examples in Wales include the Climbing Higher plan or the £5 million Healthy and Active Fund. The School Health Research Network (SHRN) revealed that only 17% of 11-16 year olds in Wales met the PA government guidelines prior to the COVID-19 pandemic. SHRN is a policy-practice-research partnership between Welsh Government, Public Health Wales, and Cardiff University that aims to improve young people's health and well-being in Wales. Similarly to reported in the SHRN the HAPPEN survey reported that only 22% of 8-11 year old children participated in sport/exercise for at least 60 minutes across all seven days (Richards et al., 2022).

Demographic factors including, but not limited to, sex, age and socio-economic status (SES) have been found to have a significant influence on PA levels (Alawneh et al., 2018; Drenowatz et al., 2010; Farooq et al., 2018). Both global and UK-specific research has shown that boys are more active than girls (Cla, 2018; Cooper et al., 2015; Mayo et al., 2020). Indeed, in a global study it was found that girls were only more active than boys in four out of 148 countries examined (Guthold et al., 2020). A similar sex difference has been reported in Wales, with boys consistently being more active than girls throughout childhood, a difference that was further exacerbated during adolescence (Farooq et al., 2018). The SHRN Report 2019/20 reported that 21% of boys met the PA guidelines compared to only 13% of girls. Further, SHRN described a decline in PA levels with age, with a greater decline for girls (Page et al., 2021). Specifically, whilst around a quarter (23%) of students in Year 7 (11-12 year olds) met the government guidelines, this decreased to only 11% by Year 11. SHRN also identified SES as another demographic factor associated with PA levels, with 1 in 10 young people from less affluent families meeting the guidelines compared to one in five from more affluent families. Lower SES has consistently been associated with poorer health in childhood, including lower levels of PA (Page et al., 2021).

3.3 Sedentary behaviour health risks

Sedentary behaviour is defined as "*any waking behaviour characterised by an energy expenditure 1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture*" (Tremblay et al., 2017). Sedentary time has become a central factor of our daily lives, especially during the COVID-19 pandemic (Hoffmann et al., 2019a; Salway et al., 2022). PA and sedentary behaviour are two independent but related lifestyle behaviours that occupy all waking hours of the day (Rodriguez-Ayllon et al., 2019; World Health Organization, 2010). PA and sedentary behaviour are independent because children who meet the PA guidelines can also still accumulate significant levels of sedentary time (Marshall et al., 2002; Pearson et al., 2014). In children and adolescents, sedentary behaviour after school and at weekends was associated with lower levels of PA (Sallis et al., 2000). This association could be explained through the 'displacement hypothesis', whereby one behaviour e.g. sitting displaces another e.g. PA. This could especially be prevalent after school which is a period when a large proportion of physically active children's PA is undertaken (Pearson et al., 2014). There is a large body of evidence highlighting the negative effects of sedentary behaviour on children's physical and mental health such as increased symptoms of depression and cardiometabolic risk factors (Asare, 2015; Carson, Hunter, et al., 2016). Previously, research has used screen time to measure children's and adolescents' sedentary time in report-based measures (Tremblay et al., 2011). Screen time combines time spent watching television, using the computer or other screen-based devices (e.g. tablets and smartphones) to watch TV, videos, movies, video games and use social media (Barnett et al., 2018). As such research has investigated the health effects of screen-time, a systematic review in adolescents identified that time spent in leisure screen-based sedentary behaviours were related to higher psychological distress and lower self-esteem (Hoare et al., 2016). Twenge and Campbell (2018) reported that in 2 to 17-year olds just 1h/day of daily screen time was associated with lower psychological well-being, including less curiosity, self-control and emotional stability. Moreover, Carson, Hunter, et al. (2016) identified that the longer the duration and higher the frequency of screen time, the greater the negative impact on body composition, cardiometabolic risk, behaviour and fitness. Although a more recent longitudinal study (Sanders et al., 2019a) and meta-analytic reported that the effect size of time spent in screen time for physical and socio-emotional and behavioural outcomes were small, and that the

duration is not the only screen exposure variable to consider(Ferguson, 2015; Orben & Przybylski, 2019; Van Ekris et al., 2017). Sanders et al. (2019a) reported that content is also a key factor to consider, as there may be some small benefits when children engage in educational types of screen time such as computer based homework.

It is pertinent to note that research has largely moved away from using screen-time to measure sedentary time as not all screen-time is sedentary (Biddle et al., 2009) and screen time only represents a proportion of total sedentary time, with Hoffmann et al. (2019b) reporting that children's average percentage of screen time was 46.2 ± 41.4% of their total sedentary time . This is especially true given the changes in the type of screen-time children and adolescents engage in, where screen time has acted as a facilitator of PA (Sanders et al., 2019b; Sweetser et al., 2012). One study in children aged 8 to 12 years old reported that energy expenditure more than doubles when sedentary screen time is converted to active screen time (Lanningham-Foster et al., 2006) The development of active video games is a prime example (e.g. the Wii Fit) which aimed to improve fitness (Lieberman et al., 2011; Sweetser et al., 2012). Another more recent development is the use of YouTube to promote PA videos such as Joe Wicks live 30 minute physical education (PE) sessions every weekday morning during COVID-19 lockdowns (Malcolm & Velija, 2020). Building on active screen time, more recent research has shown that the effect of screen time on children's outcomes appears to be moderated by the type of screen time. For instance, educational screen time could confer small benefits in school achievement and persistence (Sanders et al., 2019a).

3.3.1 Sedentary behaviour guidelines and prevalence

There is ever increasing evidence regarding the negative effects of sedentary behaviour on children's and adolescents' health (Carson, Hunter, et al., 2016), which led to governments starting to recommend children and adolescents minimise their sedentary time (Gibson-Moore, 2019; Tremblay et al., 2016). The Canadian 24-hour movement guidelines were the first to include sedentary time, citing that children and adolescents should have no more than two hours of screen time a day and limit sitting for extended periods of time (Tremblay et al., 2016). The relatively recent developments in research led to the UK government including sedentary behaviour recommendations for the first time in 2019, stating that "children should aim to minimise the amount of time spent being sedentary" (Gibson-Moore, 2019). The 2018

Wales Active Healthy Kids (AHK) Report Card using global screen-time guidelines (no more than two hours a day) reported that 81% of children and adolescents had at least two hours screen-time on a weekday and over 92% on weekend days in Wales (Edwards et al., 2018). Currently, all national surveillance in all four devolved nations for sedentary behaviour use report-based measures in the form of self-report questionnaires or proxy-report questionnaires to assess sedentary behaviour by measuring screen time, rather than measuring total sedentary time using accelerometers (Strain et al., 2020). Report-based measures and accelerometers should be used in conjunction to measure children and adolescents sedentary behaviour to capture their sedentary time and the context of their sedentary behaviour including sedentary screen time. Proxy-report questionnaires refer to when someone other than the participant completes the questionnaire on their behalf, for example, a parent or caregiver (Strain et al., 2020).

3.4 Measures of PA

There are a number of different methods to assess PA which create a broad picture of children's and adolescents' PA, including report or device-based measures. The different methods have varying levels of accuracy, making direct comparisons between studies difficult (Strain et al., 2020). PA levels are measured using report-based (e.g. self-report questionnaires) or device-based means (e.g. accelerometers). Report-based methods are the most popular methods to measure children's and adolescents' PA due to the lost cost, low researcher and participant burden, higher applicability of use and replicable results (Blair et al., 2013; Kowalski et al., 2004; Saint-Maurice et al., 2020). As such, over the last decade, significant progress has been made in global PA surveillance, with over 120 countries nationally assessing children's and adolescents' PA levels (Ding et al., 2020; Sallis et al., 2016). This increase has been driven by the International Physical Activity Questionnaire (Craig et al., 2003) and the Global Physical Activity Questionnaire (GPAQ; Bull et al., 2009). Both have facilitated a standardised approach to measuring PA, enabling easier comparative assessment of PA levels across countries and over time (Ding et al., 2020).

In the UK, surveillance of PA is complex and fragmented, with surveillance undertaken separately in each of the devolved nations and multiple surveys in each nation covering different age groups (Strain et al., 2020). Strain et al. (2020) recommended that the UK moves

towards a more harmonised approach of nationally assessing PA and sedentary behaviour, whether this be by using one of the existing questionnaires across all surveys or introducing device-based methods.

The short fallings of current report-based means of assessing children's and adolescents' PA has led to researchers suggesting that a combination of report-based (e.g. PAQ) and device-based (e.g. accelerometers) measures of PA should be used (Hidding et al., 2018). Both report and device-based measures provide unique and valuable insights into PA behaviours (Saint-Maurice et al., 2020). Report-based measures provide context regarding the type of PA that children and adolescents are engaging in, whereas device-based measures are able to quantify the time and intensity of the activity. Thus, the focus should be on selecting the most appropriate PA tool for assessing the PA outcome of interest (Saint-Maurice et al., 2020).

3.4.1 Characteristics of report-based measures

A key characteristic when measuring PA using report-based measures is reference to activity frequency (e.g. number per week), duration (minutes per session), intensity (effort) and type (e.g. aerobic). Report-based measures usually target two or more of these key characteristics (Saint-Maurice et al., 2020). However, in children and adolescents, there are three key measurement issues regarding the assessment of PA using report-based methods. Specifically, i) the period of recall, ii) how the questions about activity are perceived by the child, and iii) capturing the intermittent activity patterns. A concern is that these measurement errors could cofound efforts to assess patterns of PA and interventions (Saint-Maurice et al., 2020).

The PAQ addresses these three measurement issues to limit measurement error. Specifically, the PAQ defines the period of recall by using short specific time frames such as 'during school break' (Baranowski, 1988; Janz et al., 2008). In children and adolescents, the longer the time frame, the greater the challenge for recall and the higher degree of recall error (Saint-Maurice et al., 2020). The PAQ addresses children's and adolescents' perception of the question by ensuring they understand the question and can define the behaviour through clear and concise language to avoid misinterpretation (Kowalski et al., 2004). For instance, the PAQ provides examples to support key terminology (e.g. "very active (playing hard, running,

jumping, throwing)") and time frames (e.g. "in the last 7 days") to support memory recall in every item to aid accurate reports of PA (Kowalski et al., 2004). Children and adolescents up to 16 years have unique behavioural patterns of PA and engage in sporadic and intermittent activity, with their activity usually occurring in bouts of less than six seconds within general activity (Petersen et al., 2020). Broad questions are likely to omit children and adolescents reporting participating in less structured and intermittent activities (Saint-Maurice et al., 2020). Therefore, the PAQ's defining terminology and using of short time frames aids in the recall of both structured and unstructured PA.

3.4.2 Device-based measures

Device-based measures are now widely available for the assessment of PA levels including heart rate monitors and pedometers, with some device-based measures such as accelerometers able to assess sedentary time as well as PA (Ferrari et al., 2020). Device-based measures predominantly provide specific frequency, time and intensity information. For instance, some device-based methods can capture LPA and sedentary time but not screen time as the context of the activity is not recorded like in report-based methods (Sylvia et al., 2014).

In the last decade, accelerometers have significantly developed to become smaller and cheaper, with more power efficient sensors. This has led to a significant increase in the number of studies using them (Hildebrand et al., 2014; Migueles et al., 2019). Triaxial accelerometers measure PA by quantifying movement along three axes (i.e. vertical, longitudinal and lateral). The increasing popularity of accelerometers has led to more brands (e.g. Axivity, Actigraph & GENEActiv) being available. As such, there has been an increase in studies validating different brands of accelerometers for measuring PA intensity and activity energy expenditure in children (Alhassan et al., 2012; Lyden et al., 2011; Plasqui et al., 2013). Traditionally, accelerometer output was in proprietary counts (Esliger et al., 2005), making comparisons between brands difficult (Hildebrand et al., 2014). Proprietary counts are the result of summing post-filtered accelerometer values into user-defined epoch lengths (Bai et al., 2016). Epoch length is the user-specified time interval to measure the magnitude of accelerations, such as 1 second (Ayabe et al., 2013). In contrast to using proprietary counts, newer models of accelerometers use a microelectromechanical system that measures

accelerations relative to the Earth's gravitational field (Karas et al., 2019). The output is raw acceleration data expressed in gravity units from three orthogonal axes, these axes are the accelerometers own frame of reference for up-down, left-right and backward-forward. The raw acceleration data allows for greater control over processing such as filters, epoch length, non-wear time, cut-points and algorithms (Migueles et al., 2017) In theory the raw data also allows for comparisons between brands although comparability studies are required for accurate interpretation of data across studies (Corder et al., 2008; Hildebrand et al., 2014). The raw acceleration data has led to the development of software such as GGIR that is an R-package that processes multi-day raw accelerometer data for PA and sleep research (Migueles et al., 2019).

Accelerometers can be attached to the hip or the wrist, as well as many other locations, although these are typically less widely used. Previously, accelerometers were predominantly attached to the hip because of the notion that the trunk would provide the most accurate measure of whole-body movement (Yang & Hsu, 2010). Recent studies have shown wrist-worn accelerometers to have similar concurrent validity to validated hip-worn accelerometers (Scott et al., 2017). This, coupled with evidence that wrist-worn accelerometers have a higher compliance rate in both adults and children (Fairclough et al., 2016; McLellan et al., 2018), has led to an increase in popularity of wrist-worn devices. Indeed, the National Health and Nutrition Examination Survey found a 100% improvement in wear time for wrist-worn compared to previous years that used hip-worn accelerometers (Rowlands, Rennie, et al., 2014). Higher compliance with wrist-worn accelerometers is especially significant in children, who find them more comfortable and less burdensome to wear (Scott et al., 2017). A higher compliance rate reduces missing data, increasing the likelihood of collecting reliable measures of habitual PA (Levin et al., 1999). A wrist-worn device further allows for the examination of low-intensity PA such as arm movements like playing video games and sedentary behaviour, activity which report-based measures are unlikely to capture (Ekblom et al., 2012).

Cut-points are developed for accelerometers and applied to the data to classify the activity intensity levels (SED, LPA, MPA, VPA and MVPA). Research observes large discrepancies in the estimation of PA intensities from different cut-points when extrapolated to different settings

(Leppänen et al., 2022) because of cut-points being developed from small studies that often underrepresent activities of daily life (Hildebrand et al., 2017). Researchers have developed cut-points to incorporate Euclidean norm minus one (ENMO), a data reduction method which results in signal vector magnitude (SVM) values not being reliant on sampling frequency or epoch length, thereby allowing comparisons between studies and brands(Hildebrand et al., 2014). ENMO cut-points have become widely used and have shown a higher agreement between brands, facilitating data harmonisation across studies (Rowlands et al., 2017).

Researchers advise that a wrist-worn accelerometer should be worn on the non-dominant hand to avoid misclassification of sedentary activity that involves large amounts of hand movements (Chandler et al., 2016). Cut-points that are derived and validated for hip-worn accelerometers cannot accurately classify sedentary behaviour when applied to wrist-worn data (Kim et al., 2014). This creates a need for further development of non-dominant wrist-worn cut-points, especially in light of the growing popularity of wrist-worn accelerometers within research (Hurter et al., 2018). There are considerably fewer validated cut-points for children and adolescents than adults, with only two having been developed and validated for wrist-worn accelerometers on the non-dominant hand in children (Chandler et al., 2016; Hildebrand et al., 2014). In children and adolescents, there are certain behaviours where cut-points will likely always misclassify activity such as a lack of movement at the wrist will be classified as sedentary. Conversely, cut-points will underestimate activity levels when active standing (moving arms while standing) is occurring (Tremblay et al., 2017). In these instances it is unlikely that cut-points for wrist-worn accelerometers are able to differentiate between active standing and LPA with ambulation, causing the misclassification of activity. From a health perspective, it is better to misclassify passive standing as sedentary behaviour than PA and overestimate sedentary behaviour as active children can still engage in interventions to decrease sedentary time without harm (Hurter et al., 2018). Further development is required for more accurate measures of sedentary behaviour and stationary time for wrist-worn accelerometers using postural approaches such as the Sedentary Sphere method in children (Rowlands, Olds, et al., 2014). The Sedentary Sphere method is used in wrist-worn triaxial accelerometers for the analysis, identification, and visual presentation of sedentary behaviours (Rowlands, Olds, et al., 2014).

Epoch length is a key part of measuring children and adolescents PA levels. The sporadic nature of children's PA means the epoch length significantly influences PA intensity classification for children (Edwardson & Gorely, 2010; Fröberg et al., 2017; Nilsson et al., 2002). Research has employed a range of epoch lengths from 1 to 60 seconds, in the last five years there has been a shift away from longer epoch lengths (Aadland et al., 2018, 2020). Longer epoch lengths result in the loss of time spent in the lower (e.g. LPA) and higher (e.g. MVPA) ends of the intensity spectrums as activity is averaged over a longer period (Aadland et al., 2020). Recent research has shown that using a 60 second epoch length underestimates SED, MVPA and VPA while overestimating LPA (Aadland et al., 2018, 2020; Fröberg et al., 2017). Both PA in bouts and total PA levels are misclassified when using longer epoch durations, therefore it is recommended that short epoch lengths of 1s-10s are used in children to allow all activity to be accurately captured (Aadland et al., 2018; Berman et al., 1998).

Despite the increased popularity in device-based measures for measuring children's and adolescents' PA, report-based measures are still required to capture the context of PA. Furthermore, report-based measures are key in measuring other key areas of children's and adolescents' health such as well-being where report-based measures are considered the gold standard.

3.5 Well-being

The WHO define health as *"a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"* (Callahan, 1973). Well-being is a key part of overall health, with interest in children and adolescents well-being having risen sharply within the UK (Smees et al., 2020). Currently there is no international consensus to the definition of well-being (Simons & Baldwin, 2021), but adolescent's well-being has recently been defined by Gennings et al. (2021) as "a multifaceted perception of an interaction between an individual's positive feelings and external influences" (p. 84). The increase in interest has led to children's well-being becoming an outcome measure in its own right in UK educational policy. Both the United Nation's convention on the rights of the child and the UK Government Every Child Matters agenda aim to support children's well-being across multiple domains (Cohen, 1989). The research on childhood well-being is very heterogeneous, predominantly focussing on subjective well-being within the multidimensional concept of well-being and limited research on children's well-being as a whole (Newland et al., 2019; Smees et al., 2020). Definitions of

children's subjective well-being in the literature contain a range of concepts such as life satisfaction, with the definition being contextually dependent. Well-being levels can also differ depending on the context of what dimension of well-being is being measured (Pollard & Lee, 2003; Smees et al., 2020) as individuals physical well-being could be different to their social well-being (Newland et al., 2019). High well-being has been linked with a number of positive outcomes including, but not limited to, improved physical health, longevity, more effective learning, prosocial behaviours and positive relationships (Diener, 2012; Huppert & So, 2013; Oishi et al., 2007). Children's and adolescents' well-being is important as, similarly to PA levels, longitudinal data has revealed that well-being in childhood predicts well-being in adulthood (Richards & Huppert, 2011).

3.5.1 Well-being levels in the UK and Wales

Comparable with PA levels, well-being in children and adolescents is concerningly low across the world and in the UK (Marquez & Long, 2021). Furthermore, UNICEF and the Programme for International Student Assessment (PISA) have both reported that the well-being of children in the UK is relatively low compared with other countries (Gromada et al., 2020; Sizmur et al., 2019). Alongside the current low levels, the UK household Longitudinal study reporting in the Good Childhood Report (2020) indicated a downward trend in well-being since 2009. This decrease in well-being is particularly evident for children's mean happiness scores for life as a whole, friends and school. A survey of over 2,600 children across Wales identified that they have some of the lowest levels of well-being across 35 countries (G Rees et al., 2020).

Longitudinal studies of the UK Longitudinal Household Survey and Millennium Cohort study have consistently highlighted significant differences in well-being according to demographic factors (e.g. age, sex and SES). The UK Longitudinal Household survey and Understanding Society survey annually report that children's well-being declines with age, beginning from 11 years old (Marquez & Long, 2021). This implies that adolescence is a period of heightened risk of poor well-being and mental health, with around half of all mental health conditions present by 14 years old (Kessler et al., 2005). Sex is another demographic factor that significantly influences well-being, with boys more likely to report higher well-being than girls (Currie et al., 2004; Marquez & Long, 2021). A survey in Wales of children and adolescents aged 11-16

years reported the age-related decline in mental well-being to be greater for girls than boys, with only a 3% difference in year 7 (11-12 years old) compared to 10% in year 11 (15-16 years old; Page et al., 2021). Researchers believe this difference stems from adolescence being a period of emerging new stressors which have a greater negative effect on girls' mental health than boys, especially in countries with more gender equalities although this could be explained through the limited number of studies in countries with a high number of gender inequalities (Campbell et al., 2021). These stressors include anxieties related to their appearance (West & Sweeting, 2003) and educational pressure, both of which are correlated with worse mental health in adolescent girls (Wiklund et al., 2012). SES is another influential factor in children's and adolescents' well-being, with children and adolescents from lower SES having a lower well-being (Bradley & Corwyn, 2002; Marquez & Long, 2021). SHRN reported young people from less affluent families were less likely to report being satisfied with their lives, have a lower mental well-being, higher risk of loneliness and report elevated mental health symptoms (Page et al., 2021). Children from less affluent families experience worse mental well-being due to the association of lower SES with deficits in cognitive, emotional, social and physical development (Boardman et al., 2015).

3.5.2 Measures of well-being

In children and adolescents, well-being is measured using report-based means, such as self-report questionnaires. In the last decade, the focus has shifted from proxy-reported measures to self-reported means due to research showing that children and adults responses to the same questions about the child's well-being differs (Goodman et al., 2010; Reitemeier, 2018). Children's and adolescents' own self-reported well-being is commonly accepted by researchers as the gold standard due to research showing the higher validity compared to other methods (Marquez & Long, 2021). There are different validated questionnaires to measure children's well-being for children eight years or older, with some of the most frequently used being the Good Childhood Index (GCI; Pople et al., 2014), the Stirling Well-being Scale (SCWBS; Liddle & Carter, 2015), Short Warwick-Edinburgh Mental Well-being Scale (Tennant et al., 2007) and the Very short well-being Questionnaire for Children (Smees et al., 2020).

There are few resources for children younger than eight years or for children with limited comprehension or attention (Smees et al., 2020). For children and adolescents younger than eight years old proxy-report or interview-based techniques are predominantly used to measure well-being, with a lack of self-report measures. Although recent research has shown that children as young as six can make accurate judgements on their health status, personality, emotions and mental health using puppet interviews or drawing based assessment (Smees et al., 2020). The lack of self-report resources for young children (under eight years old) has led to the use of proxy-report to measure their parents/carers perspective on the child's well-being. As such a measure is required to capture children's under eight years old own perspectives on their well-being (Smees et al., 2020).

Globally there is a vast number of different surveillance systems for children and adolescent's well-being aged eight years or older. The Office for National Statistics' (ONS) programme to measure children's well-being uses both subjective and objective measures and is composed of 31 indicators within seven domains (Tinkler, 2015). A recent ONS review reported that the indicators need updating for children's current lifestyles especially in light of the changed environment due to the COVID-19 pandemic as the indicators were developed six years ago (Hefferon et al., 2021). Within the surveillance systems for children and adolescents there are several challenges in trying to populate all the indicators to measure well-being. These challenges include varying geographic coverage and granularity, infrequent data collection and small sample sizes that do not allow for disaggregation by area or group (Hefferon et al., 2021). One such surveillance system is the Health Behaviour in School-aged Children (HSBC) which operates internationally including in Wales and collects data on children's subjective well-being every four years (Currie et al., 2009). Although the HSBC survey is used within the devolved nations the survey is not always consistent making comparisons complicated or impossible (Hefferon et al., 2021). As such, limited comparisons of children's and adolescents' PA and well-being between nations can be made.

The current surveillance systems to measure children's and adolescents' well-being should have been adapted during the COVID-19 pandemic to allow for more frequent surveillance to monitor the trend of outcomes from the regularly changing situation created by the COVID-19 pandemic. COVID-restrictions differed within countries and areas meaning it is vital that

countries had their own means of measuring children's well-being and mental health during the pandemic. In the UK the independent body of the Children's Society publish a report annually on children's subjective well-being using the Good Childhood Index (Pople et al., 2014). In Wales children and adolescent's mental health and well-being was a key policy priority in Wales (King, 2021), as such SHRN was created to measure children's mental health and well-being in Wales. SHRN allows for an ongoing assessment of children's well-being nationally and regionally in Wales and for international comparisons to be made (Page et al., 2021). During the COVID-19 pandemic measuring children's and adolescents' well-being annually was not frequent enough to reflect the impacts of the COVID-19 pandemic because of the restrictions changing monthly (see figure 2).

3.6 COVID-19 restrictions

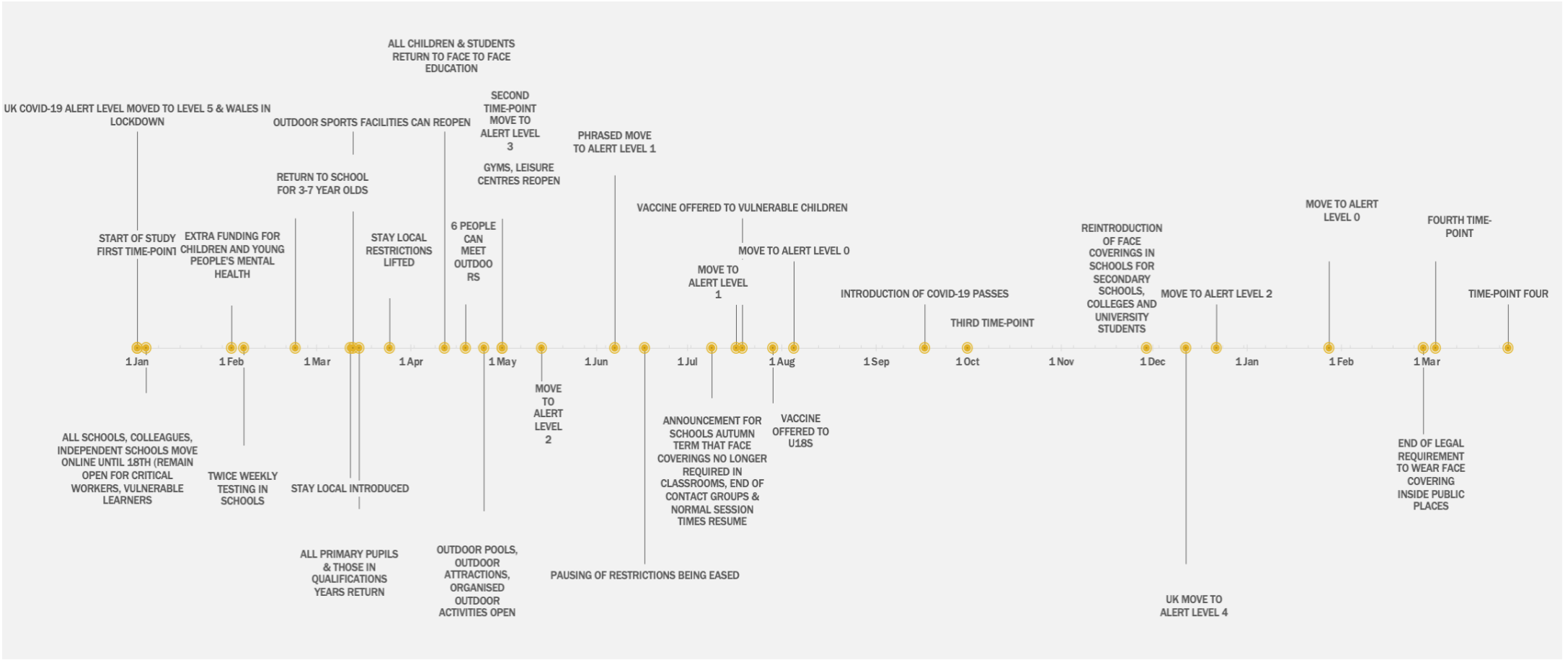
In March 2020, COVID-19, an infectious disease caused by the severe acute respiratory disease, was declared a global pandemic (Jebril, 2020). This marked the start of a period of turmoil worldwide, including within the UK. Government's responses to the pandemic differed vastly across the world. The Oxford Coronavirus Government Response Tracker (OXCGRT) project created a COVID-19 Stringency Index composed of nine response metrics to measure the severity of COVID-19 restrictions and allow for comparisons between countries (Hale et al., 2021). The nine response metrics focused on key areas affected by COVID-19 restrictions; the metrics are

- school closures
- workplace closures
- cancellation of public events
- restrictions on public gatherings
- closures of public transport
- stay-at-home requirements
- public information campaigns
- restrictions on internal movements
- international travel controls

The UK's index score throughout the pandemic ranged from 11.11 (March 2022) to 87.96 (January 2021, 1st time-point) out of 100. This is in contrast to Sweden who had more relaxed

COVID-19 restrictions throughout the pandemic, never having a national lockdown, causing their score to never go beyond 70. Across Europe, all except Sweden closed schools during the pandemic to limit the spread of COVID-19 (Crawley et al., 2020), with UNESCO reporting 91% of children worldwide experienced education disruption (UNESCO, 2020).

Research on the impacts of COVID-19 restrictions in the UK where all devolved nations are put into one category need to be treated with caution due to the devolved nations having different rules and laws during the COVID-19 pandemic. Hence why it is important for research to focus on one devolved nation to understand the impact of the country specific COVID-19 restrictions. Alongside being country specific it is vital that research clearly describes the environment experienced by participants to be able to accurately inform future decisions should a pandemic happen again. Figure 1 outlines the COVID-19 restrictions relating to children and adolescents in Wales during the study. A detailed timeline of all COVID-19 restrictions in Wales can be found in the Appendices 1 and 2.


ALL CHILDREN & STUDENTS RETURN TO FACE TO FACE EDUCATION
SECOND TIME-POINT MOVE TO ALERT LEVEL 3
UK COVID-19 ALERT LEVEL MOVED TO LEVEL 5 & WALES IN LOCKDOWN
OUTDOOR SPORTS FACILITIES CAN REOPEN
PHRASED MOVE TO ALERT LEVEL 1
GYMS, LEISURE CENTRES REOPEN
RETURN TO SCHOOL FOR 3-7 YEAR OLDS
VACCINE OFFERED TO VULNERABLE CHILDREN
MOVE TO ALERT LEVEL 0
START OF STUDY FIRST TIME-POINT
EXTRA FUNDING FOR CHILDREN AND YOUNG PEOPLE'S MENTAL HEALTH
STAY LOCAL RESTRICTIONS LIFTED
6 PEOPLE CAN MEET OUTDOORS
MOVE TO ALERT LEVEL 1
INTRODUCTION OF COVID-19 PASSES
THIRD TIME-POINT
REINTRODUCTION OF FACE COVERINGS IN SCHOOLS FOR SECONDARY SCHOOLS, COLLEGES AND UNIVERSITY STUDENTS
MOVE TO ALERT LEVEL 2
MOVE TO ALERT LEVEL 0
FOURTH TIME-POINT
TIME-POINT FOUR
1 Jan
1 Feb
1 Mar
1 Apr
1 May
1 Jun
1 Jul
1 Aug
1 Sep
1 Oct
1 Nov
1 Dec
1 Jan
1 Feb
1 Mar
ALL SCHOOLS, COLLEAGUES, INDEPENDENT SCHOOLS MOVE ONLINE UNTIL 18TH (REMAIN OPEN FOR CRITICAL WORKERS, VULNERABLE LEARNERS
TWICE WEEKLY TESTING IN SCHOOLS
STAY LOCAL INTRODUCED
MOVE TO ALERT LEVEL 2
ANNOUNCEMENT FOR SCHOOLS AUTUMN TERM THAT FACE COVERINGS NO LONGER REQUIRED IN CLASSROOMS, END OF CONTACT GROUPS & NORMAL SESSION TIMES RESUME
VACCINE OFFERED TO U18S
END OF LEGAL REQUIREMENT TO WEAR FACE COVERING INSIDE PUBLIC PLACES
ALL PRIMARY PUPILS & THOSE IN QUALIFICATIONS YEARS RETURN
OUTDOOR POOLS, OUTDOOR ATTRACTIONS, ORGANISED OUTDOOR ACTIVITIES OPEN
PAUSING OF RESTRICTIONS BEING EASED
UK MOVE TO ALERT LEVEL 4

3.7 Relationship between PA and well-being

Research has consistently shown that PA is inherently good for young people's psychosocial health (Landers & Arent, 2007). Indeed, studies in children examining the impact of PA on subjective well-being have generally reported a positive effect (Becchetti et al., 2008; Downward & Dawson, 2016; Pawlowski et al., 2011). A recent meta-analysis concluded that the relationship between PA and subjective well-being is positive and consistent across PA settings, activity models (e.g. intensity) and different subjective well-being measures (Buecker et al., 2021). This relationship was however stronger in experimental studies where PA interventions were implemented compared to quasi-experimental and correlational studies. The difference reported in the relationship highlights how study design influences the evidence provided. For instance, the experimental studies in the Buecker et al. (2021) meta-analyses included a structured PA intervention which may produce larger effects than unstructured PA as is typically reported in correlational studies. Similarly, the relationship reported in experimental studies only represents the relationship between PA and well-being during a short-term, intense PA intervention and may therefore lack generalisability. Despite the large body of evidence from studies with different study designs showing the positive effects of PA on well-being, further research is required to examine the mechanisms affecting the factors that underly the association between subjective well-being and PA (Buecker et al., 2021). The majority of research examining the relationship between PA and well-being in children and adolescents focused on mental health rather than well-being as a whole. Beauchamp and colleagues (2018) state that the "scientific evidence suggests that regular PA protects against deficits in mental health and supports cognitive function". A review of reviews in children aged 5-18 years old found the relationship to be strongest for improving depression and cognitive function, with those who are physically active less likely to experience mental health problems (Biddle et al., 2019). The review further identified a positive causal association for cognitive function, in part for depression, but not for self-esteem (Biddle et al., 2019). The lack of association for PA and self-esteem can potentially be explained through the complexity of self-esteem. Self-esteem is multi-dimensional and inconsistently defined leading to a mixed picture of the effects of PA on self-esteem. Currently there is no evidence of a dose-response relationship between PA and mental health outcomes due to a lack of evidence. The relationship between PA and mental health is complex when looking at domains of PA, with limited research examining whether different types of PA alter

the mental health outcomes (Asztalos et al., 2009; Biddle et al., 2019). Biddle et al. (2019) concurred that there should be a greater policy emphasis on PA for young people based on the latest evidence showing that regular PA protects against deficits in mental health and supports cognitive function (Beauchamp et al., 2018).

3.8 Effect of COVID-19 on children's PA

Research has shown that children tend to be less susceptible to COVID-19 infection and experience less severe illness, often having mild or no symptoms (Lee & Morling, 2021; Viner et al., 2021). Consequently, COVID-19 restrictions pose a greater threat to children's health than COVID-19 infection because of the significant disruption to key areas of their lives, such as school which is key to children's health and development. Such a disruption could have a lifelong impact for some children and adolescents (WHO, 2021). A global systematic review comparing pre and during COVID-19 children's PA levels and sedentary behaviour revealed that all studies reported a decrease in PA levels and an increase in sedentary time during COVID-19 (Stockwell et al., 2021). The review however was limited in the number of studies included, with only six for PA and five for sedentary behaviour. All the studies within the review used self-report questionnaires with only half using validated questionnaires and many retrospectively asking participants their pre-COVID-19 levels of activity, bringing into question the accuracy of their recall (Stockwell et al., 2021). The limited number of studies included within the review is partly due to studies not meeting the inclusion criteria, studies were only included if they had received written ethical approval from an ethics committee. During COVID-19 there was a rapid publication of studies related to the pandemic meaning many bypassed the typical institutional ethical approval so were not included in the review (Stockwell et al., 2021).

Studies of children in China (Xiang et al., 2020), Italy (Pietrobelli et al., 2020), Canada (Carroll et al., 2020; Moore et al., 2020) and Spain (López-Bueno, López-Sánchez, et al., 2020) reported decreases in PA and increases in screen time at the start of the pandemic. In Spain, a reduction of PA of 103 minutes per day and increase in screen time by 174 minutes per day was reported during lockdown (López-Bueno, López-Sánchez, et al., 2020). All these studies used questionnaires to measure PA levels, with there being a lack of studies using device-

based methods during the pandemic. There is concern that these detrimental effects of COVID-19 were long lasting, with post COVID-19 PA levels being lower than pre-pandemic levels, worsening the physical inactivity epidemic. A Dutch study of children wearing accelerometers found that lower levels of total PA were reported during the pandemic than pre-pandemic even after the easing of COVID-19 restrictions and reopening of school and sports clubs (Ten Velde et al., 2021). Similar to the UK and Wales, the Netherlands had a nationwide shutdown of schools, sport clubs and restaurants. Although the duration of the lockdown and other COVID-19 restrictions significantly differed between the Netherlands and Wales, so comparisons between nations need to be made with caution and evidence nationally is required.

In contrast to global research on children's and adolescents' PA levels during the COVID-19 pandemic the longitudinal HAPPEN survey in Wales reported an increase in PA. The HAPPEN survey used a self-reported online questionnaire to measure primary school children's (8-11 year olds) health by comparing data collected during school closures in 2020 with data from the same period in 2019 and 2018 (James, Marchant, et al., 2021b). The study found that during 'school closures' in 2020 there was a significant improvement in children's PA levels (4.5% increase in number achieving 60 minutes of PA a day). The contrast in reported change in PA levels could potentially be explained through the HAPPEN survey having data on participants activity levels prior to COVID-19 and not asking participants retrospectively, thus reducing the risk of recall error. The HAPPEN survey also reported that the increase in PA is likely to be in children from a higher SES, as in those from a low socio-economic deprivation activity levels decreased (James, Marchant, et al., 2021b). This is unsurprising given that children and adolescents from higher socio-economic families are more likely to have access to gardens and other green spaces providing them with more opportunity to be physically active and break up sedentary behaviour (Gray et al., 2015; Love et al., 2019; Medrano et al., 2021).

During the COVID-19 pandemic research found that contrary to pre-pandemic data there were no age or sex associations with PA levels but sedentary behaviour increased with age (Hurter et al., 2022; Runacres et al., 2021). The lack of sex associations could be explained by changes in the type of PA children and adolescents were participating in during the period of

COVID-19 restrictions (Dunton et al., 2020). Girls participate in organised sport at a substantially lower rate than boys (Slater & Tiggemann, 2011), with girls withdrawing from athletic participation at an early age (Kirshnit et al., 1989). The decrease in sports activity during COVID-19 restrictions (Schmidt et al., 2020) and increase in free play and walking (Dunton et al., 2020), indicates an environment more suited to girls PA. The findings are consistent with a prospective analysis of PA levels and correlates that found PA among boys decreased to a greater extent than among girls because of the nature of activity boys participate in and their higher first time-point levels (Sekulic et al., 2020). The environment created by COVID-19 restrictions can be viewed to have better suited girls type of PA with boys needing to alter the type of activity they participate in.

3.9 Effect of COVID-19 on children's mental health and well-being

In Wales, there is contrasting evidence on the effects of COVID-19 restrictions on children's and adolescents' mental health and well-being. The HAPPEN survey reported improvements in children's well-being, family well-being and happiness with life both improving in 2020 compared with in 2019 (James, Marchant, et al., 2021b). This is in contrast to the COVID and young people survey (11-15 years) which investigated the long-term impacts of 'school closures'. The COVID and young people survey (11-15 years) found that well-being deteriorated amongst young people on the whole during the pandemic (Ford et al., 2021). This difference could partly be explained through the differences in the periods during the COVID-19 pandemic the surveys assessed. The HAPPEN survey assessed well-being during the first COVID-19 lockdown when being away from school was a novelty whereas the COVID and young people survey measured well-being during the latter stages of the pandemic. Research identified this stating that the long-term impacts of school closures on children's and adolescent's education, health and well-being including, but not limited to, feelings of isolation, stress, increased anxiety and decreased PA opportunities are likely to have a more detrimental impact than the short-term impacts, thus potentially explaining the contradictory results (James, Jones, et al., 2021). Three main themes were identified to influence children and adolescent's well-being during the COVID-19 pandemic, these themes differed between primary (physical health, being with friends & COVID-19 concerns) and secondary school children (mental health support, exam pressure & uncertainty and future prospects; James,

Jones, et al., 2021). Further research in Wales through the Comres Welsh sport survey (2022) also reported negative effects of COVID-19 on children, such as decreased PA levels and participation in organised sport. This was particularly prevalent in those from lower socioeconomic backgrounds tended to participate in less sport and PA during lockdown than previously. These findings were consistent with Welsh teacher's perceptions that their pupils had been less active during lockdown and observed upon the phased return to school that some children had gained weight (Hurter et al., 2022; Marchant et al., 2021). To summarise, in Wales there is conflicting evidence regarding the effects of the COVID-19 pandemic on children's and adolescents' PA and well-being. To gain a more accurate insight to children's and adolescents' PA and well-being during the duration of COVID-19 pandemic, research should include validated questionnaires and multiple time-points.

3.10 Summary

To conclude, the trend of low PA levels worldwide seemingly has continued during the COVID-19 pandemic, with the pandemic potentially exacerbating the downward trend in PA levels. The environment COVID-19 created meant that the majority of research during the pandemic was in the form of report-based measures. A subsequent consequence of the dominance of report-based measures of PA were questions around the accuracy of the self-reported PA data and a lack of information to quantify the duration, intensity and frequency of children's PA. Future research should include a combination of validated questionnaires and device-based measures to monitor children's change in well-being and PA during the pandemic. At present, the majority of studies have used a cross-sectional or short longitudinal approach, leaving significant questions around the longer-term effects of COVID-19 restrictions. Future studies should use a longitudinal study design to identify demographic groups and areas where children and adolescent's require interventions to prevent long term detriments to their PA and well-being levels.

4.0 Methods

4.1 Procedures and recruitment to the study

In January 2021, a list of all state school email addresses in Wales was obtained from Sport Wales that they had collated for the School Sport Wales Survey in 2018. Emails were sent to schools asking for their assistance to recruit children and adolescents of the target ages. Schools were asked to forward an invitation to take part in the study containing a registration link, to the appropriate parents. A copy of the parental consent form parents were asked to complete can be found in Appendix A. As well as gaining consent for the questionnaire the parental consent form asked for the participants date of birth, school name, postcode, consent for the accelerometer and address. Along with emailing all schools, a twitter account was set up for the study that shared information about the study and tweeted schools, councils and sports clubs to help increase uptake of the study. On completion of the parental consent form, the child was assigned a master ID which was linked to their demographics and their parents' consent form. Participant assent (Appendix B) was obtained at the outset of each questionnaire at each time-point. Ethical approval was granted by the College of Engineering Research Ethics and Governance Chair (Ref: KM_04-08-20b).

The main recruitment phase occurred in January 2021 prior to the first time-point with top-up recruitment undertaken prior to the third time-point (September 2021) and the fourth time-point (February 2022). Schools were only recontacted for top-up recruitment; this occurred twice during the study prior to the third time-point (September 2021) and the fourth time-point (February 2022). In September 2021, all primary schools from the Sport Wales 2018 list were asked to send out the study information and link to their new year four's (eight year olds). In February 2022, all schools from the Sport Wales 2018 list were contacted, with the study's information and a 'Summary Findings' document which they were asked to share with parents and pupils. From this, 588 new participants were recruited to the study which were sent the survey link at the fourth time-point. The new participants were only included in the accelerometer sample if they were replacing a participant that had withdrawn or not returned their monitor at a previous time-point.

4.2 Participants

4.2.1 Questionnaire sample

The inclusion criteria for participation in the questionnaire were children and adolescents aged 8-16 years at their first point of contact with the study, living in Wales, providing informed assent and having internet access at home. There were no mental or physical health exclusion criteria.

4.2.2 Accelerometer sub-sample

A sub-sample of around 800 participants was randomly selected from the questionnaire sample to wear an accelerometer for seven days. Parents had to consent to their child wearing an accelerometer as well as participants for them to be in the selection sample. The random selection of participants was stratified according to socio-economic status (SES), age and sex with ten participants from each demographic to ensure the sample was representative of each demographic group. SES was measured using the Welsh Index of Multiple Deprivation 2019 (WIMD), which calculated participants quintile (1-5, 1 most deprived) based on their postcode. The sub-sample inclusion criteria were the ability to provide informed assent and the ability to self-ambulate. Participants were excluded from the accelerometer sub-sample at future time-points if their accelerometer was not returned.

4.3 Study design

A longitudinal observational study design was utilised over the course of a 24-month period, assessing participants at four time-points. Table 1 describes the COVID-19 restrictions in place in Wales at each of the time-points.

Table 1. COVID-19 restrictions in Wales at each time-point over the 24-month study period

Time-point	Date	COVID-19 Restrictions
1	January 2021	Alert level 4 • National lockdown with all non-essential services closed • Schools partially closed with only pupils of critical workers and vulnerable children allowed in school • Pupils completed at home learning predominantly online
2	May 2021	Alert level 2 • Most non-essential services reopened and some restrictions on social interaction remained in place (e.g. only mixing with five other people in a public indoor space or outdoors including a private garden) • Mandatory for pupils to wear masks for face-to-face teaching in school • Sport courts, playgrounds and leisure/fitness facilities reopened with children's organised sport returned since March 2021 • Children 12+ years must continue to wear face-coverings in indoor public places
3	October 2021	Alert level 0 • No legal limits on the number of people mixing • All children and adolescents having face-to-face teaching in school
4	March 2022	Alert level 0 • No legal limits on the number of people mixing • All children and adolescents having face-to-face teaching in school

4.3.2 Implementation of the questionnaire

For all time-points, the questionnaire was sent to the parents, for them to get the children to complete it. At the start of the questionnaire, there were five questions related to the participant's assent. For each of the four time-points, the questionnaire was open for a month, except for the fourth time-point where the questionnaire was only open for three

weeks due to time constraints of school holidays. All participants received an email reminder to complete the questionnaire two weeks after it opened. Participants and parents were able to withdraw from the study, ask questions or provide feedback at any time.

4.3.3 Implementation of the accelerometers

At the first time-point once the questionnaire had closed, the random sub-sample of 800 participants was selected from those who consented to wear an accelerometer in the questionnaire. The sub-sample was stratified with ten participants from each demographic of age, socio-economic status (SES) and sex. The accelerometers were charged, initialised and manually assigned to a participant. The child-assigned accelerometers were then placed into the corresponding numbered envelope to ensure the data corresponded with the correct child. The envelopes were posted to participants containing the accelerometer, an information letter and pre-paid return envelope. Parents were contacted via email and telephone to remind them to return the monitors and continued to be contacted unless the monitor was returned or reported lost. This process was repeated for subsequent time-points, with the exception of the selection of the sub-sample. Participants who wore a monitor at the previous time-point were selected, unless they withdrew, did not consent to wear the accelerometer again or did not return their accelerometer. These participants were replaced with a participant who had matching or similar demographics.

4.4 Measures

4.4.1 Questionnaire measures

To assess children and adolescent's self-reported PA and mental health and well-being, validated questionnaires were used, where possible. The questionnaires took approximately 10 minutes to complete. Children's own self-reported well-being and mental health is commonly accepted as the gold standard, being shown to be more accurate than proxy-reports (The Children's Society, 2020). The questionnaires were available bilingually (English and Welsh) and hosted on JISSC online survey software, which is GDPR compliant.

4.4.2 Physical activity

Self-reported PA levels were measured using the validated and reliable Physical Activity Questionnaire for Older Children (PAQ-C) for those aged 8-11 years or the Physical Activity

Questionnaire for Adolescents (PAQ-A) for those aged 12-18 years (Kowalski et al., 2004). Aggio et al. (2016) regards the PAQ as one of the most suitable self-report means for assessing PA in children and adolescents.

The PAQ-C consists of eight items and the PAQ-A ten items. Each scale is scored on a five-point Likert scale. An example of a PAQ question is '*In the last 7 days, during your PE classes, how often were you very active (playing hard, jumping, throwing etc.)?*', with '*I didn't have PE lessons*' being 1 and '*always*' being 5. For item one and the last item mean scores were calculated from all activities or days, with the mean score contributing to the final PAQ score. From all the items a mean score is derived with scores ranging from 1-5 for participants. The PAQ questions for the first time-point (during lockdown, January 2021) had additional home learning references to aid memory recall (Table 2). The PAQ questions for the subsequent three time-points reverted back to the original questions due to children and adolescents returning to face-to-face teaching. The PAQ-A differs to the PAQ-C due to the removal of the school break time question and the addition of active travel and before school question. The removal of school break time questions and addition of active travel questions reflects the shift in PA habitats that occurs from childhood to adolescence.

Table 2. PAQ questions that were modified for the first time-point

Original Question	Modification for the first time-point
1. In your spare time (that is your time outside of school) over the past 7 days (last week), have you done any of the follow activities? 2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing, etc.)?	1. In your spare time **(*when you are not busy doing school work*)** over the past 7 days (last week), have you done any of the follow activities? 2. Added as answer option: *I don't get PE lessons to do at home*

3. In the last 7 days, what did you do most of the time during school break time?	3. In the last 7 days, what did you do most of the time ***while taking a break from home learning***?
4. In the last 7 days, on how many days right after school, did you do sports, dance, or play games in which you were very active?	5. In the last 7 days, on how many days right ***after you have finished school work***, did you do sports, dance, or play games in which you were very active?

Note: Bold text highlights modifications made to the validated questionnaire.

A concern for the accuracy of the PAQ data was the participants ability to accurately recall their activity levels. Memory cues were implemented within the questions to aid recall such as 'at lunch' and 'in PE classes at school or for home learning' (Baranowski, 1988). Both the PAQ-A and PAQ-C has been validated against objectively measured PA, being shown to have acceptable internal consistency and good test-retest reliability (Aggio et al., 2016; Kowalski et al., 1997). Table 3 demonstrates the high levels of internal consistency within the study at all time-points for both the PAQ-C and PAQ-A.

Table 3. Cronbach's alpha for the PAQ at each time-point

Time-point	Sub-scale	N	Items	Cronbach
1	PAQ-C	861	8	0.765
	PAQ-A	846	10	0.742
2	PAQ-C	728	8	0.739
	PAQ-A	704	10	0.699
3	PAQ-C	344	8	0.776
	PAQ-A	567	10	0.700
4	PAQ-C	325	8	0.750
	PAQ-A	452	10	0.707

4.4.3 Mental Health and Well-being

4.4.3.1 Good Childhood Index (GCI)

Subjective well-being was assessed using the Good Childhood Index (GCI), a validated questionnaire for children aged eight years and over (Pople et al., 2014). The GCI has a single-item measure of happiness and 16 questions measuring well-being in ten aspects of children's lives. The 10 aspects are: family, friends, health, appearance, time use, the future, home, money and possessions, school, amount of choice. Eleven of the questions are scored using an 11-point Likert scale ranging from 0 being 'very unhappy' to 10 being 'very happy'. A composite score is created of an average from the 11 items. The questionnaire assumes a reading age of eight years and was therefore appropriate for use with the target population.

The remaining questions within the GCI are derived from the Huebner's Modified Life Satisfaction Scale (HMLSS), which consists of five items that measure life satisfaction (Huebner, 2001). The scale uses a 6-point Likert scale, with 0 'don't know', 1 'strongly disagree' and 5 'strongly agree'. For the item 'I wish I had a different kind of life', reverse scoring is used with 'strongly disagree' as 5 and 'strongly agree' as 1. The score for the scale is calculated by summing all five items together, with scores ranging from 0-25. Table 4 outlines the levels of internal consistency within the study at all time-points for life satisfaction. The life satisfaction data collected during the study was not used in the analysis for this thesis as the Stirling Children's Well-being Scale (SCWBS) results were used to investigate children's and adolescents' emotional and physiological well-being during the COVID-19 pandemic.

Table 4. Cronbach's alpha for the Good Childhood Index at each time-point

Time-point	Sub-scale	N	Items	Cronbach
1	Life satisfaction	1,708	5	0.820
2	Life satisfaction	1,280	5	0.877
3	Life satisfaction	606	5	0.857
4	Life satisfaction	734	5	0.690

4.4.3.2 Stirling Children's Well-being Scale (SCWBS)

Emotional and psychological well-being were measured using the SCWBS. The scale consists of 15 questions, using a 5-point Likert scale, with 1 'never' and 5 'all of the time'. Within the SCWBS, only 12 of the 15 questions contribute to the participant's score. Three items excluded from the participant's composite score (items 2, 7 and 13) is a sub-scale measure of social desirability. A score of greater than 14 on the social desirability sub-scale suggests that there is a predominance of socially desirable answers (Liddle & Carter, 2010). At each time-point participants' SCWBS score was excluded if their social desirability score was greater than 14, at the first time-point this meant 30 participants SCWBS score was excluded, 20 at the second, 10 at the third and 12 at the fourth time-point. The SCWBS scores range from 12-60 with the remaining 12 questions split into two well-being sub-components: positive emotional state (items 9-15) and positive outlook (items 1, 3-6, 8). Currently, there is no agreed gold standard for measuring well-being in children; the SCWBS has shown good reliability and construct validity. The SCWBS has been found to have good internal and external reliability using a test-retest method (Liddle & Carter, 2010). Table 5 describes the levels of internal consistency at each time-point for the SCWBS. Good construct reliability was shown when comparing the SCWBS with other widely used well-being questionnaires. The SCWBS has been strongly correlated to other validated questionnaires including the Warwick-Edinburgh Mental Well-being scale and the DuBois Self-Esteem Scale (Liddle & Carter, 2010). The SCWBS data was used in the analysis to provide data on children's and adolescent's emotional and physiological well-being during the COVID-19 pandemic and measure the relationship between well-being and PA.

Table 5. Cronbach's Alpha for the Stirling Children's Well-being Scale at each time-point

Time-point	Sub-scale	N	Items	Cronbach
1	Positive Outlook	1,698	6	0.824
	Positive Emotional State	1,704	6	0.883
	Social Desirability	1,701	3	0.461
2	Positive Outlook	1,432	6	0.831
	Positive Emotional State	1,432	6	0.889
	Social Desirability	1,432	3	0.411
3	Positive Outlook	911	6	0.848
	Positive Emotional State	911	6	0.893
	Social Desirability	911	3	0.420
4	Positive Outlook	778	6	0.858
	Positive Emotional State	778	6	0.902
	Social Desirability	778	3	0.484

4.5.4 Questionnaire amendments

Variations were made to the questionnaire at each time-point in order to correspond with the regulations being implemented by Welsh Government and following personal correspondence from parents. Specifically, at the second time-point, questions regarding COVID-19 infections and experiences were added because of the increasing number of children and adolescents across Wales testing positive for COVID-19. For the third time-point, the COVID-19 questions were removed because of concerns over the length of the questionnaire and the lack of meaningful data collected. For the final time-point questions concerning COVID-19 were adapted from the second time-point and re-added to the questionnaire due to increased availability and frequency of COVID-19 testing. Table 6 outlines the COVID-19 questions included in the questionnaire at different time-points.

Table 6. COVID-19 Questions included in the questionnaire

COVID-19 Questions Time-point 2	COVID-19 Questions Time-point 4
And finally, do you think you might have had COVID over the last year?	Have you ever had a positive COVID test (PCR or lateral flow)?
Do you still have any symptoms of COVID, often called long COVID?	When did you test positive?
What symptoms do you have and for how long has this been going on?	Did you experience any symptoms of COVID-19 4 weeks after your positive test? This is often called long-COVID.
	What symptoms do you have? Please select all that you are experiencing.

4.6 Device-based measure and data processing

4.6.1 Accelerometers

PA levels were measured in a sub-sample using the Axivity AX3 monitor, a tri-axial accelerometer worn on their non-dominant wrist for seven consecutive days. A systematic review found triaxial accelerometers to be accurate in measuring sedentary time and PA levels in children (Lynch et al., 2019). The Axivity AX3 monitor is an accurate and reliable device, with a higher balanced accuracy in children than the Actigraph GT3X+ (Doherty et al., 2017; Hedayatrad et al., 2020). Wrist-worn accelerometers were chosen because they have a greater detection of upper body movements than hip or dominant hand accelerometer locations (Chandler et al., 2016; Phillips et al., 2013; van Hees et al., 2011) and have a higher compliance rate and total wear time in children (Scott et al., 2017), which has led to an increase in their popularity with researchers (Sabia et al., 2014). Whilst the GENEActiv is frequently used in research, the Axivity AX3 has exhibited equivalent signal vector magnitude output on multi-axis shake tests. This is important as the Axivity AX3 is substantially cheaper than the GENEActiv (Doherty et al., 2017; Ladha et al., 2013).

The accelerometers were set to a sampling frequency of 100Hz and an epoch length of 1 second used in the analysis. Short epoch lengths of 1-10s are recommended when measuring PA in children due to the sporadic nature of their activity (Aadland et al., 2018). The wear

time criteria for a valid day was set as a minimum of 16 hours per day and one day per week. A sensitivity analysis was run to determine the number of days required for inclusion, with the analyses run for three valid days, two valid days and one valid day. The analysis revealed there was no significant difference irrespective of the number of valid days, therefore one valid day was chosen to allow more participant's data to be included.

4.6.2 Accelerometer data processing

The raw accelerometer data was analysed using GGIR Version 2.3-0 (Migueles et al., 2019). GGIR facilitates data cleaning through the detection of non-wear time and the extraction of user-defined acceleration levels that reflect PA intensity levels (Hildebrand et al., 2014). For processing the raw data the default non-wear time settings were used; GGIR imputes non-wear time by utilising the average at similar time-points on other days. For determining PA, GGIR uses published cut-points for moderate physical activity (MPA) and vigorous physical activity (VPA; Migueles et al., 2019). Specifically, 191.6 milli-gravity (mg) and 695.8 mg were used for MPA and VPA, respectively. The sedentary threshold differed from previously published cut-points and was set at 50 mg as advised by Hurter et al. (2018) to allow comparisons between different brands of accelerometers.

4.7 Statistical analysis

Descriptive statistics (mean ± standard deviation) were calculated for every variable at each time-point. Participants were grouped by sex, SES quintiles (1-5) using WIMD and school age groups according to their school year; years 4-6, years 7-9 and years 10-13. The percentage of children meeting the UK government PA guidelines was calculated by school age group and sex. Participants who had engaged in ≥ 60 minutes of MVPA were considered to have met the UK government PA guidelines.

Linear mixed models (LMM) were conducted separately for each PA metric to investigate the influence of time-point, age, sex and socio-economic status (SES) and their interaction, on PA metrics. A LMM was also run to examine the influence of time-point, age, sex and SES on well-being and the relationship between well-being and PA metrics. LMM were used to analyse the data due to their ability to cope with unbalanced and missing data compared with other

statistical methods such as ANOVAs. The LMM did not, however, have control variables so differences in the sample distribution were not accounted for. Planned contrasts were conducted to further analyse the influence of variables. Results are reported as beta coefficients (β), 95% confidence intervals (CI) and p values, with the level of significance set at $p<0.05$. Statistical analysis was conducted in STATA MP (version 13, StataCorp., College Station, TX, USA).

5.0 Results

5.0 Descriptive statistics

The response rate for the questionnaire decreased throughout the study (Table 1). A total of 1,711 participants (50% boys, 53% primary school; Table 1) participated in the questionnaire at the first time-point in January 2021 following initial recruitment, with 659 children and adolescents returning valid accelerometer data (Table 2). At the subsequent three time-points, participants were re-invited to take part, with variation in participation rates. Table 3 provides the frequency distribution of the accelerometer sub-sample at every time-point during the study. Throughout the study there was no significant difference in the number of boys and girls participating at each time-point (all $p>0.05$). However, at all four time-points, there was a significantly higher proportion of participants from Years 4-9, compared to children and adolescents from school Years 10-13 (all $p<0.001$). At the third (X^2 (4)=12.2, $p=0.016$) and the fourth time-point (X^2 (4)= 46.0, $p<0.001$), there was a significantly higher proportion of participants from the least-deprived background, compared to the most deprived.

Table 1. Number of participants who completed the questionnaire and the response rate of parents who consented for their child(ren) to participate at each time-point

Time-Point	School	Number of Participants	Response rate (%)
1	Primary	866	40
	Secondary	845	38
2	Primary	731	29
	Secondary	704	26
3	Primary	349	20
	Secondary	599	17
4	Primary	327	17
	Secondary	464	12

Table 2. Number of accelerometers sent out and worn at each time-point

	Number of accelerometers sent out	Number of new participants sent an accelerometer	Number of accelerometers returned with valid wear time	Percentage of accelerometers returned with valid wear time
1st time-point	800	0	659	82
2nd time-point	800	66	647	81
3rd time-point	800	257	567	71
4th time-point	538	337	408	76

Table 3. Frequency distribution of participants who returned accelerometers with valid wear time at each time-point

Time-point	Variable	Categories	N (%)
1	Sex	Boy	314 (48)
		Girl	345 (52)
	Year-group	Years 4-6	237 (36)
		Years 7-9	254 (39)
		Years 10-13	168 (26)
	Deprivation	1 (Most deprived)	115 (18)
		2	123 (19)
		3	136 (21)
		4	151 (23)
		5 (Least Deprived)	134 (20)
2	Sex	Boy	316 (49)
		Girl	335 (51)
	Year-group	Years 4-6	247 (38)
		Years 7-9	239 (37)
		Years 10-13	164 (25)
	Deprivation	1 (Most deprived)	114 (18)
		2	127 (20)
		3	137 (21)
		4	144 (22)
		5 (Least Deprived)	128 (20)
3	Sex	Boy	280 (49)
		Girl	288 (51)
	Year-group	Years 4-6	207 (36)
		Years 7-9	209 (37)
		Years 10-13	152 (27)

	Deprivation	1 (Most deprived)	89 (16)
		2	104 (18)
		3	117 (21)
		4	139 (25)
		5 (Least Deprived)	119 (21)
4	Sex	Boy	201 (50)
		Girl	205 (51)
	Year-group	Years 4-6	187 (46)
		Years 7-9	148 (36)
		Years 10-13	71 (18)
	Deprivation	1 (Most deprived)	59 (15)
		2	56 (14)
		3	63 (16)
		4	122 (30)
		5 (Least Deprived)	106 (26)

Note: Welsh Index of Multiple Deprivation 2019 used to measure Socio-economic Status (SES) Quintile

Table 4 presents the sample characteristics and physical activity levels of participants from the accelerometer sub-sample at each time-point during the study. Over the course of the four time-points, both moderate-to-vigorous physical activity (MVPA) and light physical activity (LPA) significantly increased by 66.9% (β=34.9; CI: 27.68-42.21); p=0.001; Table 5) and 39.2% (β=50.7; CI: 33.52-67.82; p=0.001; Table 5), respectively. Well-being also significantly increased by 14.8% (p=0.005; Table 5), across time, equating to an average increase of four points (out of 60 points) on the Stirling Well-being Scale. Contrastingly, sedentary time decreased by 13.6% (β=65.7 minutes; CI: 109.09- -22.31); p=0.003) over the same time frame.

Table 4. Sample characteristics and physical activity levels of participants from the accelerometer sub-sample at each time-point

	1st Time-point n= 659	**2nd Time-point** n= 651	**3rd Time-point** n= 568	**4th Time-point** n=406
Age (Years)	12.1 ± 2.4	12.2 ± 5.0	11.9 ± 2.5	11.6 ± 2.3
SES	3.10 ± 1.4	3.06 ± 1.4	3.17 ± 1.4	3.39 ± 1.4
MVPA (mins)	38.1 ± 24.4	50.3 ± 29.6	55.3 ± 28.7	63.6 ± 34.0
LPA (mins)	131.3 ± 58.4	170.9 ± 72.4	177.9 ± 59.3	182.8 ± 6
Sedentary time (mins)	844.4 ± 201.8	757.1 ± 155.5	654.1 ± 118.6	729.3 ± 138.5
Well-being	43.2 ± 7.52	43.1 ± 7.51	45.7± 7.71	49.6 ± 5.60

Note: Values in **bold** indicate statistical significance (p<0.05).
Abbreviations: SES=Socio economic status; MVPA moderate-to-vigorous physical activity; LPA= Light physical activity

The percentage of children in the accelerometer sub-sample meeting the UK government MVPA guidelines increased at every time-point. By sex, the percentage meeting the MVPA guidelines was lowest at the first time-point (boys 16%; girls 13%) and highest at the fourth time-point (boys 62%; girls 39%). Throughout the study, there was a higher percentage of boys meeting the MVPA guidelines than girls. The difference in boys and girls meeting the MVPA guidelines was not significant at the first time-point (p=0.245) but was significant at the remaining time-points (p<0.001). Across the three school-year-group categories, the percentage meeting the MVPA guidelines was lowest at first time-point (9-23%) and highest at the fourth time-point (13-63%). At every time-point, there was a significant difference in school year-group and the percentage of children and adolescents meeting the MVPA guidelines (all p<0.001). A higher percentage of primary school children (Years 4-6) met the guidelines compared to secondary school children in Years 7-9 and Years 10-13, irrespective of time. The percentage of children and adolescents meeting the MVPA guidelines from different SES was not significant (p>0.05) apart from at the third time-point (p=0.008), where a higher percentage of children and adolescents from the fourth and fifth quintiles met the guidelines, this could reflect the changes in sample distribution noted in Table 3.

5.2 PA metrics

5.2.1 MVPA

Reverse adjacent contrasts showed MVPA significantly increased at every time-point when compared to the previous time-point, with the greatest increase in MVPA between the first and second time-points (11.1 ± 1.5 minutes; $p<0.001$). There was a significant effect of school year-group on minutes spent in MVPA, with secondary school children participating in significantly less MVPA than primary school children (Table 5). There was only a significant effect of SES on minutes spent in MVPA for children and adolescents from the fourth SES quintile ($p=0.017$; Table 5), relative to children and adolescents from SES quintile 1, and no significant effect of sex on time spent in MVPA ($p=0.666$).

Planned contrasts according to time-point and year-group revealed that MVPA significantly increased after each time-point for children in Years 4-6, with the greatest increase between the first and second time-point (+17.0 ± 2.4; $p<0.001$) and the smallest (but still significant) increase being between the third and fourth time-point (+6.3 ± 2.7; $p=0.017$). MVPA only significantly increased in children in Years 7-9 between the first and second time-point (13.2 ± 2.4; $p<0.001$). There were no significant increases in MVPA for Years 10-13, irrespective of time-point (Table 5). Subsequent reverse adjacent contrasts revealed that there was a significant sex difference in MVPA from the second time-point onwards ($p<0.001$), with boys participating in more MVPA than girls.

Table 5. The influence of time-point, age, sex and SES on PA metrics during the COVID-19 pandemic

Effect	Coefficient	(95%CI)	p
MVPA			
2nd Time-point	20.8	(14.2 to 27.5)	**<0.001**
3rd Time-point	29.4	(22.5 to 36.4)	**<0.001**
4th Time-point	35.0	(27.7 to 42.2)	**<0.001**
Sex-Girl	1.7	(-6.2 to 9.7)	0.666
School-year-group- Years 7-9	-12.0	(-18.7 to -5.4)	**<0.001**
School-year-group- Years 10-13	-12.0	(-19.6 to -4.4)	**0.002**
SES-2	2.9	(-2.3 to 8.1)	0.268
SES-3	3.6	(-1.7 to 8.9)	0.183
SES-4	5.9	(1.0 to 10.7)	**0.017**
SES-5 (Least deprived)	3.8	(-1.3 to 8.9)	0.146
LPA			
2nd Time-point	41.8	(26.1 to 57.5)	**<0.001**
3rd Time-point	50.9	(34.4 to 67.3)	**<0.001**
4th Time-point	50.7	(33.5 to 67.8)	**<0.001**
Sex- Girl	18.7	(-0.0 to 37.4)	0.051
School-year-group - Years 7-9	-24.7	(-40.4 to -9.1)	**0.002**
School-year-group- Years 10-13	-13.0	(-31.1 to 5.0)	0.157
SES-2	1.8	(-16.1 to 19.7)	0.847
SES-3	9.5	(-8.1 to 27.1)	0.291
SES-4	5.5	(-11.6 to 22.5)	0.532
SES-5 (Least deprived)	-19.7	(-37.4 to -2.0)	0.030
Sedentary			
2nd Time-point	-73.8	(-113.5 to -34.1)	**<0.001**
3rd Time-point	-196.8	(-238.4 to -155.2)	**<0.001**
4th Time-point	-65.7	(109.1 to -22.3)	**0.003**
Sex-Girl	18.6	(-28.8 to 66.0)	0.442
School-year-group- Years 7-9	58.0	(18.4 to 97.7)	**0.004**
School-year-group- Years 10-13	91.6	(45.9 to 137.2)	**<0.001**
SES-2	-5.0	(-50.4 to 40.5)	0.831
SES-3	-4.5	(-49.2 to 40.2)	0.842
SES-4	14.6	(-28.7 to 58.0)	0.508
SES-5 (Least deprived)	-4.2	(-49.2 to 40.7)	0.854

Note: Time-point 1, boys, Years 4-6, and SES Quintile 1 (most deprived) are the reference values. Values in **bold** indicate statistical significance ($p<0.05$).

Abbreviations: CI= confidence interval; SES=Socio economic status; MVPA moderate-to-vigorous physical activity; LPA= Light physical activity

5.2.2 LPA

Reverse adjacent contrasts identified that LPA significantly increased between the first and second time-point (38.2 ± 3.5; p<0.001) and the second and third time-point (7.5 ± 3.6; p=0.038) but did not significantly increase between the third and fourth time-point (2.2 ± 4.3; p=0.610). There was a significant difference in LPA amongst participants in Years 4-6 and Years 7-9 (p=0.002; Table 5). A significant increase was found for LPA between the first and second time-point, irrespective of year-group (p<0.001). However, no significant increase was present at the latter time-points, with only children in Years 4-6 having a significantly increased LPA between the second and third time-point (15.8 ± 5.8; p=0.007). There was no overall sex difference for LPA at any time-point.

5.2.3 Sedentary time

There was a significant effect of time-point on sedentary time relative to the first time-point (2nd and 3rd time-point: p<0.001, 4th time-point: p=0.003; Table 4), with subsequent planned contrasts showing that there was a significant difference in sedentary time between all time-points when compared to the previous time-point (all p<0.001). The greatest decrease in sedentary time was between the second and third time-points (-103.7 ± 9.1 mins; p<0.001). Sedentary time also significantly decreased between the first and second time-point (-88.0 ± 8.2 mins; p<0.001). However, sedentary time significantly increased between the third and fourth time-points (74.7 ± 10.8 mins; p<0.001). Year-group had a significant effect on sedentary time (Table 4); relative to primary school children (Years 4-6), Years 7-9 (β=58.0; CI:18.3-97.7; p=0.004), and Years 10-13 (β = 91.6; CI:45.9-137.2; p<0.001), children engaged in significantly more sedentary time. The linear mixed model (LMM) showed that there was no overall sex difference for sedentary time (β=18.6; CI:-28.8-66.0; p=0.442; Table 5).

5.3 Well-being and the relationship with PA metrics

A LMM found a significant difference in well-being for the fourth time-point relative to the first time-point (β =4.2; CI: 1.3- 7.1; p=0.005; Table 6). Further analysis using planned contrasts revealed that there was no significant change in well-being between the first and second time-points (-0.3 ± 0.7; p=0.673). Well-being did, however, significantly increase between the second and third time-points (2 ± 0.7; p=0.005) and the third and fourth time-

points (5 ± 1.8; p= 0.007). The LMM revealed a significant relationship between well-being and MVPA (β=0.3; 95% CI:0.0-0.5; p=0.008; Table 6), with no significant relationship between LPA and well-being, or sedentary time and well-being (both p>0.05).

Table 6. The influence of PA metrics on well-being

	Coefficient	**(95%CI)**	**p**
Light	-0.0	(-0.0 to 0.0)	0.536
Sedentary	-0.0	(-0.0 to 0.0)	0.797
MVPA	0.3	(0.0 to 0.5)	**0.008**
2nd Time-point	-0.6	(-3.3 to 2.1)	0.667
3rd Time-point	2.0	(-0.7 to 4.7)	0.154
4th Time-point	4.2	(1.3 to 7.1)	**0.005**
Sex	-2.3	(-5.7 to 1.1)	0.184
Year-group- Years 7-9	-1.2	(-3.7 to 1.5)	0.408
Year-group- Years 10-13	-2.8	(-6.0 to 0.4)	0.082
SES-2	1.5	(-0.8 to 3.8)	0.209
SES-3	-0.1	(-2.5 to 2.2)	0.908
SES-4	-0.7	(-2.9 to 1.4)	0.511
SES-5	-0.6	(-2.9 to 1.7)	0.588

Note: Time-point 1, boys, Years 4-6, and SES Quintile 1 (most deprived) are the reference values. Values in **bold** indicate statistical significance (p<0.05).
Abbreviations: CI= confidence interval; SES=Socio economic status; MVPA moderate-to-vigorous physical activity; LPA= Light physical activity

6.0 Discussion

The aim of this study was to determine the change in children's and adolescents' physical activity (PA) and well-being during the COVID-19 pandemic. Overall, PA levels were influenced by the severity of COVID-19 restrictions, and at their lowest when restrictions were at their strictest during the winter lockdown (first time-point). All PA metrics significantly increased, and sedentary time significantly decreased, with the easing of COVID-19 restrictions; the greatest change was the increase in moderate-to-vigorous physical activity (MVPA) and light physical activity (LPA) with the return to face-to-face teaching in schools (2nd time-point) after lockdown (first time-point). Similar to PA metrics, well-being was at its lowest when COVID-19 restrictions were at their strictest during lockdown. Both PA and well-being levels at the fourth time-point (March 2022) were significantly greater than at the first time-point (the third national lockdown in January 2021). Across all four time-points, there was a positive relationship between MVPA and well-being, with children who were more physically active reporting higher levels of well-being. The COVID-19-related restrictions had substantial impact on children's and adolescents' PA levels and well-being. Despite these levels increasing and enhancing, respectively, with the easing of restrictions, as with prior to the COVID-19 pandemic they remain worryingly low with only 50% of children and adolescents meeting the MVPA guidelines and well-being only slightly rising beyond reported pre-pandemic levels (Liddle & Carter, 2015). The longer-term effects of the significant decline during the COVID-19 pandemic remains to be elucidated, warranting further research.

6.1 Change in MVPA relative to pre-COVID-19 levels

Time spent in MVPA during lockdown (first time-point) was low in comparison to values reported pre-COVID-19 (Brazendale et al., 2021). This study shows that, in January 2021, only 15% of the current children and adolescents met the UK government PA guidelines of an average of 60 minutes per day. Such findings are congruent with other studies conducted in Wales and across the world during lockdown (Paterson et al., 2021; Stockwell et al., 2021). This finding does, however, need to be examined in the context that the lockdown occurred during winter, a period when PA levels in children and adolescents are reported to be lower (Atkin et al., 2016; Carson & Spence, 2010; Gomes et al., 2020; Rich et al., 2012). Children and adolescents have been reported to engage in 15-30% less MVPA during autumn and winter

compared to spring (Atkin et al., 2016). Although seasonal variation may play a part in the lower time spent in MVPA found during lockdown, it is unlikely to be the sole cause.

Low MVPA may have been expected given that children and adolescents were engaging in online schooling, a predominantly sedentary activity, and that COVID-19 related restrictions severely limited children's and adolescents' opportunities to be physically active (e.g. closure of sports clubs). Physical education (PE) provides regular and structured PA opportunities for children and adolescents in school (Fairclough & Stratton, 2005), whilst also developing competence in a range of physical activities and engaging children in competitive sport (Smith et al., 2009). Research has also shown that PE significantly contributes to children's and adolescents' overall time spent in MVPA and reduces sedentary time (Meyer et al., 2013; Mooses et al., 2017). During remote learning, schools had to schedule at least 90 minutes for PE lessons for children aged up to 16 years old but there were often limited resources to effectively teach PE online. This led to individuals and organisations releasing resources, usually in the form of a video, to help children and adolescents to be active during lockdown. The limited resources for online PE provision by schools during lockdown (first time-point) likely contributed to the lower time spent in MVPA compared to otherwise reported pre-pandemic levels. As the present study utilised device-based measures, limited conclusions can be drawn regarding reasons for the change in PA metrics , given the lack of individual context.

6.2 Change in MVPA levels during the study

The biggest increase in MVPA (+11.1 ± 1.5 minutes) occurred between first time-point and the second time-point (May 2021), which aligned with the greatest changes in COVID-19-related restrictions, with non-essential services re-opening, including schools. This increase could be explained by children and adolescents having significantly more opportunities to be physically active than during lockdown (first time-point). These opportunities included active travel to and from school and school break time and sports clubs, which have been shown to make up large proportions of children's daily PA (Saint-Maurice et al., 2018). Nonetheless, it could be argued that the increase in MVPA was small and therefore, given all these opportunities, children and adolescents were not engaging with all the activities that were

available to them. This disengagement in PA opportunities was present prior to the COVID-19 pandemic as the percentage of children and adolescents who actively travel to school is relatively low (Edwards et al., 2018). A pre-pandemic survey in Wales identified that only 44% and 33% of primary and secondary school children, respectively, actively travel to school, with levels on a downward trend (Edwards et al., 2018; Hewitt et al., 2019). School typically accounts for the largest proportion of daily MVPA over weekdays (Long et al., 2013; Saint-Maurice et al., 2018), with the School Sport and Activity Action Plan citing that half of children's recommended PA (30 minutes) should be accrued during school hours (Foster & Roberts, 2019). Similar to active travel, the majority of children and adolescents in the UK do not engage in 30 minutes of PA in school, with Sport England reporting that, prior to the COVID-19 pandemic, only 40.4% of children and adolescents aged 5-16 years old were active for an average of 30 minutes in school (Sport England, 2019). Saint-Maurice et al. (2018) also noted that after-school programmes account for approximately 15 minutes of children's and adolescents' daily MVPA, but only 35% of children and adolescent's attend an after-school club in the UK (Department of Education, 2018). The low percentage of children and adolescents who actively travel to school, engage in after-school programs, and engage in 30 minutes of PA during school, potentially explains why the desired increase in PA levels with the return to school was not evident. Whilst the return to face-to-face teaching reinstated opportunities to be physically active, it can assumed from the low PA levels prior to the pandemic (Edwards et al., 2018; Hewitt et al., 2019) that few children and adolescents engaged in these opportunities (e.g. active travel to school) once they were re-instated, suggesting no change in attitudes prior to pre-pandemic. This can however not be gleaned directly from the accelerometer PA data as we do not have the context of PA children and adolescents were engaging in with the return to face-to-face teaching. Future analysis should include the contextual information from the questionnaire measures to allow greater understanding of the factors influencing children's and adolescents' PA during the COVID-19 pandemic.

Despite the return to face-to-face teaching for all children and adolescents, there were still restrictions within schools, such as class bubbles and staggered break times. These restrictions placed constraints on children's and adolescents' PA during school, with these restrictions only lifted after the second time-point in May 2021. The restrictions within

schools particularly affected PE lessons; a survey conducted across the UK at the start of the COVID-19 pandemic by the Youth Sport Trust (Youth Sport Trust, 2020) reported that 65% of all teachers surveyed said that logistical issues caused by the COVID-19 restrictions were barriers to delivering PE. These logistical issues included cleaning equipment, social distancing, class bubbles or staggered break times. Further, the study reported that 40% of schools would be delivering no extracurricular PE in the 2020 Autumn term and around half of schools would be delivering less than before the COVID-19 pandemic (Youth Sport Trust, 2020) which continued during the pandemic . In reality, on return to school after lockdowns, more than half of primary schools and almost two-fifths of secondary schools in the UK reported that they had reduced hours for subjects such as PE and music in school (Achtaridou et al., 2022). This is despite evidence that Active Recovery strategies which aimed to prioritise time spent being active and outdoors improved children and adolescent's social, academic, emotional, and physical well-being (Youth Sport Trust, 2021). Future policies and interventions should look to incorporate active recovery strategies after lockdowns to aid children and adolescent's recovery rather than focusing solely on catching up academically. Especially as research has shown that PA is beneficial to children and adolescent's academic performance especially attainment and concentration (Alvarez-Bueno et al., 2017; Zeng et al., 2017). Despite the reduced hours for PE within schools, the time spent in MVPA continued to rise with the easing of COVID-19 restrictions for children and adolescents.

COVID-19 restrictions continued to be eased throughout the study until, at the third time-point (October 2021), all COVID-19 restrictions had been lifted (Table 4.2). In line with this easing of COVID-19 restrictions, time children and adolescent's accumulated in MVPA increased throughout the study, with the highest time accumulated in MVPA reported at the fourth time-point. Children and adolescents engaged in an average of 63.58 minutes of MVPA at the fourth time-point (March 2022), with 50% of children and adolescent's aged 8-18 years-old meeting the UK PA government guidelines (Gibson-Moore, 2019). The percentage of children and adolescents meeting the PA guidelines at the fourth time-point (50%) is significantly higher than the self-reported levels of young people (aged 11-16 years), where only 17% met the PA guidelines regarding time spent in MVPA before the COVID-19 pandemic (Page et al., 2021). However, time accumulated in MVPA reported at the fourth time-point are similar to levels in the 2018 National Survey for Wales (NSW), where 51% of 3-17 year

olds met the UK government guidelines (Edwards et al., 2018). This comparison needs to be interpreted with caution due to the NSW using a proxy-report method to measure the percentage of children and adolescent's meeting the government PA guidelines. Researchers have reported conflicting evidence on the accuracy of proxy-reports (Burrows et al., 2010; Saint-Maurice et al., 2020), with parents reported to overestimate their child's PA levels (Corder et al., 2010). Prior to the COVID-19 pandemic, all studies reporting the percentage of children and adolescent's meeting the UK PA guidelines in Wales used report-based measures (Strain et al., 2020). As such, the only comparisons of the percentage of children and adolescent's meeting the guidelines before and after the COVID-19 pandemic in Wales can be made using the report-based data and accelerometer data. Thus, the limited comparisons that can be made indicate that the percentage of children and adolescent's meeting the UK government guidelines recovered to similar levels as prior to the COVID-19 pandemic. Nonetheless, a large proportion of children and adolescents were insufficiently active. The large proportion of children and adolescents who were physically inactive (not meeting the government PA guidelines) are at increased risk of having negative health implications (Booth et al., 2017). Physical inactivity is a strong risk factor for the development of chronic diseases with resulting morbidity and mortality (Kumar et al., 2015). Previous research has identified that physical inactivity during adolescence can lead to a four-fold increase in the risk for obesity by 25 years (Pietiläinen et al., 2008). As with before the COVID-19 pandemic, the childhood physical inactivity epidemic (Guthold et al., 2020) continued throughout and following the COVID-19 pandemic. Therefore, public health policy should continue to focus on improving PA levels through interventions to reduce physical inactivity and mitigate the adverse health implications.

The continued increase in children and adolescent's MVPA after the third time-point could be explained through the Savanta ComRes March 2021 survey, which reported people's worries and fears about returning to sport, with the majority of adults not feeling confident about returning to indoor facilities to exercise (Sport Wales, 2021). Adults cited different reasons for this fear including, but not limited to, being close to people, too many people and catching COVID-19. Moreover, Suffren et al. (2021) reported that the more fears parents had about COVID-19, the greater the fears their child had. Children and adolescents have reported some of these fears, reporting fearing a family member, or they themselves, would become ill from

COVID-19 (Götz et al., 2020). These fears from both adults and children could have acted as a barrier for some children and adolescent's to immediately return to PA and sport, with them only returning once they felt safe to do so and COVID-19 levels continued to fall, potentially explaining the increase in MVPA at time-point four.

6.2.1 The Effect of age on MVPA levels

During the course of the study, primary school children in (Years 4-6) engaged in an average of 12 ± 3.9 minutes more MVPA than secondary school children (Years 7-13; 12-18 years). This finding is in line with research conducted prior to the COVID-19 pandemic (Page et al., 2021) and is echoed in the percentage of children meeting the UK government PA guidelines (Gibson-Moore, 2019), which declined with age. Primary school children (Years 4-6) had the greatest increase in the percentage of children meeting the guidelines, increasing 47% from January 2021 (first time-point) to March 2022 (fourth time-point). Children in Years 4-6 (8-11 years) had the greatest increase in the percentage meeting the PA guidelines across every time-point, suggesting that younger children's PA was more affected by the COVID-19-related restrictions than secondary school children (Years 7-13; 12-18 years). This is perhaps anticipated after lockdown (first time-point) because younger children are less likely to independently go outside the home environment where there are more opportunities to be physically active, rather relying on parents or teachers to accompany them (Hurter et al., 2022; Marzi & Reimers, 2018). Furthermore, at-home learning, rather than face-to-face teaching, during lockdown removed a key source of PA for children and adolescent's; primary school children are significantly more physically active than secondary school children and adolescent's within the school environment, especially during break time (Hurter et al., 2022; Morton et al., 2016). Primary school children's sources of PA and dependence on adults potentially explains why their PA levels were significantly more affected by the COVID-19 restrictions than secondary school children.

During the winter lockdown (first time-point), when schools were closed and children were engaging in remote learning, there was only a 14% difference in the percentage of children and adolescents in Years 4-6 (8-11 years) and Years 10-13 (15-18 years) meeting the PA guidelines. Once children had returned to face-to-face teaching in school (May 2021; second time-point), the difference in Years 4-6 (8-11 years) and Years 10-13 (15-18 years) children

and adolescent's meeting the PA guidelines rose to 39%. The difference in the percentage of children and adolescent's meeting the guidelines continued to rise with the easing of COVID-19 restrictions and beyond, with a difference > 50% at the fourth time-point when all COVID-19 restrictions had been removed for seven months. This finding is congruent with the self-reported data as part of the School Health Research Network (SHRN) study conducted in Wales, where an age gradient was found, with 11-year-olds reporting higher amounts of MVPA (20%) compared to 16-year-olds (10%; Page et al., 2021; Richards et al., 2022). The widening of the percentage of children and adolescent's meeting the PA guidelines with the easing of COVID-19 restrictions and re-opening of society reinforces the importance of environmental factors, such as access to parks, on children and adolescent's' PA levels (Nash, 2018; Saunders et al., 2020). The unique environment COVID-19-related restrictions created, such as the banning of organised sport, provides a rare opportunity for future research of the COVID-19 pandemic to further examine the environmental factors that influence the decline in PA levels in children and adolescents. The contextual data collected from this study through the PAQ and GCI could be utilised in future analysis to provide insight into the environmental factors that influence an increase and decrease in PA levels. Further, the age-related decline in PA levels supports the notion that PA interventions and policies should target children early on rather than during adolescence to prevent the significant decline in PA levels rather than attempt to increase PA once levels have declined (Farooq et al., 2018; Saunders et al., 2020).

6.2.2 Sex differences in MVPA

Contrary to research conducted prior to the COVID-19 pandemic where sex differences were identified (Fairclough et al., 2015; Guthold et al., 2020), there was no significant sex difference in time children and adolescent's spent in MVPA during the winter lockdown (first time-point). The absence of sex differences during lockdown can likely be explained, at least in part, by the COVID-19 restrictions which prevented organised sport participation (Dunton et al., 2020). Previous research identified that girls engage in organised sport at a substantially lower rate than boys (Slater & Tiggemann, 2011). It is therefore anticipated that the lockdown environment of decreased sports activity (Schmidt et al., 2020) and limited free play and walking opportunities impacted girls PA less than boys (Dunton et al., 2020). This is in agreement with other studies, such as Elnaggar et al. (2020) who reported a greater drop in boys PA levels compared to girls in Saudi Arabia during the pandemic when organised sport

was banned. Girls consistently accrue less PA than boys (Cla, 2018; Cooper et al., 2015; Mayo et al., 2020) with their PA levels and sport participation significantly declining during adolescence, with 64% of girls quitting sport by 16-17 years old (Women in Sport, 2016). As such, policies and interventions should target girls to aim to increase their participation in sport because of the wide range of physical, mental and social health benefits (Eime et al., 2013) and their total PA time. Further, people who maintain sport participation throughout childhood report a higher health-related quality of life, compared to those who do not engage in sport (Vella et al., 2014), and are more likely to be active as adults (Dohle & Wansink, 2013; Richards et al., 2007).

The significant difference in boys and girls MVPA was re-established after lockdown, with the difference in the percentage of boys (43%) and girls (23%) meeting the UK government guidelines widening (first time-point; boys: 16%, girls: 13%). At the second time-point, boys accrued an average of 10 minutes more MVPA than girls, potentially due to the re-opening of non-essential services, such as sports clubs and leisure facilities. The re-opening of these facilities meant children and adolescents could re-engage in PA during school and sport, both within and outside of school, which are periods where boys are significantly more active than girls (Saint-Maurice et al., 2018). This therefore supports the notion that the school environment is more conducive to boys being physically active than girls (Hurter et al., 2022).

The return of organised sport could have been an opportunity by the Welsh Government and sporting bodies to engage previously disengaged populations, such as girls, to engage in organised sport. The Welsh Government and other sporting governing bodies introduced policies and campaigns to encourage girls to engage in sport, both before the COVID-19 pandemic and after. One campaign in Wales is “#FelMerch” which aims to inspire, support, and empower young women and girls to keep active and break down the barriers that prevent women/girls from participating in sport (Urdd, 2022). During the COVID-19 lockdowns, many children and adolescent’s reported missing their friends (Crawley et al., 2020; Holt & Murray, 2022; Orben et al., 2020); sport could have been promoted to girls by highlighting the social qualities of participating (Cardinal, 2020), especially as even after lockdown there were still restrictions on the number of people one could socialise with, and schools had class bubbles in place. The limited interventions meant that, similar to before the COVID-19 pandemic, boys

engaged in sport at a significantly higher rate, with the COVID-19 pandemic widening the inequalities in sport (Sport Wales, 2020). The low percentage of children and adolescent's meeting the UK PA guidelines means that, as with before the COVID-19 pandemic, PA interventions should continue to target both girls and boys of all ages. The interventions that aimed at increasing PA should differ among boys and girls as girls engage in less organised sport, receive less social support to engage in PA and are perceived to enjoy PE less than boys (Cowley et al., 2021; Telford et al., 2016).

6.2 Changes in LPA

Consistent with the impact of time on MVPA, LPA significantly increased by an average of 38.2 ± 3.5 minutes at the first time-point to 170.9 ± 72.4 minutes at the second time-point with the easing of restrictions, e.g. the return to face-to-face teaching. There are limited studies on children and adolescent's time spent in LPA globally this could partly be due to children and adolescent's tending to be less accurate in recalling LPA than MVPA due to the more unstructured nature of LPA (Finger et al., 2015; Fuezeki et al., 2017a). Prior to the COVID-19 pandemic, a large study in UK adolescents reported that they engage in an average of 516.5 minutes of LPA (Collings et al., 2014). Another UK-wide study of 7-year-old children that utilised accelerometers reported that boys engaged in an average of 282.8 minutes and girls an average of 279.46 minutes of LPA (Ahn et al., 2018). In contrast to both of these UK studies, children and adolescents engaged in significantly less LPA, irrespective of time-point, engaging in a maximum of 182.8 ± 60.0 minutes. These stark differences in reported LPA can be explained by the methodological differences between the studies. Both Ahn et al. (2018) and Collings et al. (2014) used a significantly longer epoch length of 30s or 15s, respectively, compared to 1s for this study. Longer epoch lengths reduce the likelihood of accurately capturing children and adolescent's PA due to the sporadic nature of their PA, resulting in MPVA being misclassified as LPA (Fabre et al., 2020). This, therefore, may explain the discrepancies with the findings of Ahn et al. (2018) and Collings et al. (2014) . Moreover, the use of different cut-points will have further compounded the issue, with the intensity of children and adolescent's PA being classified differently in each study, precluding inter-study comparisons. The change in LPA prior to the COVID-19 pandemic to after cannot therefore be determined.

LPA significantly increased over time, relative to first time-point (lockdown). At the fourth time-point, children and adolescents, on average, were engaging in 182.8 ± 60.0 minutes of LPA, 50.67 minutes (CI: 33.52 to 67.82) more than during the lockdown (first time-point). Between the third (October 2021) and fourth time-points (March 2022), there was no significant difference in LPA. This could be, at least in part, due to all COVID-19 restrictions being removed in August 2021, meaning children and adolescents had been offered the opportunity to re-engage or had re-engaged in all the LPA they wished to.

Currently, there is limited understanding of the health benefits of LPA in children and adolescent's; research predominantly focuses on the adult population regarding LPA (Fuezeki et al., 2017a). As such, there are no specific LPA recommendations for LPA for children and adolescent's in the UK (Gibson-Moore, 2019). This is despite LPA having been shown to have huge potential for increasing total PA and energy expenditure, given it is more accessible and feasible to accrue for longer periods of time than MVPA (Amagasa et al., 2017; Donahoo et al., 2004; McGregor et al., 2021). Therefore, future research should investigate the health benefits of LPA in children and adolescents to help inform future PA guidelines of the recommended volume to achieve benefits.

6.3 Change in sedentary time

Children and adolescent's sedentary time was at its highest during lockdown (first time-point), with an average of 844.4 ± 201.8 minutes. During this time schools were closed with only vulnerable and key workers' children allowed to attend school in person. The closure of schools and reduced opportunities to be physically active could explain the increase in sedentary time, especially as children and adolescents have been shown to be more sedentary outside of school (Arundell et al., 2016; Lubasch et al., 2020). This, combined with children participating in remote learning, a predominantly sedentary activity, created an environment that facilitated sedentary behaviour (Stockwell et al., 2021). Time spent sedentary is substantially higher than figures reported prior to the COVID-19 pandemic. For example, research using the International Children's Accelerometery Database (ICAD), comprising of eight studies across five countries, including three studies conducted in the UK, identified that children and adolescent's aged 4-17 years-old accrued a total of 247-387 minutes per day being sedentary (Van Ekris et al., 2020). However, it is pertinent to note that

the ICAD used different methods, monitors and data processing to the present study, thereby precluding inter-study and pre- and post-COVID-19 pandemic comparisons. Moreover, all the studies included in Van Ekris et al. (2020) were reintegrated to a 60s epoch, which can significantly influence PA classification for children and adolescent's due to the sporadic nature of their activity (Fröberg et al., 2017). Longer epoch lengths, such as 60s, have been reported to under-estimate sedentary time, with shorter epoch lengths, such as 1s as used in this study, being more accurate to capture PA in children and adolescent's (Aadland et al., 2018). Furthermore, the database used counts per minute (CPM) to classify activity intensity specifically less than 100 CPM for sedentary time (Van Ekris et al., 2020). The use of CPM means it is difficult to make comparisons between different brands (Hildebrand et al., 2014). The use of raw acceleration thresholds, used in this study, allowed for greater control over processing the data and future inter-brand and -study comparisons.

Although a direct comparison between children's and adolescents' sedentary time before and during the COVID-19 pandemic cannot be made, it is likely that children and adolescent's sedentary time increased due to the environment the COVID-19-related restrictions created. The expected increase in sedentary time is evident in a cross-sectional accelerometer-based study (Salway et al., 2022). The study of children and adolescent's aged 10-11 years-old in England measured PA metrics pre (2018) and post COVID-19 lockdown (May 2021) from the same schools. Indeed, Salway et al. (2022) reported that children's sedentary time increased by 25.4 minutes (95% CI: 15.8 to 35.0) and 14.0 min (95% CI: 1.5 to 26.5) for week and weekend days, respectively, after the COVID-19 lockdown compared to before. Salway et al. (2022) measured sedentary time via accelerometers, rather than relying on retrospective self-report measures; this strengthens the accuracy and provides confidence in the reported increase in sedentary time. During the post COVID-19 lockdown period (May 2021), England and Wales had similar COVID-19 restrictions, with all children and adolescent's being back in school. It could therefore be suggested that such findings could be consistent to those in Wales.

Sedentary time significantly increased with age during the lockdown (first time-point), with children and adolescents in Years 10-13 accruing an average of 91.6 minutes ± 23.3 more sedentary time than primary school children in Years 4-6. This finding is in agreement with

research conducted before the COVID-19 pandemic (Janssen et al., 2016; Tanaka et al., 2014). Indeed, Van Ekris et al. (2020) reported that total sedentary time increased, on average, by 21.4 minutes per day each year. A review of environmental correlates identified that being in an indoor location was associated with more LPA and more sedentary behaviour in adolescents aged 12-17 years (Prince et al., 2019). This is particularly important given that people were asked to remain in their homes during lockdown, resulting in additional sedentary behaviour (Moore et al., 2020). As such, there needs to be a focus on increasing PA in indoor locations and encouraging people outdoor as much as possible such as through active play or outdoor education projects (Bento & Dias, 2017), albeit within the restraints should further lockdowns occur.

Throughout the study, there was no statistically significant sex difference in children and adolescent's sedentary time. This is in contrast to findings reported before the COVID-19 pandemic but in agreement with a meta-analysis of the impact of the COVID-19 pandemic on sedentary time (Runacres et al., 2021). Prior to the COVID-19 pandemic, it was consistently reported that girls were more sedentary than boys (Carson, Tremblay, et al., 2016; Prince et al., 2020; Steene-Johannessen et al., 2020). The lack of sex difference during the COVID-19 pandemic may suggest that the pandemic had a greater impact on sedentary time in boys than girls (Runacres et al., 2021). The absence can, in part, be explained by children and adolescent's type of sedentary behaviour, boys consistently report increased screen time compared to girls (Kallio et al., 2020), the COVID-19 environment, in particular lockdown, likely exaggerated screen time. The absence of a sex difference at the third (October 2021) and fourth (March 2022) time-points is somewhat surprising given that all COVID-19 restrictions had been removed. Thus, suggesting that the COVID-19 pandemic had sustained implications on children and adolescent's sedentary time. Further research is needed to identify the COVID-19 related-restrictions that influenced the absence of a sex difference in children and adolescent's sedentary time.

As with other PA metrics, sedentary time significantly decreased with the re-opening of society until the fourth time-point. The greatest decrease in sedentary time during the study occurred between the second (May 2021) and third time-point (October 2022), where sedentary time decreased by 74.7 ± 10.8 to 729.3 ± 138.5 minutes, the lowest throughout the

study. This decrease coincided with the removal of COVID-19 restrictions in schools, such as class bubbles and social distancing.

Sedentary time increased by 74.7 minutes after the third time-point (October 2022) to an average of 739.3 minutes, despite all COVID-19 restrictions having been lifted. Despite the increase in total sedentary time, the time accrued was still below (65.7 minutes) that found during lockdown. The increase in sedentary levels at the fourth time-point is somewhat surprising given that no COVID-19 restrictions were in place. The increase could potentially be explained through the period of adjustment in schools, and their initial emphasis on time and space for play, exercise, extra-curricular activities and socialising (Rainer, 2020). This, coupled with the initial novelty of no COVID-19 restrictions for children and adolescents at the third time-point (October 2021), the first time since the start of the COVID-19 pandemic, possibly meant children and adolescents engaged in more activities than before the pandemic. Once the emphasis on play and exercise ended and the novelty of the no-COVID-19-restrictions had ended, it could be postulated that children and adolescents began to reverted to pre-pandemic habits. Interventions should be implemented to prevent the further increase of sedentary time and aim to reduce the high amounts reported before and during the COVID-19 pandemic. School is a key setting to target sedentary time as children and adolescent's spend 57% of their waking time at school, with around 65% of this time being sedentary (Van Stralen et al., 2014; Yıldırım et al., 2011). School-based interventions have been shown to be effective in preventing excessive sedentary time and unfavourable health outcomes in children and adolescent's (van Grieken et al., 2012). A systematic review identified that school-based interventions are effective in reducing sedentary time, with replacing all classroom standardised desks and chairs with sit-to-stand desks being the most effective in reducing children and adolescent's device-assessed sedentary time (Hegarty et al., 2016). This is coupled with the British Heart Foundation (2012) emphasising the need for policy makers to encourage schools to reduce extended periods of sitting for pupils.

Sedentary behaviour has been identified as a risk factor for health in children and adolescent's (Carson, Hunter, et al., 2016) regardless of PA patterns (Mitchell & Byun, 2014; Salmon et al., 2011). The high sedentary time reported throughout the present study is likely to have severe health implications on children and adolescents. Research has shown

that high sedentary time in children and adolescents is associated with unfavourable health indicators including, but not limited to, lower physical fitness (Gray et al., 2015), higher fatness (Must & Tybor, 2005), clustered cardiometabolic risk scores (Atkin et al., 2013) and lower self-esteem (Suchert et al., 2015). Currently, there is some evidence that excessive sedentary time is associated with mental illness and poorer cognitive function (Falck et al., 2017; Liu et al., 2016). Therefore, it is essential that interventions seek to reduce children and adolescents sedentary time to prevent the negative health implications, especially as sedentary time tracks from childhood into adulthood (Li et al., 2022).

6.4 Change in children and adolescent's well-being

Children's and adolescents' average SCWBS well-being score was the same (43) during lockdown (first time-point) and at the second time-point. The average SCWBS score at the first and second time-point was lower by one point when compared to pre-pandemic mean score of 44 for children in Scotland aged 8-15 years (Liddle & Carter, 2015). This comparison is limited due to the pre-pandemic score being from a different population; children and adolescents have previously been reported to have higher well-being in Scotland than Wales (Pedace, 2008). This, coupled with the pre-pandemic scores only being reported for children and adolescents up to 15 years old, means the change in children and adolescent's well-being from before to during COVID-19 cannot be determined. However, the HAPPEN survey in Wales reported an improvement in children and adolescent's well-being during the initial school closures compared with 2019 (James, Marchant, et al., 2021a). The HAPPEN survey only measured well-being during the early stages of the pandemic and therefore does not provide an overall reflection of children and adolescent's well-being throughout the COVID-19 pandemic. The present study's numerous time-points throughout the COVID-19 pandemic provide an overview of children and adolescent's well-being across the pandemic, as well as the effect of different COVID-19 restrictions on their well-being. As such, COVID-19 restrictions appeared to have a negative impact on children's and adolescent's well-being, with it being the lowest during lockdown (first time-point) and the second time-point (May 2021). Low well-being in children and adolescents during COVID-19 is reflected in a survey of 23,000 children and adolescents in Wales, which reported that 16% of secondary-school pupils described feeling sad most of the time during lockdown (Child Poverty Action Group,

2020). COVID-19 restrictions and the unknown of the ever-changing environment placed an extremely high mental burden on people (Ogden, 2020; Shevlin et al., 2020). The COVID-19 restrictions affected all key domains that are important to children and adolescent's well-being laid out by the Children's Society, such as school, friends and choice (Pople et al., 2014), with PA being one of the few reliefs for children from the stressors of the pandemic. The impact to the friends domain is evident in a survey conducted in the UK in 2020 which reported that 80% and 60% of primary and secondary school pupils, respectively, said they were most looking forward to seeing their friends when they returned to school (Child Poverty Action Group, 2020). The disruption in children's routines from school closures and social distancing was detrimental to well-being (Lee, 2020; McArthur et al., 2021), with COVID-19 restrictions appearing to negatively affect children and adolescent's well-being in Wales.

Compared to PA levels, well-being did not immediately recover after the lockdown and the easing of COVID-19 restrictions at the second time-point. Children's and adolescents' well-being only significantly increased from the third time-point onwards once all COVID-19 restrictions had been lifted. Children's and adolescents' well-being was at its highest at the fourth time-point (49.6), with the greatest increase (4.9 ± 1.8) occurring between the third and fourth time-point. The delayed increase in well-being could potentially be explained through the 'period of adjustment' for schools to manage the emotional and mental distress of pupils (Rainer, 2020). Children and adolescents require consistent support from sensitive caregivers (e.g. parents or teachers) and a safe physical and emotional environment with routine for their well-being to flourish (Bartlett et al., 2020). Therefore, children were expected to take some time to reintegrate back into school life and to re-establish friendships and routine before their well-being increased (Rainer, 2020). The national children's bureau further advised that schools should be allowed flexibility in the curriculum so alongside pupils catching up academically there is an emphasis on time and space for play, exercise, extra-curricular activities and socialising (Rainer, 2020). To aid this period of adjustment and recovery, the Welsh Government provided additional funding of £9.4 million in February 2021 (after the first time-point) to improve the emotional and mental health support in schools and for Child and Adolescent Mental Health Services for more intensive support (Parliament, 2021). Once COVID-19 restrictions had been removed and children had a period of

adjustment, well-being steadily recovered and increased, to above the mean reported prior to the pandemic (Liddle & Carter, 2015).

6.4.1 The relationship between well-being and MVPA

Research prior to the pandemic consistently reported that PA had a positive relationship with children's and adolescents' well-being across all PA settings and intensities (Downward & Dawson, 2016; Pawlowski et al., 2011). In line with this, there was a significant positive relationship between MVPA and well-being in the present study, with children and adolescents who engaged in more MVPA demonstrating higher well-being. This is in agreement with research conducted during the pandemic where parent's perceived PA, in particular the amount of time playing outside (e.g. riding bikes, walking with the family), was shown to have the greatest impact on mental well-being during COVID-19 restrictions (Gilbert et al., 2021). In contrast to the present findings, research conducted prior to the COVID-19 pandemic only reported a weak association between PA and well-being (Buecker et al., 2021). Indeed, it is pertinent to note that, although there was a positive relationship between PA and well-being, this was for the whole period of the study. Therefore, the effect of different COVID-19 restrictions on the relationship between PA and well-being cannot be determined. It could be postulated that the strictness of the COVID-19 restrictions influenced the relationship between PA and well-being. This could be explained using the 11 domains The Children's Society (2021) identified as being important to children's and adolescents' well-being. PA was one domain that children and adolescents were able to engage in throughout the COVID-19 pandemic, albeit limited at different points this could have created a greater reliance on PA for children's and adolescents' well-being as other domains were removed or severely limited.

6.5 Strengths and limitations

This study had several strengths. Specifically, it is one of the only studies to utilise device-based PA assessments in children and adolescents at multiple time-points during the COVID-19 pandemic, including a COVID-19 lockdown in Wales. The wide age-range of participants within the study enabled inter-age comparisons throughout the pandemic, including between primary and secondary school children. The study also had a large sample size that was

country-specific, with the sub-sample participants stratified by age, sex and socio-economic status (SES). Nevertheless, the study is not without its limitations. The remote implementation of the questionnaire either precluded those with a reading age less than eight years from participating or may have led to misinterpretation for children with learning difficulties or with a lower reading then biological age, which can be minimised if children and adolescents had support completing the questionnaire in the school environment. The two methods of recruitment through schools and twitter may have led to a self-selection bias and the inclusion of those who engage in higher levels of PA. It is also important to note that at the fourth time-point less than 800 accelerometers were sent out, due to participants withdrawing, not consenting to wear the accelerometer again, or not returning the accelerometer at previous time-points. The majority of children who did not consent to wear the accelerometer again cited that they found it uncomfortable to wear. It is noteworthy that the dropout rate was particularly high in secondary school children, which led to a smaller proportion of secondary school children within the sub-sample. Similarly at the third and fourth time-point, there was a significantly higher proportion of children and adolescents from the least deprived SES background, this difference was not controlled for in the LMM. The SES comparisons made at the third and fourth time-point therefore need to be interpreted with caution as the least deprived SES group were overrepresented. As with other research, the over representation of those from the least deprived SES group was partly due to the high dropout rate and lower participation of those from the most deprived SES group from the start of the study. These limitations are commonly reported in longitudinal observational studies (Caruana et al., 2015) and were attempted to be mitigated, where possible, for example by replacing withdrawn participants with those with similar demographics and using LMM which account for missing data. Despite these attempts, the withdrawal rate across the study meant the SES demographics of the sample did change, so the reported change should be interpretated with caution.

7.0 Conclusion

COVID-19 restrictions were detrimental to children's overall PA levels and well-being, with lockdown having the most severe effect. During the easing, and subsequent removal, of COVID-19 restrictions, children's and adolescents' PA and well-being increased, with restrictions appearing to only affect children's and adolescents' PA whilst they were implemented. PA levels in primary school children and boys, irrespective of age, were more negatively affected by the lockdown than secondary school children and respectively aged girls, though COVID-19 lockdown did not appear to have a long-term effect on boys or primary school children's PA. In accord with research prior to the pandemic, age was associated with overall PA levels, with a higher percentage of boys, than girls, meeting the UK government PA guidelines (Gibson-Moore, 2019). This means that secondary school girls remain a demographic group that should be targeted with PA interventions. During the ever-changing environment that COVID-19 restrictions created, there was a positive relationship between MVPA and well-being, with children who accumulated more MVPA having a higher well-being score. Therefore, PA should continue to be promoted as a means to aid children's well-being and alleviate the ever-increasing prevalence of mental illness, post COVID-19. Despite children's and adolescents' PA and well-being levels increasing as COVID-19 restrictions eased, levels remain worryingly low, and the longer-term effects of the significant decline during the COVID-19 pandemic remains to be elucidated.

Appendices

APPENDIX A: Parental consent at first time-point

Thank you for taking the time to read this. We would like to invite your child to take part in a survey. It involves completing an online survey and some children will be asked to wear a monitor (like a FitBit) on their wrist for a week. The study will give the Welsh Government insight into how COVID-19 has affected children's physical activity levels and their mental health and wellbeing. It will provide the government with important information on how to deal with COVID-19 for children going forward. Information about the study can be found *here.* The information sheet provides details of the study, data protection, anonymity, confidentiality as well as our contact details in case you have any questions.

If you agree for your child to take part in our study, please answer the following questions:

1. I confirm that I have read and understood the information sheet for the above survey and have had the opportunity to ask questions.

YES

2. I understand that my child's participation is voluntary and that they are free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected.

YES

3. I understand that sections of any data obtained may be looked at by responsible individuals from Swansea University or from regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to these records.

YES

4. I understand that data my child provides may be used in reports and academic publications in an anonymous manner.

YES

5. I agree for my child to take part in the above study.

YES

6. Please type your name out to verify your consent.

Note: If you have more than one child eligible for the study (between 8 and 16 years old), please complete a separate form for each child.

7. What is your child's date of birth?

8. Please type the full name of the school your child attends.

9. What is your postcode?

10. Are you happy for your child to be randomly selected to wear an activity monitor? This will be posted to you in January 2021, for them to wear on their wrist for one week, with a pre-stamped return envelope. We will ask them to wear it again a few months later.

YES / NO

10.a) Please provide your full address where we can send the monitor to.

11. Please provide a phone number if you'd prefer us to call you regarding your child wearing an activity monitor. *(optional)*

12. Please provide an email address for us to send the survey link for your child to participate. It will only be used for the purpose of this study.

If you have more than one child but wish to use the same email address for all, that is fine. Remember to complete a separate form for each child. We will send you one email per child, with their birthday in the message, so you will know which child should complete which survey (primary school surveys are different from secondary school surveys).

In the second week of January 2021, we will send the link to the children's survey to the email address you provided. If your child is randomly selected and you have agreed, we will send the activity monitor to your home address (also in January). Thank you for allowing your child(ren) to participate in our study. Your child(ren) will be giving important information that could dramatically change the way the government deals with COVID-19 for children going forwards.

APPENDIX B: Participant's assent and questionnaire at first time-point

Thank you for reading this. We would like you to take part in our project. But before you do – It's important you know what the project is and what you have to do. *Click here* to read more about the project. To take part, we will ask you to answer a few questions on an online form, so you can tell us how you are feeling. If you're lucky, you may also be selected to wear a cool wristband that measures how much you move. It's a little bit like a FitBit, and we would ask you to wear it for one week. You do not have to wear this though if you do not want to. We will ask you to do this twice over the next few months. Remember, no one will know what you've said on the form, and no one will know how active you've been, because we will give you a number instead of your name. It is totally up to you if you want to take part.

Arolwg y plant

Diolch am ddarllen hwn. Hoffen ni ichi gymryd rhan yn ein prosiect. Ond cyn ichi wneud hynny - mae'n bwysig eich bod yn gwybod beth yw'r prosiect a beth mae'n rhaid ichi ei wneud. *Cliciwch yma* i ddarllen mwy am y prosiect. Er mwyn cymryd rhan, byddwn ni'n gofyn ichi ateb ambell i gwestiwn ar ffurflen ar-lein fel y gallwch chi ddweud wrthon ni sut rydych chi'n teimlo. Os byddwch chi'n lwcus, byddwch chi'n cael eich dewis i wisgo band llawes gwych sy'n mesur faint rydych chi'n symud. Mae ychydig bach yn debyg i FitBit, a hoffen ni ichi ei wisgo am wythnos. Ond, fydd dim rhaid ichi wisgo hwn os nad ydych chi'n eisiau gwneud hynny. Byddwn ni'n gofyn ichi wneud hyn ddwywaith dros y misoedd nesaf. Cofiwch, fydd neb yn gwybod beth rydych chi wedi'i ddweud ar y ffurflen, a fydd neb yn gwybod pa mor actif rydych chi wedi bod gan y byddwn ni'n rhoi rhif ichi yn lle eich enw. Chi yn unig fydd yn penderfynu a ydych chi eisiau cymryd rhan.

Please answer the following questions:
Page 1: Consent

1. I have read and understood the information sheet for the above project and have asked questions if I have any.
   YES

Atebwch y cwestiynau canlynol:
Tudalen 1: Cydsyniad

1. Rwy wedi darllen a deall y daflen wybodaeth am y prosiect uchod ac rwy wedi gofyn cwestiynau posibl a oedd gen i.
   YDW

2. I understand that I can choose not to take part in the project if I don't want to, and that I am free to stop taking part at any time.
   YES

2. Rwy'n deall y galla i ddewis peidio â chymryd rhan yn y prosiect os nad ydw i eisiau gwneud hynny, ac y galla i beidio â chymryd rhan ar unrhyw adeg.

YDW

3. I understand that parts of my answers may be looked at by responsible people from Swansea University or expert groups where it is relevant.
   YES

3. Rwy'n deall ei bod yn bosibl y bydd pobl gyfrifol o Brifysgol Abertawe, neu grwpiau arbenigol pan fydd hyn yn berthnasol, yn edrych ar rannau o'm hatebion.
   YDW

4. I understand that answers I give may be used in reports and academic publications in an anonymous manner (that means it won't show my name).
   YES

4. Rwy'n deall ei bod yn bosibl y bydd atebion y bydda i'n eu rhoi'n cael eu defnyddio mewn adroddiadau a chyhoeddiadau academaidd mewn ffordd ddienw (sy'n golygu na fydd yn dangos fy enw).
   YDW

   If you get selected, are you happy to wear an activity monitor for one week?
   Yes / No
   Os cewch eich dewis, a ydych yn hapus i wisgo monitor gweithgaredd am wythnos?
   YDW/ NAC YDW

5. I agree to take part in the study.
   YES / NO
5. Rwy'n cytuno i gymryd rhan yn yr astudiaeth.
   YDW / NAC YDW

Page 2: Describing yourself

6. I am a: boy / girl

Tudalen 2: Disgrifio eich hun

6. Bachgen / merch **ydw i**:

7. **My age is:** 7 years / 8 years / 9 years / 10 years / 11 years / 12 years / 13 years / 14 years / 15 years / 16 years / 17 years

7. Fy oedran i yw: 7 mlwydd / 8 mlwydd / 9 mlwydd / 10 mlwydd / 11 mlwydd / 12 mlwydd / 13 mlwydd / 14 mlwydd / 15 mlwydd / 16 mlwydd

8. **Over the past 7 days, I have been:** in school on weekdays / at home during lockdown (home learning) / at home self-isolating / other: …….
   8a) Please explain why you chose 'other'.

8. Yn ystod y 7 niwrnod diwethaf, dw i wedi bod : Yn yr ysgol ar ddyddiau'r wythnos / Gartref yn ystod cyfnod y cyfyngiadau symud / Hunan-ynysu gartref / Arall
8a)

Page 3: Physical Activity questions

We are trying to find out about your level of physical activity from the last 7 days (in the last week). This includes activities like sports and exercise, games or dance that make you sweat, breathe hard, or make your legs feel tired. There are no right or wrong answers, and this is not a test. We know you may not be in school at the moment and may not be doing the same activities as usual. This is fine, just answer all the questions as honestly as you can – this is very important.

Tudalen 3: Cwestiynau am weithgarwch corfforol

Rydyn ni'n ceisio cael gwybod am lefel eich gweithgarwch corfforol yn ystod y 7 niwrnod diwethaf (yn ystod yr wythnos diwethaf). Mae hyn yn cynnwys gweithgareddau megis chwaraeon ac ymarfer corff, gemau neu ddawns sy'n achosi i chi chwysu, anadlu'n galed, neu'n achosi i'ch coesau deimlo'n flinedig. Does dim atebion cywir neu anghywir, ac nid prawf yw hwn. Rydyn ni'n gwybod nad ydych chi yn yr ysgol ar hyn o bryd ac nad ydych chi'n gwneud yr un gweithgareddau ag y byddwch chi'n eu gwneud fel arfer. Felly atebwch bob un o'r cwestiynau mor onest ag y gallwch chi – mae hyn yn bwysig iawn.

In your spare time (when you are not in school or busy with home learning) over the past 7 days (last week), have you done any of the following activities? If yes, how many times? (Tick one box per row.)

	No	1-2 times	3-4 times	5-6 times	7 times or more
9. Skipping					
Tag					
Walking for exercise					
10. Cycling					
Gymnastics					
Dance					
11. Swimming					
Skateboarding					
Rollerblading					
12. Jogging or running					
Football					
Rugby					
13. Tennis					
Cricket					
Athletics					
14. Badminton					
Volleyball					
Hockey					
15.Basketball					
Netball					
Martial Arts					
16. Played outside with friends					
Played outside with family					
Played on playground equipment					

Yn ystod eich amser hamdden (pan na fyddwch chi yn yr ysgol neu'n brysur gyda'ch dysgu gartref) yn ystod y 7 niwrnod diwethaf (yr wythnos diwethaf), ydych chi wedi gwneud un o'r gweithgareddau dilynol? Os ydych chi, sawl gwaith? (Ticiwch un blwch fesul rhes.)

	Dim Unwaith	1-2 waith	3-4 gwaith	5-6 gwaith	7 gwaith neu fwy
9. Sgipio					
Chwarae tic					
Cerdded er mwyn ymarfer corff					
10. Seiclo					
Gymnasteg					

Dawnsio					
11. Nofio					
Sgrialu					
Llafnrolio					
12. Loncian neu redeg					
Pêl-droed					
Rygbi					
13. Tenis					
Criced					
Athletau					
14. Badminton					
Pêl foli					
Hoci					
15.Pêl fasged					
Pêl rwyd					
Crefft Ymladd					
16. Chwarae y tu allan gyda ffrindiau					
Chwarae y tu allan gyda'r teulu					
Chwarae ar gyfarpar y cwrt chwarae					

17. Did you do anything else in your spare time this past week to keep active?

Yes / No

17.a) What sports / activities did you do?

17. b) How many times over the last 7 days?

1-2 times / 3-4 times / 5-6 times / More than 7 times

17. Wnaethoch chi unrhyw beth arall yn ystod eich amser hamdden yn ystod yr wythnos diwethaf hon i gadw'n actif?

Do / Naddo

17.a) Pa chwaraeon / weithgareddau wnaethoch chi?

17. b) Sawl gwaith yn ystod y 7 niwrnod diwethaf?

1-2 waith / 3-4 gwaith / 5-6 gwaith / Mwy na 7 gwaith

18. In the last 7 days, during your physical education (PE) classes (at school or for home learning), how often were you very active (playing hard, running, jumping, throwing, etc.)?

I didn't have PE lessons

Hardly ever

Sometimes

Quite often

Always

18. Yn ystod y 7 niwrnod diwethaf, yn ystod eich dosbarthiadau addysg gorfforol (yn yr ysgol neu yn achos dysgu gartref), pa mor aml roeddech chi'n actif iawn (chwarae'n galed, rhedeg, neidio, taflu ac ati.)?
Doedd dim gwersi addysg gorfforol gen i
Bron byth

Weithiau

Yn eithaf aml

Bob amser

19. In the last 7 days, what did you do most of the time *during school break time*? For those doing home learning, what did you do *while taking a break from home learning*?

Sat down (talking, reading, watching TV, playing video games etc.)

Stood around or walked around

Ran or played a little bit

Ran around and played quite a bit

Ran and played hard most of the time

19. Yn ystod y 7 niwrnod diwethaf, beth wnaethoch chi y rhan fwyaf o'r amser *yn ystod amser chwarae yn yr ysgol*? I'r rheiny ohonoch chi sy'n dysgu gartref, beth wnaethoch chi *wrth gymryd seibiant oddi wrth eich dysgu gartref*?

Eistedd (siarad, darllen, gwylio teledu, chwarae gemau fideo ac ati)
Sefyll neu gerdded

Rhedeg neu chwarae ychydig

Rhedeg a chwarae eithaf tipyn

Rhedeg a chwarae'n galed y rhan fwyaf o'r amser

20. In the last 7 days, what did you normally do *at lunch time* (besides eating lunch)?

Sat down (talking, reading, doing schoolwork, watching TV, playing video games etc.)

Stood around or walked around

Ran or played a little bit

Ran around and played quite a bit

Ran and played hard most of the time

20. Yn ystod y 7 niwrnod diwethaf, beth wnaethoch chi fel arfer *amser cinio* (ar wahân i fwyta eich cinio)?

Eistedd (siarad, darllen, gwylio teledu, chwarae gemau fideo ac ati)
Sefyll neu gerdded

Rhedeg neu chwarae ychydig

Rhedeg a chwarae eithaf tipyn

Rhedeg a chwarae'n galed y rhan fwyaf o'r amser

21. In the last 7 days, on how many days *right after you have finished school / home learning*, did you do sports, dance, or play games in which you were very active?

None

1 time last week

2 or 3 times last week

4 times last week

5 times last week

21. Yn ystod y 7 niwrnod diwethaf, sawl diwrnod *yn syth ar ôl ichi orffen yn yr ysgol/ gyda'ch dysgu gartref* wnaethoch chi chwaraeon, dawnsio neu chwarae gemau yr oeddech chi'n actif iawn ynddyn nhw?

Dim un diwrnod

Unwaith yr wythnos diwethaf

2 neu 3 gwaith yr wythnos diwethaf

4 gwaith yr wythnos diwethaf

5 gwaith yr wythnos diwethaf

22. In the last 7 days, on how many *evenings* did you do exercise, sports, dance, or play games in which you were very active?

None

1 time last week

2 or 3 times last week

4 or 5 last week

6 or 7 times last week

22. Yn ystod y 7 niwrnod diwethaf, sawl *noswaith* wnaethoch chi chwaraeon, dawnsio neu chwarae gemau yr oeddech chi'n actif iawn ynddyn nhw?

Dim un noswaith

Unwaith yr wythnos diwethaf

2 neu 3 gwaith yr wythnos diwethaf

4 neu 5 gwaith yr wythnos diwethaf

6 neu 7 gwaith yr wythnos diwethaf

23. *Last weekend*, how many times did you do exercise, sports, dance, or play games in which you were very active?

None

1 time

2 — 3 times

4 — 5 times

6 or more times

23. *Yr wythnos diwethaf*, sawl gwaith wnaethoch chi chwaraeon, dawnsio neu chwarae gemau yr oeddech chi'n actif iawn ynddyn nhw?

Dim unwaith

Unwaith

2 — 3 gwaith

4 — 5 gwaith

6 neu fwy o weithiau

24. Which *one* of the following describes you best for the last 7 days? Read *all five* statements before deciding on the *one* answer that describes you.

All or most of my free time was spent doing things that involve little physical effort

I sometimes (1 — 2 times last week) did physical things in my free time (like played sports, running, cycling)

I often (3 — 4 times last week) did physical things in my free time

I quite often (5 — 6 times last week) did physical things in my free time

I very often (7 or more times last week) did physical things in my free time

24. Pa *un* o'r canlynol sy'n eich disgrifio chi orau yn ystod y 7 niwrnod diwethaf? Darllenwch *bob un o'r pum* datganiad cyn penderfynu ar yr *un* ateb sy'ch eich disgrifio chi.

Treuliais i'r cyfan neu'r rhan fwyaf o'm hamser hamdden yn gwneud pethau sy'n golygu ychydig o ymdrech gorfforol

Gwnes i bethau corfforol weithiau (unwaith neu ddwywaith yr wythnos diwethaf) yn ystod fy amser hamdden (megis gwneud chwaraeon, rhedeg, seiclo)

Gwnes i bethau corfforol yn aml (3 — 4 gwaith yr wythnos diwethaf) yn ystod fy amser hamdden

Gwnes i bethau corfforol yn eithaf aml (5 — 6 gwaith yr wythnos diwethaf) yn ystod fy amser hamdden

Gwnes i bethau corfforol yn aml iawn (7 neu fwy o weithiau'r wythnos diwethaf) yn ystod fy amser hamdden

25. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

	None	Little bit	Medium	Often	Very often
Monday					
Tuesday					
Wednesday					
Thursday					
Friday					
Saturday					
Sunday					

25. Nodwch pa mor aml y buoch chi'n gwneud gweithgarwch corfforol (megis gwneud chwaraeon, gemau, dawnsio neu weithgarwch corfforol arall) ar gyfer pob diwrnod yr wythnos diwethaf.

	Dim byd	Ychydig	Rhywfaint	Yn aml	Yn aml iawn
Dydd Llun					
Dydd Mawrth					
Dydd Mercher					
Dydd Iau					
Dydd Gwener					
Dydd Sadwrn					
Dydd Sul					

Page 4: Questions about your feelings

Here are some statements or descriptions about how you might have been feeling or thinking about things over the past couple of weeks. For each one please put a tick in the box which best describes your thoughts and feelings. There are not right or wrong answers.

Tudalen 4: Cwestiynau am eich teimladau

Dyma rai datganiadau neu ddisgrifiadau am sut y gallech chi fod wedi bod yn teimlo neu'n meddwl am bethau yn ystod yr ychydig wythnosau diwethaf. Ar gyfer pob un ticiwch y blwch sy'n disgrifio'ch meddyliau a'ch teimladau orau. Does dim atebion cywir neu anghywir.

	Statement	Never	Not much of the time	Some of the time	Quite a lot of the time	All of the time
26	I think good things will happen in my life					
	I have always told the truth					
	I've been able to make choices easily					
27	I can find lots of fun things to do					
	I feel that I am good at some things					
	I think lots of people care about me					
28	I like everyone I have met					
	I think there are many things I can be proud of					
	I've been feeling calm					
29	I've been in a good mood					
	I enjoy what each new day brings					
	I've been getting on well with people					
30	I always share my sweets					
	I've been cheerful about things					

	I've been feeling relaxed					

	Datganiad	Byth	Ddim yn aml	Weithiau	Yn eithaf aml	Bob amser
26	Dw i'n meddwl y bydd pethau da yn digwydd yn ystod fy mywyd					
	Rwy bob amser wedi dweud y gwir					
	Rwy wedi gallu gwneud dewisiadau'n hawdd					
27	Rwy'n gallu dod o hyd i lawer o bethau sy'n hwyl i'w gwneud					
	Rwy'n teimlo fy mod i'n gallu gwneud rhai pethau'n dda					
	Rwy'n meddwl bod llawer o bobl yn gofalu amdana i					
28	Rwy'n hoffi pawb rwy wedi cwrdd â nhw					
	Rwy'n meddwl bod llawer o bethau y galla i fod yn falch ohonyn nhw					
	Rwy wedi bod yn teimlo'n llonydd					

29	Rwy wedi bod mewn hwyliau da					
	Rwy'n mwynhau'r hyn y bydd pob dydd yn ei gyflwyno					
	Rwy wedi bod ar delerau da gyda phobl					
30	Bydda i bob amser yn rhannu fy melysion					
	Rwy wedi bod yn llon ynghylch pethau					
	Rwy wedi bod yn teimlo'n ymlaciedig					

Page 5: Questions about your life

Please say how much you disagree or agree with each of the following statements:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Don't know
31 My life is going well						
My life is just right						
31.a) I wish I had a different kind of life						
I have a good life						
I have what I want in life						

Tudalen 5: Cwestiynau am eich bywyd

Dywedwch faint rydych chi'n anghytuno neu'n cytuno â phob un o'r datganiadau canlynol:

	Yn anghytuno'n gryf	Yn anghytuno	Ddim yn cytuno nac yn anghytuno	Yn cytuno	Yn cytuno'n gryf	Ddim yn gwybod
31 Mae fy mywyd i'n mynd yn dda						
Mae fy mywyd i'n iawn fel y mae						
31.a) Byddai'n dda gen i pe bai math gwahanol o fywyd gen i						
Mae bywyd da gen i						
Mae gen i'r hyn rwy ei eisiau mewn bywyd						

Please tick one of the boxes to say how happy you feel with things in your life. These questions use a scale from 0 to 10. On this scale:

0 means 'very unhappy'
5 means 'not happy or unhappy'
10 means 'very happy'

Ticiwch un o'r blychau i ddweud pa mor hapus rydych chi'n ei deimlo am bethau yn eich bywyd. Mae'r cwestiynau hyn yn defnyddio graddfa o 0 i 10. Ar y raddfa hon:

Mae 0 yn golygu 'yn anhapus iawn'
Mae 5 yn golygu 'ddim yn hapus nac yn anhapus'
Mae 10 yn golygu 'hapus iawn'

32. How happy are you with your life as a whole?

How happy are you with your relationships with your family?

How happy are you with the home that you live in?

33. How happy are you with how much choice you have in life?

How happy are you with your relationships with your friends?

How happy are you with the things that you have (like money and the things you own)?

34. How happy are you with your health?

How happy are you with your appearance (the way you look)?

How happy are you with what may happen to you later in your life (in the future)?

35.How happy are you with the school that you go to (when there's no lockdown)?

How happy are you with the way that you use your time?

32. Pa mor hapus ydych chi gyda'ch bywyd yn gyffredinol?

Pa mor hapus ydych chi gyda'ch perthnasoedd yn eich teulu?

Pa mor hapus ydych chi gyda'r cartref rydych chi'n byw ynddo fe?

33. Pa mor hapus ydych chi gyda faint o ddewisiadau sydd gennych chi yn eich bywyd?

Pa mor hapus ydych chi gyda'ch perthnasoedd gyda'ch ffrindiau?

Pa mor hapus ydych chi gyda'r pethau sydd gennych chi (megis arian a'r pethau rydych chi'n berchen arnyn nhw)?

34. Pa mor hapus ydych chi gyda'ch iechyd?

Pa mor hapus ydych chi gyda'ch golwg (y ffordd rydych chi'n gweld eich hun neu'r ffordd y mae pobl yn eich gweld)?

Pa mor hapus ydych chi gyda'r hyn a allai ddigwydd ichi yn nes ymlaen yn eich bywyd (yn y dyfodol)?

35. Pa mor hapus ydych chi gyda'r ysgol rydych chi'n mynd iddi hi (pan na fydd cyfyngiadau symud)?

Pa mor hapus ydych chi gyda'r ffordd rydych chi'n defnyddio'ch amser?

Page 6: School

Please answer these questions about your time doing schoolwork at home or in school:

	Never	Almost never	Sometimes	Often	Always
36. I struggle to concentrate on my schoolwork.					
I find schoolwork hard.					
37. The teacher/my parent/my guardian tells me off.					
It is hard to follow the rules at school.					
It is hard to do schoolwork from home.					

Tudalen 6: Ysgol

Ac yn olaf, atebwch y cwestiynau hyn am eich amser yn yr ysgol:

	Byth	Bron byth	Weithiau	Yn aml	Bob amser
36. Rwy'n cael trafferth yn canolbwyntio ar fy ngwaith ysgol.					
Rwy'n cael gwaith ysgol yn anodd.					
37. Mae'r athrawes neu'r athro/fy rhiant/fy ngwarcheidwad yn rhoi stŵr imi.					
Mae'n anodd dilyn y rheolau yn yr ysgol.					
Mae'n anodd gwneud gwaith ysgol gartref.					

Page 7: And finally, please answer these questions by reflecting on the difference between being in lockdown compared to usual.

38. How active are you during lockdown compared to usual?

I am less active during lockdown

I maintain the same level of activity

I am more active during lockdown

38. a) Can you explain why you are less active?

38. b) Can you explain how you are able to maintain your usual level of activity?

38. c) Can you explain why you are more active?

Ac yn olaf, atebwch y cwestiynau hyn drwy fyfyrio am yr hyn sy'n wahanol rhwng y cyfyngiadau symud a'r sefyllfa fel arfer.

38. Pa mor weithgar ydych chi yn ystod y cyfyngiadau symud o'i gymharu â'r sefyllfa arferol?
Rwy'n llai actif yn ystod y cyfyngiadau symud
Rwy'n cynnal yr un lefel o weithgarwch
Rwy'n fwy actif yn ystod y cyfyngiadau symud

38. a) Allwch chi esbonio pam rydych chi'n llai actif?
38. b) Allwch chi esbonio sut rydych chi'n gallu cynnal eich lefel arferol o weithgarwch?
38. c) Allwch chi esbonio pam rydych chi'n fwy actif?

39. How does lockdown make you feel?

39. a) Why do you feel this way?

39. Sut rydych chi'n teimlo yn sgîl y cyfyngiadau symud?
39. a) Pam rydych chi'n teimlo felly?

Final page:

Thank you for taking part in our study! Your answers will help the Welsh government make important decisions on how to help children during the coronavirus pandemic. We would

really like to hear from you again to see if things have changed, so will send you another survey in a few months' time.

Diolch am gymryd rhan yn ein hastudiaeth! Bydd eich atebion yn helpu Llywodraeth Cymru i wneud penderfyniadau pwysig ynghylch sut i helpu plant yn ystod pandemig y coronafeirws. Hoffen ni'n fawr glywed gennych chi unwaith eto i weld a yw pethau wedi newid, felly byddwn ni'n anfon arolwg arall atoch chi mewn rhai misoedd.

[For ages 12-16 years, the PAQ-A has the following changes - no question about break times, but these added]

In the last 7 days, on how many days before starting school or home learning, did you do exercise, sports, dance, or play games in which you were very active?

None

1 time last week

2 or 3 times last week

4 times last week

5 times last week

Yn ystod y 7 niwrnod diwethaf, sawl diwrnod cyn yr ysgol wnaethoch chi chwaraeon, dawnsio neu chwarae gemau yr oeddech chi'n actif iawn ynddyn nhw?

Yr un diwrnod

Unwaith yr wythnos diwethaf

2 neu 3 gwaith yr wythnos diwethaf

4 gwaith yr wythnos diwethaf

5 gwaith yr wythnos diwethaf

In the last 7 days, on how many mornings did you actively travel (for example, walking, cycling, scootering and skateboarding) to school?

I am at home during lockdown

None

1 time last week

2 or 3 times last week

4 times last week

5 times last week

Yn ystod y 7 niwrnod diwethaf, sawl diwrnod wnaethoch chi deithio i'r ysgol mewn ffordd actif (er enghraifft cerdded, seiclo, defnyddio sgwter neu fwrdd sgrialu)?

Rwy gartref yn ystod y cyfyngiadau symud
Yr un diwrnod

Unwaith yr wythnos diwethaf

2 neu 3 gwaith yr wythnos diwethaf

4 gwaith yr wythnos diwethaf

5 gwaith yr wythnos diwethaf

In the last 7 days, on how many afternoons did you actively travel (for example, walking, cycling, scootering and skateboarding) from school?

I am at home during lockdown

None

1 time last week

2 or 3 times last week

4 times last week

5 times last week

Yn ystod y 7 niwrnod diwethaf, sawl diwrnod wnaethoch chi deithio o'r ysgol mewn ffordd actif (er enghraifft cerdded, seiclo, defnyddio sgwter neu fwrdd sgrialu)?

Rwy gartref yn ystod y cyfyngiadau symud
Yr un diwrnod

Unwaith yr wythnos diwethaf

2 neu 3 gwaith yr wythnos diwethaf

4 gwaith yr wythnos diwethaf

5 gwaith yr wythnos diwethaf

APPENDIX Table 1- Interactions of time-point, age, sex and SES on PA metrics and well-being

	Coefficient	(95%CI)	p
Well-being			
Time-point*Sex- 2-Girl	1.36	(-2.28 to 4.99)	0.464
Time-point*Sex-3-Girl	0.81	(2.78 to 4.41)	0.657
Time-point*Sex-4-Girl	-0.86	(-5.04 to 3.32)	0.686
Time-point*School age Group-2-Lower secondary school	0.42	(-3.63 to 4.47)	0.840
Time-point*School age Group-2-Upper secondary school	2.16	(-2.68 to 7.0)	0.383
Time-point*School age Group-3-Lower secondary school	0.15	(-3.54 to 3.84)	0.937
Time-point*School age Group-3-Upper secondary school	0.22	(-4.64 to 5.07)	0.930
Time-point*School age Group-4- Lower secondary school	1.12	(-3.15 to 5.39)	0.607
Time-point*School age Group-4-Upper secondary school	3.75	(-10.53 to 18.03)	0.606
Sex*School age Group-Girl-Lower secondary school	-1.71	(-5.23 to 1.89)	0.341
Sex*School age Group-Girl- Upper secondary school	-0.37	(-4.69 to 3.96)	0.868
Time-point*Sex*School age Group-2-Girl-Lower Secondary school	-4.37	(-9.86 to 1.11)	0.118
Time-point*Sex*School age Group-2-Girl-Upper secondary school	-3.02	(-9.50 to 3.48)	0.363
Time-point*Sex*School age Group-3-Girl-Lower secondary school	-0.57	(-5.80 to 4.67)	0.831
Time-point*Sex*School age Group-3-Girl-Upper secondary school	-3.89	(-10.45 to 2.67)	0.245
Time-point*Sex*School age Group-4-Girl-Lower secondary school	6.55	(-0.37 to 13.48)	0.064
Time-point*Sex*School age Group-4-Girl-Upper secondary school	0.89	(-19.31 to 21.10)	0.931
SES*Sex-2-Girl	0.90	(-2.42 to 4.21)	0.595
SES*Sex-3-Girl	1.98	(-1.26 to 5.22)	0.230
SES*Sex-4-Girl	3.24	(0.15 to 6.34)	**0.040**
SES*Sex-5-Girl	3.51	(0.30 to 6.71)	**0.032**
MVPA			

Time-point*Sex-2-Girl	-7.45	(-17.09 to 1.59)	0.104
Time-point*Sex-3-Girl	-8.19	(-17.96 to 1.58)	0.100
Time-point*Sex-4-Girl	-6.63	(-16.69 to 3.44)	0.197
Time-point*School age Group-2- Lower secondary school	-0.54	(-9.88 to 8.81)	0.911
Time-point*School age Group-2- Upper secondary school	-16.03	(-26.81 to -524)	**0.004**
Time-point*School age Group-3 Lower secondary school	-4.46	(-14.31 to 5.19)	0.359
Time-point*School age Group- 3 Upper secondary school	-21.70	(32.68 to -10.72)	**<0.001**
Time-point*School age Group-4-Lower secondary school	-6.51	(-16.84 to 3.83)	0.217
Time-point*School age Group-4 Upper secondary school	-21.27	(-34.32 to -8.23)	**0.001**
Sex*School age Group-Girl- Lower secondary school	5.05	(-4.22 to 14.32)	0.286
Sex*School age Group-Girl-Upper secondary school	-3.17	(-13.57 to 7.23)	0.550
SES*Sex-2-Girl	-2.27	(-9.62 to 5.08)	0.545
SES*Sex-3-Girl	-2.46	(-9.65 to 4.73)	0.503
SES*Sex-4-Girl	1.19	(-5.69 to 8.08)	0.735
SES*Sex-5-Girl	4.63	(-2.44 to 11.71)	0.199
LPA			
Timepoint*sex-2-Girl	-7.45	(-17.09 to 1.59)	0.104
Timepoint*sex-3-Girl	-8.19	(-17.96 to 1.46)	0.100
Timepoint*sex-4-Girl	-6.63	(-16.69 to 3.44)	0.197
Time-point*School age Group-2-lower secondary school	-0.54	(9.88 to 8.81)	0.911
Time-point*School age Group-2-upper secondary school	-16.03	(-26.81 to -5.24)	**0.004**
Time-point*School age Group-3-lower secondary school	-4.56	(-14.31 to 5.19)	0.359
Time-point*School age Group-3-upper secondary school	-21.70	(-31.68 to -10.72)	**<0.001**
Time-point*School age Group-4-lower secondary school	-6.51	(-16.84 to 3.83)	0.217
Time-point*School age Group-4-upper secondary school	-21.27	(-34.32 to -8.26)	**0.001**
Sex*School age Group-girl-lower secondary school	5.05	(-4.22 to 14.32)	0.286

Sex*School age Group-girl-upper secondary school	-3.17	(-13.57 to 7.23)	0.550
Time-point*Sex*School age Group-2-Girl-Lower Secondary school	-6.53	(-19.67 to 6.61)	0.330
Time-point*Sex*School age Group-2-Girl-Upper secondary school	4.80	(-9.90 to 19.50)	0.522
Time-point*Sex*School age Group-3-Girl-Lower secondary school	-11.07	(-24.77 to 2.63)	0.113
Time-point*Sex*School age Group-3-Girl-Upper secondary school	9.48	(-5.65 to 24.61)	0.219
Time-point*Sex*School age Group-4-Girl-Lower secondary school	-11.44	(-26.07 to 3.19)	0.125
Time-point*Sex*School age Group-4-Girl-Upper secondary school	1.31	(-16.43 to 8.87)	0.885
SES*Sex-2-Girl	-2.27	(-9.62 to 5.08)	0.545
SES*Sex-3-Girl	-2.46	(-9.65 to 4.73)	0.503
SES*Sex-4-Girl	1.19	(-5.69 to 8.08)	0.735
SES*Sex-5-Girl	4.63	(-2.44 to 11.71)	0.199
Sedentary			
Timepoint*sex-2-Girl	-3.28	(-59.07 to 52.51)	0.908
Timepoint*sex-3-Girl	-29.61	(-87.99 to 28.77)	0.320
Timepoint*sex-4-Girl	-61.49	(-121.65 to -1.35)	**0.045**
Time-point*School age Group-2-lower secondary school	-13.02	(-68.87 to 42.83)	0.648
Time-point*School age Group-2-upper secondary school	-30.71	(-95.17 to 33.75)	0.350
Time-point*School age Group-3-lower secondary school	-2.67	(-60.94 to 55.59)	0.928
Time-point*School age Group-3-upper secondary school	-13.03	(-78.64 to 52.59)	0.697
Time-point*School age Group-4-lower secondary school	-64.22	(-125.99 to -2.46)	**0.042**
Time-point*School age Group-4-upper secondary school	-104.58	(-182.53 to -26.62)	**0.009**
Sex*School age Group-girl-lower secondary school	-61.13	(-116.54 to -5.71)	**0.031**
Sex*School age Group-girl-upper secondary school	-53.69	(-115.74 to 8.54)	0.091
Time-point*Sex*School age Group-2-Girl-Lower Secondary school	17.08	(-61.46 to 95.62)	0.670

Time-point*Sex*School age	Group-2-Girl-Upper secondary school	-4.80	(-92.63 to 83.03)	0.915
Time-point*Sex*School age	Group-3-Girl-Lower secondary school	84.45	(2.58 to 166.32)	**0.043**
Time-point*Sex*School age	Group-3-Girl-Upper secondary school	66.68	(-23.74 to 157.1060	0.148
Time-point*Sex*School age	Group-4-Girl-Lower secondary school	101.56	(14.14 to 188.99)	**0.023**
Time-point*Sex*School age	Group-4-Girl-Upper secondary school	113.07	(7.07 to 219.06)	**0.037**
SES*Sex-2-Girl		17.75	(-26.16 to 61.66)	0.428
SES*Sex-3-Girl		47.07	(4.11 to 90.04)	0.032
SES*Sex-4-Girl		16.91	(-24.23 to 58.04)	0.421
SES*Sex-5-Girl		11.54	(-30.76 to 53.84)	0.593

Note: Time-point 1, boys, upper primary school, and SES Quintile 1 (most deprived) are the reference values. Values in **bold** indicate statistical significance ($p<0.05$).

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