PHYSICAL ACTIVITY FOR HEALTH

Department of Psychological Sciences and Health

Title: Moderate-to-Vigorous Intensity Physical Activity During School Hours in Primary School Children

By

LAN SUM WONG BEdu. (Hons), MEd

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Signed:

Date: 10/11/2024

COVID-19 impact statement on PhD

1 Overview of the pre-COVID-19 research plan

The original objectives of my PhD were as follows:

1) To systematically research and provide concrete data and strategies for better or more effective teaching of physical education (PE) to develop a more physically active approach to delivering PE in primary schools (Study 1).
2) To modify intervention strategies, identified from the systematic review, according to Hong Kong local context to increase moderate-to-vigorous physical activity (MVPA) content of PE and benefit children as well as for consideration by school policymakers and teacher trainers (Study 2).
3) To test the feasibility and acceptability of the new approach to increase the MVPA content of PE lessons in primary schools in Hong Kong. So, the World Health Organization (WHO) MVPA guidelines can be achieved (Study 3).
4) To provide a series of concrete and sustainable strategies and steps to benefit school policymakers and for teachers' reference. The aim was also to provide a clearer insight into the issues so that a more active teaching approach can be adopted to motivate children to participate more in physical activities (Study 4).

Original Research Design, Methods, Analytical Methods

Plan A - Study 1- Systematic review: literature search and random-effects meta-analysis will be used to identify intervention strategies to increase the MVPA content of PE.

Study 2 - A protocol paper: to explain the rationale and ways of assessing the feasibility and acceptability of an adapted version to see if the strategies could be translated for use in other settings including Hong Kong. A combination of process measures, observations, session delivery records, questionnaires, accelerometry, and semi-structured interviews with teachers

and pupils will be used. The feasibility and suitability of the intervention for a future Randomised Control Trial (RCT) will be assessed.

Study 3 - a feasibility study for collecting primary data – to assess whether applying the adapted intervention is feasible in Hong Kong primary schools. Identification of any modifications to the intervention or evaluation will provide insight for a fully powered effectiveness trial in the future.

Study 4 - a paper on how schools can contribute to children's MVPA to improve pupils' health. Based on the data analysis provided by Study 3, it will be useful to consolidate the results to see how schools can provide pupils with adequate MVPA levels via different PA opportunities e.g., PE, recess, breaks, during school hours.

2. The Extent of COVID Disruption and How That Impacted My Research

In the first six months of my PhD course (from Oct 2019 – March 2020), I started Study 1 - a systematic review of global evidence to find promising ways and behavioural science techniques to make PE more active in Hong Kong primary schools. At the same time, I tried to apply for funding from Hong Kong in the hope that the new data and skills that I gained from the systematic review could be trialled and evaluated (via an intervention study) in a few primary schools in Hong Kong.

Difficulties Before the COVID Pandemic

Various problems occurred during that period. The major problems which had arisen at that time were the serious and unexpected barriers to my PhD investigation. First, the unrest situation (serious riots and school closures) in Hong Kong up to the end of 2019 meant that I had to make contingency plans to move the study away from Hong Kong. It was an extremelydifficult year 1 of my PhD research (initially because unrest in Hong Kong meant the plans todo fieldwork there had to be abandoned).

Plan B - Starting in early 2020, I contacted a fellow PE colleague who was teaching at Macau University, and he said it was possible to liaise with a few primary schools for me to implement the intervention and there was also a possibility to work with some sister schools in China. Unfortunately, in late December 2019, COVID-19 broke out in China. By early January 2020, Hong Kong started to lock down and on 28th Feb 2020, all schools in Macau closed due to the coronavirus outbreak and there was no date for reopening. So, I was not able to collect my intervention data either in Hong Kong or in Macau and China.

Plan C - Starting in March 2020. I tried to find education partners in Scottish schools/local authorities in the hope that the research could be conducted here. We managed to contact PE specialists who worked in the Hub of PEPASS (Physical Education, Physical Activity and School Sport) and a primary school PE teacher in East Renfrewshire. A promising theory and evidence-based intervention 'SHARP' has evidence of efficacy in England and was identified in Study 1. One PE teacher was keen on adapting/adopting the SHARP intervention and there was a good chance to implement this intervention in his school (together with other schools in the same clusters). The original developer of the SHARP intervention (Dr. Emma Powell) had officially been accepted by the University of Strathclyde as my third supervisor in early July 2020.

Then, I started the write-up of the intervention development and the protocol study (Study 2) with reference to the Scottish context. However, the UK was also under COVID lockdown starting on 23rd March 2020 and the school environment had been very unstable since then. The feasibility study (Study 3) was originally planned to be implemented from January to April2021 in East Renfrewshire. The Education Department of East Renfrewshire was contacted several times between July to September 2020 to seek permission to conduct a feasibility studyof SHARP in Scotland. To make things worse was teacher and support staff strikes during post lockdown and it meant that schools were often disrupted and closed. Hence, no definite answer

had been received from the Department during this period.

All the preparation work was still moving on from April to Dec 2020 while I was waiting for the lockdown to be lifted. Other local councils also were unable to provide settings for the feasibility study. As COVID-19 made the situation in the school very unstable and visiting schools became impossible, Plan C to implement the feasibility study in the local school had to be put on hold but not yet fully abandoned. At the same time, the protocol paper was completed by the end of 2020.

Covid-19 had presented unprecedented problems and large number of supervisory changes had taken place since I started. From early 2020 to 2021, two supervisors have been changed and finally Dr Harrington joined as second supervisor in spring 2021. Since I started my course in Oct 2019, I had changed three second supervisors in one and a half years. These supervisory changes had added uncertainty to what was a PhD beset with uncertainty and caused additional burdens to my research.

Plan D - As COVID-19 made fieldwork impractical everywhere, I had to change Study 3 from primary data collection to a secondary data analysis of the SPACES dataset. Since I had done a systematic review in year 1, the only possible study at this point was the secondary data analysis, which allowed me to answer research questions more closely linked to my original PhD objectives. Furthermore, the addition of Dr Harrington in Spring 2021 as my second supervisor was very timely: she has expertise in secondary analysis of school-based accelerometry data and was leading on supervision of the secondary analyses (thesis Studies 3 and 4).

The secondary data was provided by the "Studying Physical Activity in Children's Environments across Scotland (SPACES)" dataset received in July 2021. The original study was carried out in the school year from May 2015 to May 2016 across Scotland in partnership between the Scottish Government and the Social and Public Health Sciences Unit, University

of Glasgow. A brief proposal was sent to seek permission from the University of Glasgow to make a formal request to assess the data hub on the SPACES dataset. Owing to the lockdown, with Scottish Government prioritising COVID issues, it took a long time for permission from the Scottish government to allow me to use the dataset. Finally, approval was given on 28 April 2021 and the whole dataset was received in July 2021. The aims of Study 3 were to investigate the children's MVPA during school hours and how it was influenced by various factors. The main problem was to extrapolate the relevant data for Study 3 because the initial SPACES Study provided data for children's activity levels for the whole day and not exclusively for school hours. It took a long time to extract the relevant (school hours) data.

Plan E – Using the same dataset to investigate how school recess contributes to the pupils' MVPA during school hours.

3. A Summary of Any Decisions Taken to Mitigate COVID-19 Restriction

Though I had to change the planned locations to collect primary data a few times, I did not have to make too many changes to the topic, or methods. Neither did I need to change to shorter or simpler studies/chapters. The biggest change was I decided to use secondary data analysis to complete Studies 3 and 4.

Besides, there were some general adverse consequences of the lockdown. Though it reduced my ability to attend conferences, I attended two online international conferences during the second year, one was held in Alberta, Canada, and the other in Denmark. A third one was in Gold Coast, Australia in year 3. In sum, I used secondary data analysis to replace the collection of primary data from primary schools and attended online conferences to mitigate COVID-19 restriction to complete my PhD research.

Abstract

Background: Physical inactivity is a global challenge that needs to be addressed urgently. Schools can make a significant impact on children's current and future physical activity behaviour as children spend more time in school than anywhere other than home. Sustainable school-based physical activity strategies are necessary to offer an active school day for large numbers of children with suitable interventions starting as early as possible to promote a long and healthy lifestyle. This thesis aims to evaluate and explore school-based strategies to increase pupils' moderate-to-vigorous physical activity (MVPA) levels during school hours (through physical education, recess, and other domains of physical activity in school). The secondary aim is to provide recommendations and a clearer insight into the issues of school-based MVPA.

Methods: The thesis is based on the findings of four studies. The first is a systematic review of interventions to increase moderate-to-vigorous physical activity (MVPA) levels inphysical education (PE) lessons for primary school children. The review was an update of Lonsdale et al.'s 2013 review. The update was necessary because the previous review was 10 years old, and the studies it included were mainly conducted in the USA, focusing on primary and secondary education levels. Research is a constantly evolving field, so more recent studies are likely to be available. Updating the review was useful, as it produced new evidence that was not included in Lonsdale et al.'s original review. This new evidence was relevant and applicable to Scotland, providing a solid basis for the thesis.

The second study is a protocol paper developed by adapting an existing intervention to a Scottish context, the aim of this study is to determine whether the strategies employed in England could be adopted in Scotland.

The third and fourth studies are based on a large nationally representative sample provided by the SPACES (Studying Physical Activity in Children's Environments across Scotland) study

conducted between May 2015 and May 2016. There were 774 children (417 females, 357 males), aged 10/11 years, randomly chosen from 471 schools, who took part. The SPACES study, with data collected inclusively during school hours and recess time across five weekdays, formed the basis for analyses in 2022. The third study looks at the MVPA levels accrued during a normal school day and risk factors including gender, socioeconomic status (SES), season, and urban or rural residency are investigated. The fourth study examines children's MVPA levels during recess time with the same risk factors plus an extra one, namely, the length of the recess. Mean time spent in MVPA during school hours and recess is computed and compared against a recommendation that children should achieve 30 minutes of MVPA during school hours and 40% of recess time should be in MVPA. Binary logistic regression, presented as odds ratio (O.R.) and confidence intervals (C.I.), analyses explored associations between meeting/not meeting the recommendation by the candidate risk factors. Key findings and implications from the four studies are summarised and recommendations for schools on engaging pupils more in MVPA during school hours are also provided.

Results: The systematic review (Study 1) identified only five studies from a total of 5459 records over the period from 2010 to 2019. All eligible studies reported favourable intervention effects. Meta-analysis was possible from 4/5 studies: The mean difference between intervention and control groups at follow-up was +14.3% of lesson time in MVPA (confidence interval (CI 2.7 to 25.8)). One apparently highly effective intervention, the SHARP Principles Model, was identified as it increased children's MVPA during PE lessons by 30% and 27% respectively when tested twice across multiple schools in England. A protocol paper (Study 2) was employed to translate the SHARP intervention for use in Scotland (SHARP Scotland). However, circumstances made the implementation not feasible due to COVID lockdowns during the time frame. This paper was proposed as the foundation and provided insight for a fully powered effectiveness trial in the future.

The results of device-based measured accelerometry data (from Studies 3 and 4) showed that children's MVPA levels during school hours (an average of 29 minutes) and recess (3.2 out of 16.1 minutes) were very low. Only 43% of children during school hours and 6% during recess met the relevant MVPA recommendations. Gender was a significant factor in meeting the MVPA recommendations, with 33% of girls vs 54% of boys meeting the recommendations during school hours, and 1% of girls versus 11% of boys during recess.

SES (socioeconomic status) was not a significant factor in meeting the MVPA recommendations during either school hours or recess. Among participants, 42% of those in the most deprived quintile met the school hours MVPA recommendation, compared to 39% in the least deprived quintile. During recess, 3.6% of those in the most deprived quintile met the recommendation, compared to 4.3% in the least deprived quintile.

Seasons were a significant factor for achieving school hours MVPA, with 42% of participants meeting the recommendation in winter, 52% in spring, 59% in summer, and 34% in autumn. Urban versus rural residency was also a significant factor, with 40% of urban participants compared to 52% of rural participants meeting the school hours MVPA recommendation.

Conclusions: Levels of MVPA during school hours and recess are very low in Scottish children included in the SPACES Study. Interventions to increase MVPA during PE are promising, and one particular intervention seemed especially promising. Any interventions run during PE lessons, recess, and other domains of physical activity in school should benefit all children.

Acknowledgements

Firstly, I am most grateful to my supervisor, Professor John Reilly, for all his valued support and guidance throughout my PhD research work. I would also like to thank my supervisor, Dr. Deirdre Harrington, for her encouragement and support during the past few years. Thank you both for your invaluable guidance, thoughtful insights, and professional input throughout my PhD studies. Your support, feedback, and advice have been greatly appreciated and I have thoroughly enjoyed working with you.

I would also like to thank all those at the Physical Activity for Health Department who have offered advice and assistance at various points throughout my PhD studies. Thanks to Dr. Ann-Marie Gibson and Dr. Fiona Muirhead for being my supervisors during the first eighteen months of my candidature. Dr. Xanne Janssen, Dr. Alexandra Mavroeidi, and colleague Abdulaziz Farooq (another PhD student) for their generosity in sharing their knowledge and advice. Your supportive and encouraging feedback was much appreciated and I greatly enjoyed working with you all over the last few years, and hope there will be many more opportunities to do so again in the future.

Working on Study 2 gave me the opportunity to engage with researchers at Newman University, Birmingham, England, and I am particularly grateful to the original SHARP team members, Dr. Lorayne Woodfield, and Dr. Emma Powell, for all their advice and guidance. I would also like to thank Mr. Cameron Stewart who participated in my research by contributing his experience as a front-line PE teacher and made the study possible.

I have been very fortunate for my collaboration with other investigators, that has allowed me to meet fantastic people during my research. A special thank you to the Medical Research Council (MRC) and Scottish Government Chief Scientist Office (CSO) as well as the Social and Public Health Sciences Unit, at the University of Glasgow, for providing me with the SPACES dataset and advice from Dr. Paul McCrorie on data management.

Finally, I want to thank all my family and friends who have been incredibly supportive during my PhD studies. I am very fortunate to be surrounded by so many good people, especially during the COVID-19 times. All your kind words, good humor, continued support, and advice have been deeply appreciated.

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List of Abbreviations

AfPE – Association for Physical Education

CAS – Creating Active School

CDC – Center for Disease Control & Prevention

CfE – Curriculum for Excellence

CI – Confidence Interval

CMO – Chief Medical Officers

CPM – Counts Per Minute

CSO – Chief Scientist Office

CSPAP – Comprehensive School Physical Activity Programme

ECA – Extra-Curricular Activities

GAPPA – Global Action Plan on Physical Activity

HBSC – Health Behaviours in School Children study

ICAD – International Children's Accelerometry Database

LPA – Light Physical Activity

METs – Metabolic Equivalents

MRC – Medical Research Council

MPA – Moderate Physical Activity

MVPA – Moderate-to-Vigorous Physical Activity

NCD – Non-Communicable Disease

OR – Odds Ratio

PA – Physical Activity

PE – Physical Education

PRISMA– Preferred Reporting Items for Systematic Reviews and Meta-Analyses

RCT – Randomised Controlled Trial

SB – Sedentary Behaviour

SBRN – Sedentary Behaviour Research Network

SEM – Social Ecological Model

SES – Socioeconomic Status

SHAPE – Society of Health and Physical Educators

SHARP – Stretching whilst moving, High repetition of skills, Accessibility, Reducing sitting and standing, and Promotion of physical activity

SHeS – Scottish Health Survey

SIMD – Scottish Index of Multiple Deprivations

SPACES – Studying Physical Activity in Children's Environments across Scotland

TEO – Theory of Expanded, Extended, and Enhanced Opportunities

UK – United Kingdom

UN – United Nations

UNESCO – United Nations Education Scientific and Cultural Organization

USA – United States of America

VPA – Vigorous Physical Activity

WHO – World Health Organization

WOS – Whole-of-School

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Summary of Publications and Presentations from Thesis

1. Published Manuscripts

Chapter 3

Wong LS, Gibson A-M, Farooq A, Reilly JJ. Interventions to increase moderate-to-vigorous physical activity in elementary school physical education lessons: systematic review. *J Sch Health*. 2021; 91: 836-845. DOI: 10.1111/josh.13070.

This paper has been recognised as a top cited paper in the Journal of School Health among work published in an issue between 1 January 2021- 15 December 2022. (Appendix I)

Chapter 4

Wong LS, Muirhead F, Powell E, Lorayne A Woodfield, Cameron Stewart, John J Reilly. Feasibility of an intervention for increasing moderate-to-vigorous intensity physical activity (MVPA) in primary school physical education: a study protocol. F1000Research 2022; 11:258 https://doi.org/10.12688/f1000research.109096.1

Chapter 5

Lan Sum Wong, John J. Reilly, Paul McCrorie, Deirdre M. Harrington. Moderate-to-vigorous intensity physical activity during school hours in a representative sample of 10-11-year-olds in Scotland. *Journal of Science and Medicine in Sport*. 2023;(26) 2:120-124. https://doi.org/10.1016/j.jsams.2022.10.014.

Chapter 6

Lan Sum Wong, John J. Reilly, Paul McCrorie, Deirdre M. Harrington. Physical activity levels during school recess in a nationally representative sample of 10- to 11-year-olds. *Pediatric Exercise Science.* 2024;36, 37-43. https://doi.org/10.1123/pes.2022-0144.

2. Conference Presentations from Thesis

Lan S Wong, Gibson A-M, Farooq A, Reilly JJ. Interventions to increase moderate-to-vigorous physical activity in elementary school physical education lessons: systematic review.

- *Scottish Physical Activity Research Connections Conference, Edinburgh, UK, November 2020.*
- *The International Association for Physical Education in Higher Education (AIESEP 2021) Scientific Conference, University of Alberta, McGill University, Canada, 7-10, June 2021.*
- *The conference on children's physical activity and health, Odense, University of Southern Denmark, 25 August 2021.*

Lan Sum Wong, John J. Reilly, Paul McCrorie, Deirdre M. Harrington. Moderate-to-vigorous intensity physical activity during school hours in a representative sample of 10-11-year-olds in Scotland. *The International Association for Physical Education in Higher Education (AIESEP) 2022 World Congress, Griffith University, Gold Coast, Brisbane, Queensland Australia 15-18 June 2022.*

Lan Sum Wong, John J. Reilly, Paul McCrorie, Deirdre M. Harrington. Moderate-to-vigorous intensity physical activity levels during school hours and recess in a representative sample of 10-11-year-olds in Scotland. *Scottish Physical Activity Research Connections Conference, Edinburgh, UK, November 2022.*

Chapter 1: Introduction and Aims

1.1 Chapter Overview

This brief chapter will provide an overview of this thesis, identify the thesis aims and objectives and detail the position of the researcher.

1.2 Thesis Structure

The initial Chapters (1-2) set the scene for the core of this thesis. Chapter 1 identifies the aims and objectives. Chapter 2 reviews the general literature in the area to complement the literature included in the individual papers.

Chapters 3 to 6 present the peer-reviewed publications from this thesis. Chapter 3 (Study 1) presents a systematic review of the interventions for making PE lessons more active. Chapter 4 (Study 2) presents a protocol paper on a feasibility study of an intervention for increasing children's MVPA levels during PE lessons. However, circumstances prevented the implementation of the feasibility study due to COVID-19 lockdowns during the period. The next steps for this feasibility protocol will be mentioned in Chapter 4. Chapters 5 and 6 (Studies 3 and 4) present two analyses of accelerometer data from a large national dataset. Additional methodologies used in extracting relevant accelerometer data (i.e., data just from school hours and from recess time) for Studies 3 and 4, from the SPACES dataset, is provided in Appendix VII and Appendix VIII.

Chapter 7 presents the overall findings of the thesis, the discussion, conclusion, as well as the strengths and limitations of this thesis, and finally the recommendations for future research.

1.3 Thesis Aims and Objectives

The author hopes that this thesis can act as a catalyst for a change in our attitudes to physical activity (PA) and make primary school hours more physically active for public health gain.

The thesis had an overarching aim to investigate moderate-to-vigorous physical activity (MVPA) during school hours, starting with physical education (PE) lessons (Studies 1 and 2), and extending into the rest of school hours (Study 3), including recess (Study 4). Specifically, the objectives of this thesis were to:

1) identify the school-based interventions to increase primary school children's MVPA levels during PE with the help of a systematic review.
2) explore the feasibility of adapting/ translating an intervention, to increase pupils' MVPA in PE lessons, to other schools' contexts by means of a protocol study.
3) assess and explore how much MVPA Scottish children typically accumulate during school hours, and whether these levels vary by risk factors (such as gender, socioeconomic status (SES), season, and urban or rural residency).
4) assess and explore how much MVPA Scottish children typically accumulate during school recess, and whether these levels vary by risk factors (such as gender, SES, season, urban or rural residency, and length of the recess).
5) provide recommendations and a clearer insight into the issues of school-based PA so a holistic school approach (via PE, recess, and other domains of PA in school) can be developed for consideration by policymakers, teachers, and research stakeholders to engage children more in MVPA.

1.4 Positioning the Researcher

The PhD candidate was born and raised in Hong Kong and lived and worked there until 2019 before relocating to Scotland for this PhD course. The author's early experience of growing up in a relatively deprived household compared to the average household in affluent Hong Kong today. Having older siblings taking care of playing outdoors gave her the impetus to engage in outdoor activities and sports freely. In this outdoor play, she experienced risk-

taking, skill-building, friendship, minor injury, teamwork, and adventure, which reflected how PA was then integrated into daily life.

Having completed primary and secondary school, she graduated from Education College with a major in PE. The author's first role was as a PE teacher in a government secondary school and was responsible for giving PE lessons to all the girls (from secondary one to secondary seven). She got first-hand experience that as the girls became older, they were less willing to participate in PE lessons. This was her first experience in teaching PE as a front-lineteacher and her teaching experience lasted for ten years. The author was then recruited into theEducation Department Headquarters of the Hong Kong government as a school inspector fulfilling her own aspiration. There she gained a greater variety of experiences in maximising pupils' participation during PE lessons and school hours through good leadership and management of PE in school. She continued working as a school inspector until her retirementafter 35 years in the PE field (with 25 years spent in curriculum development, school inspection, and administration).

In Hong Kong, other than some talented pupils (normally school sports team members) who participate keenly in various sports disciplines, many pupils are not physically active even in PE lessons (even though lessons must be conducted by qualified PE specialists). This is compounded by the growing loss of PA time, especially at the senior secondary level, due to increasing demands for more curriculum time allocated to academic subjects. There is a lack of support from school personnel and parents as they prefer pupils to spend more time preparing for public examinations. PE is perceived as a lower-priority subject and has led to restrictions on PA times for pupils. Hence, the issue is now on how to develop more effective, efficient PE lessons and create more PA opportunities in school to provide pupils with adequate PA levels and the necessary skills and knowledge of sports to help them develop an active and healthy

lifestyle. After retirement, the author embarked on a PhD course which provides the opportunity to study the subject from a wider perspective, since low PA is a global issue.

Chapter 2: Background and Literature Review

2.1 Chapter Overview

This chapter reviews the literature and provides the background to this thesis. The information presented aims to provide a critical analysis of the research to date and the rationale for focusing on primary children's MVPA levels during school hours. Furthermore, it highlights the need for school PA opportunities that may help improve children's overall activity level inside and outside school hours and thus meet the health recommendations for MVPA made by many leading organisations.

2.2 Background

2.2.1 The Benefits of Physical Activity for Children and Adolescents

It is well-known that regular physical activity (PA) is associated with numerous health benefits for children and adolescents [1]. As stated in the World Health Organization (WHO) 2020 guideline [1], in children and adolescents (aged 5-17 years), "*regular physical activity (PA) can improve physical fitness (cardiorespiratory and muscular fitness), cardiometabolic health (blood pressure, dyslipidemia, glucose, and insulin resistance), bone health, cognitive outcomes (academic performance, executive function), and mental health (reduced symptoms of depression and anxiety hence it improves mood and sleep quality) and reduced adiposity"* [2]. Undoubtedly, PA ensures the best opportunity for healthy growth and development in children and adolescence and improves overall well-being [3].

As noted above, the benefits of PA also include improved capacity for pupils to learn and attain educational goals [4]-[9]. Participation in organised sports can also enhance social integrationand development of social skills [10]. Several systematic reviews have reported PA benefits in terms of physical, developmental, psychological, cognitive, and social health as well as academic achievement [10]-[14]. These multiple beneficial health outcomes in children and adolescentsare essential for their current and future health and well-being.

2.2.2 The Definitions of Key Concepts and the Health-Related Benefits of Different PA Levels

2.2.2.1 Physical Activity, Light, Moderate and Vigorous Physical Activity

We must define several terms and understand what they mean first. Physical activity (PA) refers to "*any bodily movement produced by skeletal muscle that requires energy expenditure*" [1]. According to the US Department of Health and Human Services [14], "*health is a human condition with physical, social, and psychological dimensions*". Positive health is associated with a capacity to enjoy life and withstand challenges. Negative health is associated with illness, and in the extreme, with premature death [14].

To encourage children and adolescents to engage in the appropriate intensity of PA and to guide future research into the health benefits of PA, it is essential to know the different intensities of PA and how much is needed for various health benefits. The level of activity depends upon the frequency, intensity, duration, and type of activities. Some activities are of a higher intensity value than others because they require more energy to do. Absolute rates of energy expenditure during PA are commonly described as light (LPA), moderate (MPA), or vigorous intensity (VPA) [16]. To gain a better understanding of the specific PA-induced health benefits, we need to have a clear concept of what is the intensity continuum of PA, such as sedentary behaviour (SB), LPA, MPA and VPA. The concept provides a common platform for those researching the health benefits of PA and these expressions of intensity should be familiar to the researchers so that different intensity levels can be used appropriately [16].

Intensity refers to the magnitude of the effort required to perform any activity. It can be expressed either in absolute or relative terms [14]. The absolute intensity of activities is determined by the rate of energy expenditure and can be defined according to the activities' Metabolic Equivalents (METs) value [16]. A METis the ratio of a person's working metabolic rate compared to their resting metabolic rate. One MET is the rate of energy expenditure while

sitting at rest and this level is called sedentary behaviour (SB). Details of SB will be discussed later in this chapter.

Light-intensity PA (LPA) is non-sedentary waking behaviour that requires <3 METs [14]. LPA include those activities that require standing up and moving around. Examples include moving around a classroom [17] walking at a slow or leisurely pace [18], colouring, reading writing, and the internet [19], or other incidental activities that do not result in a substantial increase in heart rate or breathing rate [1]. The Fuzeki et al. [20] systematic review suggests that in adults even LPA is associated with a range of health benefits, including lower risk of obesity and all-cause mortality, and improved markers of lipid and glucose metabolism [20]. The UK national PA guidelines [21] recommend that children and adolescents break up long periods of not moving with at least LPA, suggesting that the health benefit of LPA needs to be recognised. Time spent in LPA might helpfully displace sedentary time in children and adolescents. However, the focus of this thesis is on MVPA, the author just deals with the LPA concept briefly here.

Moderate-intensity PA (MPA) is from 3 to <6 METs. When adolescents (aged 10-12) are engaged in MPA, it raises their heart rate and makes them sweat. They are breathing harder than normal and can still talk but they can't sing a song [22]. According to a youth compendium of PA, examples of MPA include housework and active video games [19], walking to school, playing in the playground, riding a scooter/skateboard, and cycling on level ground or gentle slopes [23]. By the mid-1990s, consensus had been reached that health benefits in adults accrued from MPA [24]. Camacho et al. [25] reported that both MPA and its duration have been shown to be related to a reduction in stress levels. Fletcher and colleagues [26] similarly support the role of modest, regular MPA in the prevention and treatment of heart disease. Although these health benefits primarily apply to adults, there are also benefits for children and adolescents. A study by Sothern et al. [27] suggested that MPA may enhance overall health and

help prevent chronic disease in youth who are at risk for this disease. More importantly, by decreasing sedentary behaviours and thus potentially increasing daily MPA, individuals may experience numerous stress-reducing benefits. Sothern et al. [27] concluded that MPA of a non-structured nature seems to facilitate most of the disease prevention goals and health promotion benefits in children and adolescents.

Vigorous-intensity PA (VPA) is defined as any activity above 6 METs [16]. VPA produces larger increases in breathing or heart rate and makes children and adolescents breathe hard and fast [14] . When they are working at this level, it makes a conversation challenging. Examples of VPA, according to the compendium of PA [19], are tennis practice and games, basketball shooting, and retrieving a basketball continuously, rope skipping and relay race [19]. For most people, greater health benefits can be achieved by engaging in PA of higher intensity or longer duration [28]. Literature provides clear evidence of the benefits of VPA on adiposity, cardiovascular fitness, and bone health in children and adolescents [29]. Sacheck et al. [29] also reported that increased VPA may benefit some health parameters of children with obesity more than increasing VPA in children of normal weight.

It is evident that different intensities of PA have independent effects on health outcomes [29]: LPA, MPA and VPA provide different types and magnitudes of benefits. The 2020 WHO PA guidelines for children and adolescents (5-17 years) [1] suggest that if children and adolescents are not meeting the recommended 60 minutes of MVPA per day, doing some PA is still beneficial, as any PA is better than none [1]. The guidelines also recommended that children and adolescents start with small amounts of PA, and gradually increase the frequency, intensity, and duration over time.

However, MVPA is often used to combine MPA and VPA highlighting that greater amounts and intensities higher than LPA optimise the health benefits of PA in children and adolescents [30]-[32]. MVPA represents a level of PA with an energy expenditure at least three

times higher than that at rest (≥3 MET) [16], and it is associated with positive health outcomes in both childhood and adulthood, including weight management [33], [34], physical fitness, bone health [35], mental well-being, and educational attainment [14].

For decades, the focus of PA studies and recommendations has been on MVPA, as it represents a category of activity intensity commonly recommended for health benefits [36]. MVPA is also the intensity of PA used in movement behaviour guidelines set by WHO, the US government, and the UK government. Therefore, the focus of this thesis is primarily on primary pupils' MVPA levels during school hours.

2.2.2.2 Sedentary Behaviour (SB)

It refers to "*any waking behaviour characterised by energy expenditure ≤ 1.5 METs such as sitting, reclining, or lying"* [2], [14]. Examples of SB in daily life include TV viewing, travelling by car, and using various forms of technology such as computers and video gaming [37]. As a relatively new area, SB has received an increasing amountof attention as a public health problem because it appears to have health risks. Lives are becoming increasingly sedentary, with motorised transport and the increased use of screens for work, education, and recreation [3]. The WHO 2020 guidelines on physical activityand sedentary behaviour [1] stated that "*children and adolescents (aged 5-17 years) should limit the amount of time spent being sedentary, particularly the amount of recreational screen time"*. Some countries issued national guidelines on screen time which are described below since among children and adolescents, higher amounts of SB are associated with detrimental effects on health outcomes, including poorer cardiometabolic health, fitness, behavioural conduct/pro-social behaviour, increased adiposity, and reduced sleep duration [1].

SB is a highly prevalent behaviour in high-income countries such as America and the UK. Data collected by devices (Actigraph accelerometer (model 7164; Actigraph, LLC, Fort Walton Beach, Florida) for 7 consecutive days) employed by the U.S. National Health and Nutrition Examination Survey 2008 [38] showed that children and adolescents (n=811) aged 6-11 years

spent approximately 6 hours per day being sedentary. In 2018, Chesham et a1.[39] collected accelerometer-assessed data (Five models of accelerometer were used: ActiGraph wGT3X-BT, wGT3X+, GT3X+, GT3X and GT1M) for Scottish primary school children and adolescents (n=391) aged 4 -12 years found that their daily sedentary time was an average of 5.8 hours. A nationally representative study in Scotland carried out by McCrorie et al. in the 2015/16 school year [40] found that early adolescents (n=774) aged 10-11 years spent a mean of 7.5 hours per day in objectively measured sedentary time. These figures show that SB is high in primary school children and typically occupies a substantial proportion of the 24-h period.

On top of the WHO 2020 guideline [1], some national guidelines [23], [41] for school-age children recommend limiting sedentary recreational screen time to no more than 2 h per day and recommend breaking up long periods of sitting as often as possible [21], or replace this with light intensity PA wherever possible [42]. Yet there is still no specific guideline for total sedentary timeper day at present, and it is difficult to quantify the amount of time children are spending in SB. It is important to know the consistent definitions and common terminology of the terms SB, PA, MVPA and 'physical inactivity.' This further improves our understanding of the health impacts of SB and different intensity levels of PA. However, the focus of this thesis is on MVPA so, further detail on SB is outside the scope of this study.

Low PA levels/physical inactivity (i.e., PA level not meeting [43], [44] the WHO's PA recommendations [45] are rising in many countries with major implications for the prevalence of non-communicable diseases (NCDs) and the general health of the population worldwide [43]. People of all age groups,including children, are all vulnerable to the risk factors contributing to NCDs, and insufficientPA is now identified as the fourth leading risk factor for global mortality [43]. It has been estimated that low PA level is responsible for at least 10% and 9% of all-cause mortality in North America and European countries [43]. It is associated with 1 in 6 deaths in the UK [21]. MVPA has been proven to help prevent and manage NCDs such as heart disease,

stroke, diabetes, andseveral cancers. Therefore, the promotion of MVPA is widely regarded as a global health priority, and the failure of large numbers of people, especially children and adolescents, to achieve recommended levels of activity can justifiably be judged as a health crisis.

In 2008 it was estimated that 31.3% of persons (28% males, 34% females) aged 15+ were insufficiently active [45]. Globally, 81% of adolescents aged 11-17 years were insufficiently physically active in 2016 [45]. Childhood MVPA is therefore crucial since it helps prevent NCDs [46], which means a lower risk of cardiovascular disease, hypertension, diabetes, and many cancers in later life [47]. Low PA level in childhood and adolescence is now recognised as a major public health concern [47], [48]. So, the provision of MVPA and health education at primary school stages can potentially have an impact that lasts a lifetime [18]. This stage is a crucial period for developing good motor and movement skills, learning healthy habits, thereby establishing a firm foundation for future lifelong health and well-being [17]. Consequently, the notion that schools serve as effective settings to promote the health and well-being of all school children is of utmost importance [18].

2.2.3 Physical Activity (PA) Guidelines

There are global and national guidelines on PA that provide coherent governance and policy framework for public health action. In 2020, the WHO updated the previous PA guideline [45] and recommended that children and adolescents aged 5-17 should accumulate at least an average of 60 minutes of MVPA per day [1]. Vigorous intensity activities, including those that strengthen muscle and bone, should be incorporated at least 3 days per week, and this group of youngsters (5 to 17 years) should limit their amount of sedentary time. There is a small change in wording but a significant change in the amount of MVPA (going from at least 60 min daily to an average across the week) in the 2010 guidelines [45] compared to the 2020 guideline [1]. The newly updated WHO guidelines in 2020 [1] also recommended that for all populations,

doing some PA is better than doing none.

Correspondingly, policymakers in different countries also try to establish their own guidelines to increase PA and reduce sedentary behaviour (SB) across the life course. For example, the PA Guidelines for Americans 2018 [14] and the UK Chief Medical Officers' (CMO) PA Guidelines 2019 [21] made country-specific recommendations that all children and adolescents (aged 6-17 and 5-18 respectively) should engage in MVPA for an average of at least 60 minutes per day [14], [21]. The Canadian'24-hour movement guidelines' in 2016 [41] and similar Australian guidelines in 2019 [23] emphasise the importance of optimal time allocation during the whole day, including high levels of PA, low levels of screen time, and optimal sleepduration for overall health. These guidelines recommend that within a 24-hour period, children,and adolescents (5-13 years old) should engage in at least 60 minutes per day of MVPA, ≤ 2 hours per day of recreational screen time, and 9-11 hours of sleep per day. This relatively new 24-hour period concept is composed of movement behaviours including PA, SB, and sleep data,but that was beyond the scope of this PhD research as this thesis has a focus on MVPA and the UK and WHO PA guidelines do not include a specific recommendation for sleep time or SB time (including screen time) for the age groups of 5-13 years old.

Like most high-income countries, the USA [14] and the UK governments [21] have a PA strategy, supplemented by guidance for raising the levels of activity for differing age groups in different settings, and to recommend daily targets at a national level. The recommendations address the links between the frequency, duration, intensity, type, and total amount of PA and are established for public health action. National PA guidelines [14], [21], [23], [41] are essential as they provide the basis for setting public health goals as well as passing on messages in language and formats relevant to particular cultural contexts.

On top of the guidelines on PA and SB in 2020, the WHO also proposed a new policy action plan to enhance PE and school-based programmes in 2018 [49]. This new Global Action

Plan on PA (GAPPA) was proposed and set a new voluntary global target for PA for 2030 [49]. Hence if school-age pupils are not currently meeting these recommendations, schools should strengthen and improve their programmes and policies for PA and physical education (PE) in the school environment, including before, during, and after school to provide health benefits to pupils [50].

2.2.4 Physical Inactivity

As noted above, global estimates indicated that over 80% of school children and adolescents (aged 11-15 years) did not meet the previous WHO MVPA [45] recommendation globally [51]. Likewise, some studies show that the opportunity for children and adolescents to be active has declined in many countries over time [17]. The causes of low MVPA or the trend towards physical inactivity (defined as an insufficient PA level to meet the 60 min MVPA daily recommendations) or sedentary lifestyles across the developed country and the developing world are complex [17], but it is highly related to the compound effects of industrial, automotive, and information technology innovations [17]. Advances in technology lead to higher duration of screen time, including TV viewing, video gaming, usage of computers and mobile phones as well as the advancement of motor transportation.

To make things worse, recently, the surveillance study Active Healthy Kids Global Alliance Global Matrix 4.0, (2022) [52] found that the outbreak of the COVID-19 pandemic in March 2020 dramatically changed the daily life of families and children throughout the world. The peer-reviewed on the movement behaviours of children and adolescents published after the pandemic all consistently reported dramatic declines in self- reported or parental-reported child PA, sports participation, and active outdoor play. Findings from Neville et al. [53] systematic review (n=22 studies, median age = 10.5 range, 3-18 years) revealed a decrease of 17 minutes per day in children's MVPA from pre-pandemic to during the COVID-19 pandemic. Salway et al. [54] conducted a study on accelerometer-measured PA and sedentary time among children

and their parents in the UK before and after COVID-19 lockdowns. They found that children (aged 10-11) had 7.7 minutes less mean weekday MVPA and 25.4 minutes more mean weekday sedentary time in 2021 (post-COVID) compared to 2018 (pre-COVID). The study concluded that children's activity levels have not returned to pre-pandemic levels. Simultaneously, there were dramatic increases in screen time due to increased family TV time and screen viewing for schoolwork [54]. This trend leads to the reduction of PA among children, resulting in poorer health outcomes [47]. Given the growing concerns about low MVPA levels and related health issues, developing regular PA behaviours in childhood become increasingly crucial.

2.2.5 Physical Activity Levels in the UK and Scotland

Despite the widely reported benefits of PA and MVPA, many children across the UK are insufficiently active to meet either the national or international PA recommendations. For example, in England, from 2020 to 2021, approximately 44% of children and adolescents in school years 1-11 (aged 5-16 years) and 42% for years 3-6 (aged 7-11 years) met the Chief Medical Officers' (CMOs) guidelines for taking part in MVPA for an average of 60 minutes or more every day according to data collected by questionnaire [55]. Children and adolescents aged 8-11 achieved lower compliance than children aged 5-7 (51%). The proportion of children achieving the recommended levels of PA differed across school year groups, with those in years 1 to 2 being more likely to meet the guideline (51%) than those in years 3 to 6 (42%) andyears 7 to 11 (43%) [55].

In Scotland, according to the major national survey, the Scottish Health Survey (SHeS) [56] in 2019, data collected via questionnaire showed that 69% of children and adolescents aged 2-15 were physically active at the recommended level (including activity at school). However, it was a significant decrease compared with SHeS in 2016 (76%). This decrease appears to be driven by a drop in activity levels among boys, for whom the proportion meeting the PA guidelines including school-based activity, was 71% (79% in 2016) and for girls, it was 68%

(72% in 2016), which showed no significant decrease for girls.

Also, the same survey [56] indicated that PA levels amongst children varied significantly by age, with the highest proportions that met the PA guideline recorded among children aged 8-10 (79%) and aged 5-7 (78%). Amongst all children, the largest increase in proportions meeting the PA guideline was recorded between 2-4 and 5-7 age groups (67% up to 78%), while the largest decrease was recorded between those aged 11-12 (from 79% down to 69%) and those aged 13-15 (69% down to 53%) [56]. However, the SHeS is based on subjective measures (parents' questionnaires) which categorise light intensity PA as MVPA which leads to an overestimation of time spent in MVPA [57]. This error may, therefore, affect the proportion of children and adolescents reaching the guideline.

Moreover, there are some other sources of evidence that show few Scottish children and adolescents meet the guidelines for PA and SB, suggesting that only a small proportion of Scottish children and adolescents achieve 60 minutes MVPA per day. The 2021 Active Healthy Kids Scotland Report Card [58] indicated that PA and the health of children and youth have not improved despite a decade of favourable policy. The Health Behaviours in School-Age Children survey (HBSC-2018) [59], which provided data for time spent in MVPA by self-report for ages 11,13 and 15 adolescents, reported that 17% (with 20% of 11-year-olds) of adolescents did 60 minutes of MVPA every day [59]. A study (with a nationally representative sample) published by McCrorie et al. in 2018 [40] showed that only 11% of adolescents aged 10-11 yearsachieved the recommended 60-minute MVPA threshold when using the 60 minutes of MVPA everyday approach.

Results from the SHeS [56] indicated that children's PA levels drop from aged 8-10 years to the largest decrease at the age of 11-12 (from 79% down to 69%). For pupils, the senior primary level (8-11 years old) is a transitional period from the primary to the secondary phase, and this may be the continuation of the decline starting earlier,from age 6-7. MVPA falls steadily on

average across childhood and adolescence [60], and it is important to understand MVPA in childhood as it can help schools prevent or minimise the age-related decline in MVPA. Janssen et al.'s study [61] reported that the largest increase in sedentary time and decrease in sedentary fragmentation was noted from age 9 to 12 years old [61]. Also, it is well documented in the literature that PA levels decline from childhood to adolescence [62], [63] and further into adulthood [64]. For example, data from the Bristol B-Proactiv cohort, which began in 2012/13 and included around 2,000 children from 57 schools, showed that the mean minutes of MVPA per day on weekdays declined by 2.2 minutes per year (95% confidence interval: 1.9 to 2.5) between 6 and 11 years of age [68].

Hence, there is a need to study the MVPA levels of this particular group (8-11 years old), namely pupils during late childhood and early adolescence. (The World Health Organization, WHO, defines a child up to the age of 9.9 years and adolescents from 10.0 to 19.9 years) [69].

2.2.6 Target Participants

According to the WHO [69]:

"Adolescence is the phase of life between childhood and adulthood, from ages 10 to 19. It is a unique stage of human development and an important time for laying the foundations of good health" [69]. The target participants of this thesis are senior primary pupils aged 8-11 years (aged 8-11 for Studies 1 and 2, aged 10-11 for Studies 3 and 4). Based on the findings from various sources mentioned above, figures indicate that substantial numbers of children and adolescents do not engage in sufficient activity during childhood and adolescence to gain health benefits. Moreover, children's MVPA levels decrease at this age range. Hence, the primary school stage of life is a crucial period, for promoting MVPA to improve their health outcomes and development, during which many health-related behaviours and interests are formed [70].

To scrutinise the activity pattern/levels and investigate the problem of declining MVPA levels in children, it is important to consider the primary school environment, as children spend

a large amount of time at school. Examining children's MVPA patterns/levels during school hours may provide insights into the development of effective MVPA interventions. In addition, there is limited evidence for a large nationally representative sample study on the school hours MVPA level for adolescents aged 10-11 years.

Therefore, the scope of work of this thesis focuses on MVPA in physical education (PE) as well as on MVPA during school hours and recess time. The first area of focus is on identifying effective strategies to make PE lessons more active. The second one is to explore and evaluate children's MVPA levels during school hours and recess in Scotland. The risk factors influencing the accrued levels are also explored. The third one is to provide a clearer insight into the issues of school-based MVPA levels, so a holistic school approach (through PE, recess, and other domains of PA in school) might be developed for consideration by policymakers, teachers, and research stakeholders to engage children more in MVPA.

2.3 Measurement of Moderate-to-Vigorous Physical Activity

The estimation of PA amongst children and adolescents is critical for quantifying PA behaviours and evaluating the effect of PA intervention [71]. Suitable approaches and instruments are crucial to assess levels of PA effectively. In other words, when measuring MVPA, it is important to employ a measuring tool that is valid (measures MVPA accurately), reliable (measures MVPA consistently and produces a good measurement of the average level of MVPA), and takes into account normal day-to-day variation [72], [73]. Though the doubly labelled water method is widely acknowledged as a gold standard for assessing total daily energy expenditure in diverse populations, it is not often used for research studies as it is expensive and time intensive. Also, it does not measure MVPA specifically and requires training and skill to administer and analyse [74], [75]. There are other types of device-based methods to measure MVPA and sedentary levels like activity monitors (e.g., heart rate, pedometers, or accelerometers) or by direct observation [71].

The subjective measurement methods for measuring MVPA in children and adolescents include self-reports, questionnaire surveys, interviews, proxy reports (e.g., parent reports), and pupils' diaries. However, some of the reports (e.g., parent reports) have been widely criticised as categorising any PA reported by parents as MVPA, leading to a substantial overestimation of time spent in MVPA [57]. The Hidding et al.[76] systematic review aimed to summarise the available studies on the measurement properties of PA questionnaires for young people under the age of 18. They found 87 articles covering 89 different questionnaires, none were identified as having conclusive evidence of both acceptable validity and reliability. This suggests that current research and practice involves using PA questionnaires with unknown validity and reliability [76], indicating that these questionnaires may not adequately reflect the PA levels of children and adolescents.

There are problems inherent with any PA measurement tools [72] as with limitations and strengths of the methods they employ. likewise, device-based methods to measure MVPA have limitations too. They are mainly related to equipment issues (e.g., setting up), the participant's ability to use equipment properly, and their adherence to protocol (i.e., poor internal validity) [77]. For example, the heart rate (HR) monitor is less commonly used in PA research, particularly among the child population, as it cannot detect PA intensities accurately [78]. HR monitoring is largely used in exercise or sports training to ensure athletes areworking at the correct PA intensity [79]. However, PA is not the sole reason for an increase in heart rate and fitter children often display a lower resting and exercising heart rate compared to less fit children [80]. The disadvantages of pedometers are that they do not record the intensity, frequency, or duration of PA [78], [81] and have significantly less data storage capacity than accelerometers [82]. Also, there are problems with accelerometers as the devices are expensive and require technical expertise, specialised hardware, software, and individual coding [83].

There are various direct observation tools that have been used as criteria for validating PA

measures in different PA contexts [84], such as the System for Observing Fitness and Instruction Time (SOFIT), the System for Observing Play and Leisure Activity in Youth (SOPLAY), and the System for Observing Children's Activity and Relationships during Play (SOCARP). These tools can quantify MVPA while simultaneously collecting qualitative data, providing contextual information that some other devices cannot. For example, SOFIT is a tool used to assess PE classes, allowing for the simultaneous collection of data on three variables including children's activity levels, lesson context and teacher promotion of PA [85]. SOPLAY is a validated instrument developed to evaluate PA across multiple leisure-time and play settings, such as recess, before- and after school programmes, and playgrounds, for all school-aged children [84]. Meanwhile, SOCARP is designed for use outside the PE context [86]. These various direct-observation methods give researchers different options to evaluate PA.

Yet, direct observation includes the high cost of time [87], and so, it is not practical for all real-world activities. Self-report questionnaires are the most common method of PA assessment and rely on participants'/parents' (when parents help their children to complete the questionnaires) recall ability. However, these subjective methods are affected by reliability and validity issues due to the requirement of participants to accurately answer questions or recall their PA levels as noted above [76], [88]. Therefore, they tend to overestimate true levels of PA in children and adults.

For this thesis, it is essential to collect consistent and repeated measures of domain-specific PA to further our understanding of how PA accumulated in different domains in school might impact overall activity levels. Accelerometers are the type of wearable monitor that has been considered an ideal tool for the objective assessment of children's PA. The device provides data on the frequency, duration, and intensity of PA for prolonged periods with minimal interference in daily life [78]. Furthermore, accelerometers are suitable for many types of comparative studies (e.g., sex, age, and health) [89]. The use of accelerometers in children has contributed

significantly to an understanding of children's PA [90], tracking of activity [91], age and sex differences in activity [92], environmental influences on activity [93], and numerous other areas. Accelerometry is often used in validation studies and is considered a more valid and reliable tool to assess MVPA than self or proxy reports [87] and these advantages are supported by some systematic reviews and individual studies [94]-[96]. Moreover, accelerometers are considered the best option for accurately estimating how active children are during school [97]. One of the most widely used devices to objectively assess PA in research is the hip-worn accelerometer ActiGraph [96], [98]. The data used for secondary analysis in this thesis was collected using a hip-worn ActiGraph accelerometer, rather than data obtained through by other measurement approaches. A study [99] found that wrist-worn accelerometers have become widely adopted [100], as children prefer the wrist as the device placement site. Additionally, the study [99] reported that wrist placement promotes better compliance compared to hip placement. A full and detailed discussion of the differences between the various methods is beyond the scope of this thesis. The following subsection will provide an evaluation of the accelerometer device for assessing children's PA.

2.3.1 Accelerometer-assessed Moderate-to-Vigorous Physical Activity

In recent years accelerometers have been recognised as the most widely used device to assess PA in research due to their accuracy, the capability of assessing large numbers of participants, and ease of administration in children [71], [101], [102]. Researchers can use accelerometer data to compute PA volume, rate, and time spent in PA of different intensities [71]. With the ability to capture MVPA and classify participants into SB, low and high categories of PA, the accelerometer data can be used for checking the achievement of public health guidelines and classification of PA levels [71]. Moreover, accelerometers provide less of a burden than that of heart rate monitors and, they can detect short bursts of PA in children [103]. Despite the benefits of accelerometers, there is a need to pay attention to some methodological issues and

limitations when using accelerometers as the method of choice in school-based PA studies.

2.3.2 A Cut-Point to Measure Time Spent in Moderate-to-Vigorous Physical Activity Using Accelerometer Data

It is necessary to explain why accelerometer cut points are needed and why they have been used. Accelerometers record accelerations, which, in the case of ActiGraph, are converted to counts and averaged per epoch, and which do not in themselves mean anything, other than the fact that the higher the count, the higher the acceleration (movement). To create the link between accelerometer counts and PA intensity, it is necessary to establish a"cut point" to quantify accumulated time in PA intensity thresholds by calibrating accelerometer data against a criterion measure, such as indirect calorimetry [97]. Cut points are used to estimate PA levels from accelerometers and to enable accelerometer data to be presented and interpreted in relation to public health guidance [97]. A cut-point defines the count per epoch threshold for moderate-intensity PA (i.e., 3 METs). Counts corresponding to defined values for energy expenditure and MVPA are then regarded as "cut point" for moderate and above intensity PA [104].

So, for the count to be interpreted as a concept which we feel matters like MVPA, calibration studies need to be done to identify at what point in the count range is MVPA measured accurately. Cut point that estimates MVPA most closely to that of the criterion measure are considered the most "accurate" and are recommended for widespread application. Measurements of PA intensity is influenced by the cut-point used when using accelerometry data [104]. Hence, choosing different cut point can influence the results of PA measurement, the amount of MVPA measured for example. Furthermore, it is important to note that the cut points we are discussing here refer to absolute intensity and do not account for differences in individuals' relative intensity (e.g., based on fitness, health status, etc.). As reported by Fridolfsson et al. [105], accelerometer-measured relative PA intensity reflects the intensity that is associated with health benefits, regardless of fitness level. This inevitably means that some

individuals may be misclassified as engaging in MVPA when they are not very fit (i.e., lower fitness), and as not engaging in MVPA when they are more fit (i.e., higher fitness).

There is no consensus regarding which accelerometer cut point is most acceptable to estimate the time spent in MVPA in children. The choice of an appropriate cut-point primarily remains a researcher-driven decision along with many other decisions that researchers make, and this might affect the amount of MVPA measured (e.g., choice of cut-point, wear location, wear time criteria, device type, etc.) [106]. Hence, the variability of accelerometer-based cut-point can lead to methodological challenges in the interpretation of PA results like the level or amount of MVPA measured [107]. The use of different cut points results in vastly different estimates of PA and varying degrees of compliance with PA guidelines [97]. It may misrepresentthe proportion of children who meet the PA recommendation [107]. As a result, a meaningful comparison between the findings of various studies is extremely difficult and could be significantly biased [107]. For example, Gaba A et al.'s [107] study analysed the influence of cut-point selection on the mean MVPA and defined the optimal thresholds of MVPA derived from different accelerometer cut-point to avoid overweight /obesity and adiposity in children and adolescents aged 7 to 12 years [107]. The results showed that out of 360 participants, the optimal thresholds for counts per minute (cpm) and MVPA derived from the Puyau's [108] cut-point (3200 cpm) and Evenson's [87] cut-point (2296 cpm) were different. Therefore, ideally, the validity of various cut points should be carefully examined for different populations [97].

In Evenson et al.'s calibration study in 2008 [87], with the help of an ActiGraph accelerometer on children's right hip, which measured counts per minute, the researchers determined the threshold counts to classify the intensity of different activities (for example watching a DVD (sedentary), slow walk (light), brisk walk (moderate) and treadmill running (vigorous)) among children 5 to 8 years of age (n=33). Analysis of cut point that maximised

both sensitivity and specificity weredetermined for sedentary, moderate, and vigorous intensity activities. The results suggested that the accelerometer can be used to distinguish differing levels of PA intensity as well as inactivity among children. In this study, Everson developed the accelerometer values ≥2296 cpm as cut-point to define children's MVPA [87].

Based on the above calibration study [87], the researcher of this thesis chose Evenson's cut points to analyse the data for this thesis. There are four reasons for this choice. First, in 2017, Migueles and colleagues [109] conducted a systematic review and included all original studies in which the GT3X/+ was used in laboratory, controlled, or free-living conditions. They aimed to review data collection and processing criteria when using GT3X/+ and provide age-specific practical considerations based on the validation/calibration studies. In this review, they adopted average counts per minute (cpm) as a measure of total PA and used Evenson cut-points [87] to define light- (101 to 2295 cpm), moderate- (≥ 2296 cpm), and vigorous-intensity (≥ 4012 cpm) physical activity. One of the studies [110] in this systematic review [109] observed a better accuracy with the cut-points proposed by Evenson than with alternative cut points [87]. Migueles et al., therefore, suggested these cut points as the most appropriate cut points for children and adolescents [109].

Second, in an independent evaluation of ActiGraph cut point for adolescents, Trost et al. [111] found Evenson thresholds have the least PA intensity classification error of all the cut point tested and show the best overall performance across all intensity levels. These cut points provided acceptable classification accuracy for all four levels of PA intensity and performed well among children of all ages [111]. However, it is important to acknowledge that in the study by Trost et al. the Evenson cut points still misclassified MVPA as LPA 20% of the time and misclassified LPA as SB 40% of the time [111], [112].

Third, the popularity of Evenson cut point makes the present thesis results relatively easy to compare with other studies. Fourthly, Evenson thresholds are more conservative and tend to

push up the amount of MVPA measured, rather than the higher cut-point from other authors such as Puyau [108] and Mattocks [113]. A full discussion of the differences between the various cut points is beyond the scope of this thesis, so no further details on cut-points will be provided here. However, it is worth noting that there are other analytical approaches for researchers to analysis and utilise accelerometer data. An international workshop leading to the GRANADA consensus in October 2019 [114] determined steps and cut-off points are not the only metrics for analysing accelerometer outcomes. Accelerometer-measured PA is generally incorporated as part of the exposure variables and health outcomes, which now include time-use and acceleration-based metrics [114]. This implies that other accelerometer outcomes and metrics are now available to explore and demonstrate the inter-relationship and interactions between different movement behaviours (including PA, SB and sleep).

2.3.3 Restrictions on the Types of Activity Accelerometer Can Measure

The accelerometer cannot capture all MVPA, since it depends on the type of activity [78], [115]. For example, accelerometry does not adequately capture movement, such as water-based activities,as the devices might be removed before these activities. Likewise, some activities (e.g., lifting objects and cycling) are poorly measured by hip-worn accelerometers [78] because there is little concordance between accelerometry and energy expenditure during movements with static hip position [116]. Since accelerometry measures the movement of only one body part (the wrist or waist where it is worn, it does not provide any contextual information [71] related to the whole body). So, as a device measurement tool that is often used in validation studies [117], the results of its assessment should be interpreted with caution. Also, accelerometer measurements do not provide information about the context in which PA is performed [118]. However, since the aim of this thesis is to understand MVPA during school hours the context is known (school) and activities such as swimming and cycling are not common in school. For these reasons, the issues mentioned above are not problematic for the

studies in this thesis.

2.3.4 Minimum Wear Time Using Accelerometer Data

When using accelerometers-assessed PA measurements, it is important to determine whether each child/adolescent wore their accelerometer for long enough to provide a reliable estimate of PA and be included in the analyses [119]. MVPA varies from day to day, therefore, it is necessary to ensure children wear the accelerometer for a sufficient period of time to measure the usual time spent in MVPA well, by defining the minimum number of minutes per day and the minimum number of days that the device needs to be worn [119]. It is better to have more days than fewer days in order to capture that variation and so obtain a more stable/reliable estimate of the amount of MVPA because reliability increases as the minimum number of days and the daily wear time increases [120], [121].

There are a limited number of empirical investigations of the length of the accelerometry monitoring periods [122] (i.e., the minimum number of days required to obtain a stable estimate of habitual PA or SB [123]), and the reliability of monitoring may vary between populations and may vary with age [120]. Trost et al.'s study in 2000 [120] established the minimal number of days of monitoring required for accelerometers to assess usual PA in children by involving 381 participants (aged 6 to 17). The results indicate that within all grade levels, the 7-day monitoring protocol produced acceptable estimates of daily participation in MVPA [120]. In 2011, Basterfield et al. [123] provided estimates of the minimum monitoring period for acceptablestability of measurements of habitual PA, MVPA, and SB among 291 English 6- to 8-year-oldschildren. They found that 7 days of monitoring (within and beyond school hours) provided reliabilities of 83% for the volume of activity (cpm), 83% for habitual MVPA, and 85% for habitual SB and these reliabilities were considered to be high and acceptable for most purposes [123]. Basterfield et al. [123] also measured (using Actigraph GT1M accelerometers) the participants in community setting, not limited to school hours and found a similar result that

3 days of monitoring provided around a widely accepted minimum of 70% reliability for estimates of habitual total volume of PA, MVPA, and SB [123].

However, there are limited large-scale studies on children to define the minimum daily wear time (and these do not focus on the time needed to obtain good measures of MVPA during school hours) [119]. Several studies make suggestions, with thresholds ranging from at least four [124] to at least 10 hours per day and three days per child [125], [126] probably the most commonly used. Scottish children typically attend school from 9 am to 3 pm (six hours) for five days (Monday-Friday). To get an eligible representation of children's usual MVPA levels on an average school day during a typical school week in Scotland, we used minimum wear criteria of ≥ three days lasting ≥4 h/ during school hours and recess/day (4-h is two-thirds of a 6-hour school day or contains at least 70% of a full school daytime) [119] in the current thesis. The minimum wear time and actual wear time are given in the individual studies later in the thesis.

2.4 The Opportunities for Physical Activity in Primary School

Schools can play an active role by 2023 to help reduce the global prevalence of physical inactivity in adolescents by 15% [49]. This plan recommended actions for schools to promote PAfor pupils including strengthening the provision of good-quality PE, providing more positive experiences and opportunities for active recreation, sports, and play for pupils, establishing and reinforcing lifelong health and physical literacy, and promoting the enjoyment of, and participating in, physical activity according to capacity and ability [49]. Though this plan [49] is related to adolescents, all these positive experiences and opportunities for PA provided by the schools should benefit both children and adolescents.

2.4.1 The Primary School as a Setting for Physical Activity Intervention

This thesis focuses on the primary school setting, as the school is a key environment in which to offer quality activity education and possibilities for an active day to large numbers of children [47], [127]. There are numerous characteristics of schools that make them excellent settings for

the promotion of health-enhancing PA. First, schools can reach the full socio-economic spectrum of the paediatric population and engage them regardless of individual circumstances [127]. Second, schools have the infrastructure (easily accessible physicalenvironments) to regularly engage children in PA [128]. Third, schools can develop children's health-related behaviours and interests during a crucial period of their developmental stage which can be carried forward into later life [129]. Fourth, schools can promote PA by integrating the knowledge, skills, attitudes, and values that underpin regular PA with other health-related messages [130]. So, schools have a role to play in this critical effort to address low PA for the enhancement of children's well-being. The WHO warns that insufficient PA levels can have serious implications for people's health [131]. Schools need to heed the warning and deliver programmes to tackle the problem of children's low PA levels amid the increasing pressure on the academic achievements of children [132].

Hence schools have vital opportunities to support PA to shape healthy habits. School policymakers and other stakeholders such as school head teachers will need to develop effective strategies for promoting MVPA [18] through different domains of PA across the primary school day. In 2022, the WHO issued a policy brief promoting PA through school [47]. The estimates indicate that a high percentage of children and adolescents in school are not meeting the recommendations of 30 minutes of MVPA per schooltime/school day [47]. The policy brief described the importance of integrating PA into schools, so that all children can be physically active on a regular basis [47].

Children and adolescents spend most of their time in school other than at home. In Scotland, though each local authority sets its own terms time and school holidays, the school year, in general, lasts at least 190 days (38 weeks) and children spend up to 6 hours daily (typically from 9 am to 3 pm) at school. The usual length of the week for most primary schoolchildren is 25 hours [133]. This opportunity makes schools an extremely attractive option for increasing

PA in pupils through PA interventions because schools are the only societal institutions in which a very large proportion of children and adolescents can be reached [17]. In addition, school is the place to offer quality PA education and possibilities for an active schoolday [47]. The school setting can influence and enable many children and adolescents at once to involve themselves in PA opportunities. Hence, schools can play a crucial role in helping their pupils meet PA guidelines [18], [134].

Moreover, numerous children from differing backgrounds, including children from lower socioeconomic or ethnic minority families, can be easily accessed through schools [17] and so curriculum-based PE programmes often become the only opportunity for all school-aged children to access health-enhancing PA [18]. By offering all pupils the same opportunities for improved health through PA programmes (which play a special role in children who cannot afford to join organised recreational sports/sports clubs), and by ensuring equity in access to PA and PE [17], [18], some schools have acted as 'socioeconomic equalisers' [18]. It has been suggested that schools are key environments for PA promotion, regardless of the individual circumstances of a child [17], [127]. The American Heart Association [128] and the UK Government [135] recommended that at least 30 minutes of MVPA should be delivered in school every day. As recommended by the WHO, all children and adolescents (age 5-17) should participate in ≥60 minutes per day of MVPA [45]. Based on this guideline, schools need to do more to encourage every pupil to get at least 60 minutes of MVPA a day. A day half (at least 30 min) of the daily recommendation for MVPA should be accrued during school hours through different domains of PA at schools [18], [135].

During the school day, PE and recess times offer children regular opportunities to engage in PA, and these are two main opportunities for children to be active at school [136]. There are also other PA opportunities within the school setting such as, active travel to and from school, extra-curricular activities (ECA), /school sports before and after the school day as well

as school-linked community programmes [18]. Some studies have suggested that school recess [137] and PE [136], [138] provided the greatest levels of children's MVPA, and they are mandatory parts of the school day in the UK. So, to promote MVPA and help children and adolescents meet the schoolhours guidelines set by the US and UK government, schools can make effective use of these two mandatory segments of school time (i.e., PE lessons and recess) as the basis for providing more PA opportunities for pupils within school hours.

Nonetheless, it should be noted that there are approximately as many school days as 'non-school' days (allowing for holidays, weekends, and absences from school). There is good supporting evidence [139], [140] globally for the hypothesis that primary schoolchildren generally get less MVPA on non-school days (non-structured days). Brazendale et al.'s [141] systematic review found that children from multiple countries/regions accumulated significantly more MVPA on weekdays versus weekend days during school months [141]. This means that other than school days and school hours, the promotion of MVPA should also be prioritised to provide opportunities for all children to access additional opportunities to be active during less-structured days, such as weekend days.

2.4.2 Physical Education Lessons

Physical education (PE) is structured and supervised PA that takes place at school and during the school day [142]. As one of the school subjects, the goals of PE are broad, including providing pupils with the knowledge, skills, abilities, and confidence to be physically active throughout their lifetime [143]. The WHO Policy brief [47] notes that PE provides children with competence and confidence in PA, and this increases the likelihood that children will choose to be active in their own time [47]. The Association for Physical Education (AfPE) [144] of Scotland recommended that the learning experience offered to children and adolescents through PE lessons should be developmentally appropriate to help them acquire the psychomotor skills, cognitive understanding, as well as social and emotional skills they need to

lead a physically active life, Therefore, PE should act as the foundation for a lifelong engagement in PA [144].

The Sallis and McKenzie paper in 1991 [145] described the importance of PE in addressing public health problems and they advocated that PE should be placed in a public health context. The two main goals of PE mentioned in this paper were: (a) to prepare pupils for a lifetime of PA, and (b) to provide them with PA during PE. These goals represent not only the lifelong benefits of health-enhancing PE that enable children and adolescents to become active adults throughout their lives, but they also benefit from an immediate, tangible outcome from participating in PE [143] because pupils gained high levels of MVPA during PE lessons.

PE is the mandatory programme for all pupils and offers an opportunity to increase MVPA during the school day, hence it could make a significant contribution to overall PA [146], both in the short term and long term. Some research suggests that PE positively affects children's out-of-school PA by promoting PA enjoyment and healthy lifestyle choices [147]. Importantly, for many children and adolescents, particularly those from less affluent backgrounds, school PE may be the only opportunity for them to participate in structured PA. The Society of Health and Physical Educators (SHAPE) America [148] recommends, therefore, that schools provide 150 minutes of PE per week for primary school children. While the Center for Disease Control & Prevention (CDC, USA) [149], and the UK Association for PE (AfPE, UK) [150] recommend that MVPA levels during primary school PE lessons should reach 50% of lesson time. These could be meaningful contributions to the 60-minute MVPA per day recommended [18]. However, systematic reviews previously reported [151] [152] that MVPA in many PE lessons falls well below the 50% threshold recommended.

The discipline of PE has great potential for impacting the PA levels of children and adolescents and, in turn, the population in general. At the simplest level this requires maximising the levels of PA pupils experience during PE teaching. Making PA meaningful for

all pupils promotes PA participation beyond the curriculum. To reach its potential as an agent of change in the health of populations around the world, strategies to maximise meaningful PA opportunities during PE and beyond are essential. Accordingly, quality PE contributes to a child's daily accumulation of PA and is of particular importance for children who are overweight or who lack access to PA opportunities in the home environment [153].

Teachers who conduct PE lessons play a vital role in this respect as they can encourage pupils to embrace school PE. Donkor et al. study [154] found that inadequate training in PE, negative perception about PE, lack of expertise/interest for teaching PE and high level of accountability for other subjects were the main teacher-related barriers to effective teaching of PE in public primary schools [154]. Therefore, if pupils perceive PE as unpleasant experience due to these teacher-related barriers, pupils may avoid PE and drop out altogether, not achieving the curriculum expected health and well-being benefits through school PE. This is a huge challenge for schools in managing and monitoring their PA policy and the role conflict that is apparent for PE teachers, it may be one of the barriers to the effective promotion of PA as well. For more than three decades the field of PE has been called to play a role in the public health battle against youth physical inactivity and associated non-communicable diseases [155]. Making PA levels a priority during PE, making teachers aware of the importance of PA, orproviding teachers with proper skills to engage pupils at high PA levels become particularly urgent [155]. However, PA levels cannot be the only target of PE-based intervention and research. The role of PE in lifelong PA is also important to the fields of health and education.

2.4.3 Interventions to Increase Moderate-to-Vigorous Physical Activity During PE Lessons

MVPA levels during PE lessons often fall short of 50% of the lesson time benchmark. Hollis et al. [152] carried out a systematic review in 2015 to examine elementary school pupils' MVPA levels during PE lessons. From thirteen studies (with pupils aged 4-12 years), they

found that a mean of 36% of PE time in MVPA was recorded in the PE lesson. In a more recent study, Crotti and colleagues 2022 [156] reported that pupils only spend between 10% and 42% ofPE time engaged in MVPA [157]-[160]. Since PE interventions serve as a convenient and inexpensive way of fostering PA, there are numerous interventions to increase children's MVPA levels during primary PE lessons and their effects vary.

To determine the effectiveness of interventions to increase pupils' MVPA in PE lessons, Lonsdale et al.'s systematic review [161] published in 2013 included fourteen studies, seven conducted in primary school (from primary years 4-6), five implemented in years 7-9 and two studies were carried out in year 10. The two main types of intervention identified in this review were 'teaching strategies' (including selecting effective activities to encourage MVPA, class organisation, management, and instruction), and 'fitness infusion (high-intensity activities were supplemented when pupils participated in sports activities). The review by Lonsdale et al. [161] concluded that the pupils in intervention conditions spent on average 24% more lesson time in MVPA than in usual practice conditions. Fitness infusion interventions were more effective than the teaching strategies [161]. Hollis et al.'s systematic review [152] also identified some effective intervention strategies including aerobically intense PE, fitness infusion strategy, and the use of specialist-taught school PE [152]. However, the long-term sustainability of the fitness infusion is unknown as this type of intervention only measured MVPA during the intervention in the lesson with no follow-up [161].

It is believed that PE-trained teachers can use more effective teaching approaches to engage pupils in activities and so increase time spent moving during the lessons and in turn increase time spent in MVPA during PE lessons. Lonsdale et al. [161] in their systematic review suggested that professional training focusing on teacher pedagogy and behaviour offers considerable potential for increasing MVPA during PE in children and adolescents. Pupils need frequent opportunities for practice to develop the skills and confidence that promote ongoing

engagement in PA [18]. PE curricula are structured to provide developmentally appropriate experiences that build the motor skills and self-efficacy that underlie lifelong participation in health-enhancing PA, and trained PE specialists are better qualified to deliver them [18]. These studies revealed that teaching pedagogy is influential in increasing children's MVPA levels during PE lessons, challenges to providing MVPA might be greater for non-PE teachers/generalist class teachers. Therefore, providing professional development programmes for generalist class teachers to teach PE is likely to be important.

2.4.4 School Recess

School recess (or break time) is part of the school standard timetable at primary level. Recess time is generally understood as the non-curricular time allocated by schools between lessons for children to engage in leisure activities [162]. It presents an opportunity to engage almost all children in healthy PA on a daily basis in an environment that often provides space and facilities for PA. There is no universal recommendation for the percentage of recess time that should be devoted to PA. However, some organisations and researchers have suggested that children should spend a significant portion of recess time being active and emphasised the importance of promoting PA during recess. Both the Centers for Disease Control and Prevention (CDC) [149] and the Society of Health and Physical Educators (SHAPE) America [148] recommended that schools provide at least 20 minutes of recess per day for elementary school children, but they did not specify the recommended percentage of recess time that should be devoted to PA/MVPA.

As proposed by Stratton and Mullan in 2005 [163], MVPA should cover at least 50% of the entire recess. However, they found that only 14% of pupils (aged 4-11 years old) met this goal.Therefore, Ridgers and Stratton [164] recommended that pupils (6-11 years old) should spend at least 40% of recess time in MVPA, and this benchmark was widely accepted and has been used in the academic field since [165]. This 40% recess time benchmark is useful as it

provides a more realistic target and a fairly widely accepted yardstick and that allows researchers and other stakeholders to make judgements about whether recess is active enough making public health surveillance possible. Surveillance normally only happens when there is some quantitative benchmark or standards or guideline to compare against and if there is not, then it is hard to monitor. However, it is noted that the benchmark (50% or 40%) has not been based on modern evidence, or on modern methods of systematic review and evidence synthesis. Despite lowering the target, the percentage of pupils who could meet the 40% recess time MVPA benchmark may possibly remain very low [166].

2.4.5 Interventions to Increase Moderate-to-Vigorous Physical Activity During Recess in Primary School

Recess time has been identified as a potentially valuable setting for the promotion of healthy behaviours especially PA [167]. Ridgers et al. [164] suggested that recess time can make a worthwhile contribution to the recommended 60 min of MVPA per day. There has been increasing interest in the promotion of children's MVPA during school recess using a number of different strategies. The number of interventions during recess has markedly increased in recent years [168]. Most schools have an outdoor play area (the playground), sometimes with equipment, a garden, or shelter. Children can spend time playing during the morning break and at lunchtime. If schools could focus on promotion of PA during recess, it might be one way to increase MVPA among boys and girls.

There is a need to examine the context of recess time and to understand and target individual as well as environmental factors to change children's PA behaviour [169]. Thus, targeted intervention strategies could be developed aiming at increasing MVPA during this daily school segment. Parrish et al.'s systematic review 2020 [168] included forty-three studies and they identified several different categories of school recess interventions to increase playground PA. These strategies included multicomponent interventions (e.g., combination of

equipment, staff training, playground modifications) [170], [171], structured recess (e.g., organised activities for pupils, generally led by a teacher or coach) [172], [173], loose equipment (e.g., games equipment and car tires) [174]. Creating natural environments within the school playground [175] as well as reducing playground density [176] should also help. The results suggest that school recessinterventions increase primary school children's PA levels during break time. However, no consistent effects on pupils' school recess MVPA levels were observed, though the multicomponent strategy was the most commonly implemented intervention. Similar findingswere observed for structured recess. Installing loose equipment and creating natural environments within the school playground suggest these strategies have promoted activities for moderate to vigorous intensities in general. There were also promising findings forintervention strategies like playground marking [177], [178].

While some studies have identified effective interventions that increase pupils MVPA during PE lessons [152], [161] and recess [179], [180], other studies have not yielded positive results. For example, Metcalf et al.'s [181] systematic review (n=30 studies, with a median participant age of 9.8 years) found that PA interventions have little impact on children's overall activity levels. The review also reported that measuring intervention effects only during specific periods, such as PE classes, recess, or school hours, may not accurately reflect the intervention's effect on whole-day PA [181]. The authors, therefore, recommended that future studies capture both whole-day activity and activity during intervention-specific periods. In addition to measuring real-time activity responses to interventions, it is also valuable to assess whether these responses are subject to replacement or compensation later on-whether gains in PA during the intervention period are lost at other times of the day. Moreover, conducting within-study risk group analyses could help determine whether the intervention achieves its intended effect in the children who stand to benefit the most [181].

Similarly, Love et al.'s [182] systematic review (n = 25 studies, participants aged 6–18

years at baseline) found that, when restricted to cluster-randomised controlled trials using accelerometer-measured outcomes, school-based interventions in children and adolescents are not effective in increasing minutes spent in MVPA across the full day. This may be due to well-designed interventions not reaching the target populations as intended, or to effects not being maintained throughout the day. Jago et al. [183] showed that the standard approach in the field, which has focused on tightly constrained interventions not adapted to the school or local context, may be limiting effectiveness.

To overcome these barriers, Jago et al. suggested that in the design and analysis of school-based PA interventions, greater consideration should be given to the school context, and a wider range of outcomes should be explored to improve children's PA and health in the long term. A context-specific approach proposed by Jago et al. [183] enables schools to account for their culture, ethos, priorities, context, and complex systems, making results more generalisable across different school settings. Furthermore, the evaluation of interventions could be driven by the specific characteristics of the intervention itself, which depend on the school context. This approach to both the design and evaluation of school-based PA interventions is likely to achieve a wider range of primary outcomes that align with the intervention's context, hopefully improving future PA intervention development and implementation.

2.5 Other Physical Activity Opportunities During and Outside School Hours

As mentioned in Section 2.4.1, school is an important arena for children's PA, hence it is important for school to provide all children with safe, equitable and varied opportunities to be active. Hence, there is a national guideline (e.g. the US [128] and the UK [135]) recommended that *"schools should ensure that all children and youth participate in a minimum of 30 minutes of moderate-to-vigorous physical activity* during the school day (both during and outside school time). Nonetheless, a systematic review carried out by Grao-Cruces et al. [184] found that pupils'MVPA levels during school hours are typically lower than 30 minutes per day. There

were twenty-nine studies (with 21 studies covering primary school) included in this review and most of them (n=19) used accelerometers to measure MVPA. The result showed that primary children (6-12 years old) spent from 4% to 11% [184] of school hours in MVPA. These studies also found that less than a quarter of children and adolescents reached the 30-minute benchmark [184]. Results from these studies suggested that schools should develop strategies for helping pupils reach the school MVPA target [184]. In addition, some of these studies included the available information on specific individual risk factors such as gender, high/low activity groups, and activity venues (e.g., traditional/outdoor day). They determined whether the risk factors are personal, social, and environmental and provided useful insight [185] for developing targeted interventions to promote children's PA engagement during school hours.

2.5.1 Other Domains of Physical Activity During School Hours

Other than PE and recess which are the two main opportunities for children to be active at school, PA can occur through different domains including in-class active breaks between lessons, and PA timeslots/extra-curricular activity sessions (such as sports Wednesday/Friday afternoon).

2.5.1.1 Active Breaks Between Lessons

A systematic review carried out by Peiris et al. [186] suggested that PA breaks within a classroom setting are likely to have positive effects on academic performance and cognitive outcomes in addition to providing health related benefits [186]. Classroom active break between lessons allows pupils to accumulate PA in short bouts throughout the day. These breaks typically last 3-5 minutes and do not require leaving the classroom. For these reasons, active classroom break may be offered frequently (as often as three times/day) [187].

Peiris et al.'s [186] systematic review identified the characteristics and the effect of In-class PA behaviour (IcPAB) interventions among primary school children (aged 6-13) and found (n=10 studies) that their health behaviours (MVPA levels) improved after the IcPAB

intervention. Out of ten eligible studies, four of them identified changes in MVPA level and SB of children (age ranging from 9-12 years old). The review confirmed the positive effects of in-classroom PA breaks for improving MVPA levels [186]. Also, Pellegrini et al.[188] found that offering activity breaks every hour decreased behavioural problems among inattentive pupils (aged 7-8) [188].

Likewise, Masini et al.'s [189] systematic review investigated the effects of active break school-based interventions carried out inside the classroom for primary school pupils (aged 6-13). Of five studies investigating MVPA levels, three reported statistically significant improvements. The findings showed a positive trend that highlights the beneficial effects of active break intervention on time spent in MVPA [189]. However, their effect depends on the teachers' contribution. In the school context, teachers should be encouraged to be flexible / adaptable choosing the moments in which to introduce PA breaks. Nonetheless, there are difficulties for classroom teachers in implementing PA breaks [190], [191] due to high curriculum demands and the time allocation for in-classroom PA break sessions seemed to differ from what the classroom teachers desired [186]. Active breaks can be relatively easily introduced in the context of primary school lessons, demonstrating the feasibility and sustainability of a novel tool to increase PA during lessons [189]. The school policy might usefully try to make teachers more aware of the importance of PA interventions [189]. Policy level recommendations for classroom teachers to promote and implement daily activity breaks during lessons are needed [186].

2.5.1.2. Other Physical Activity Timeslots (Extra-Curricular Activities During School Hours)

PA can be organised under the heading of school extra-curricular activities (ECA) domains which might add MVPA to school hours. These ECA sessions during school hours can be delivered by staff, peer leaders, or volunteers /coaches from the local community/ non-profit

organisations [192]. ECA sessions can be arranged in the afternoon during the school day (e.g., Wednesday/ Friday afternoon) so that activity programmes are made available for all pupils. They should also be offered for free, or at a price that does not discourage pupils from benefitting [192].

In addition, schools may need to develop some community-based strategies including collaborations between community-based organisations, public agencies, educational institutions, and private-sector organisations to increase pupils' PA, as interventions with existing youth organisations appear likely to increase activity. This may also assist schools in creating a more active school environment by adding moments of engagement in PA throughout the school day. For example, schools could join some PA programmes, such as the'Daily Mile,' during school hours. The Daily Mile (TDM) is promoted by the Scottish Government and the arrangement is that pupils run or walk outside for approximately 15 minutes (~1 mile) at a self-selected pace each day during class time [39]. Chesham et al. [39] investigated the effects of TDM on children's PA levels, SB, fitness, and body composition. The study used accelerometer-assessed method to measure 391 children (age 4-12 years) and concluded that this programme intervention is effective in increasing MVPA levels (a relativeincrease of 9.1 min per day was observed) and physical fitness, as well as reducing sedentary time and improving body composition [39].

Routen et al. [193] did a survey of forty-two schools, and 17 (i.e., 40.5%) of them reported never running TDM. 96.0% of participating schools reported delivering TDM on three or more days per week. Some barriers to participation were identified, including space limitations (inadequate all weather running surface), time constraints (timetabling and curriculum pressures) [193], [194], safety issues, as well as reluctance from pupils and teachers [193]. Hence, to implement TDM, it needs greater teacher engagement, a more conducive and school culture/ethos, effective communication of the initiative, and substantial delivery adaptations

[193].

2.5.2 Physical Activity Outside School Hours

2.5.2.1 Active Travel to and from School

Active transport (or active commuting) to school is considered an important contributor to the achievement of daily MVPA [195]. The usual modes of active travel to and from school include walking and cycling [196]. Results from Scotland's 2021 report card on PA and health for children and youth [58] quoted three surveys, including Hands Up Scotland 2019, HBSC 2018, and Scottish Household Survey (SHS) 2019 [197],[198],[199], suggesting that just over 40% of children and adolescents actively travel to school. Martin et al.'s [196] systematic review (with twelve eligiblestudies) investigated the contribution of walking to/from school to daily MVPA in children andadolescents (4-19 years old). Out of twelve included studies, nine were related to primary schools, involving a total sample size of 3422 children. The findings showed that the weighted mean MVPA accumulated in walking to and from school was 17 min/day. The pooled analysisfor those children who walked regularly to/from school showed that the commute represented 23% of daily MVPA on school days. This study concluded that active travel to and from schoolmakes a meaningful contribution to individual school hours MVPA [196].

However, as noted in the previous Section 2.4.1 non-school days are almost as many as school days, and the prevalence of walking to school is low in many countries. The effect of active travel alone may not be able to make a useful contribution to daily MVPA. Active travel has received a great deal of attention in recent years since it is likely that it will produce a meaningful increase in pupils' MVPA. However, the biggest concern about active travelling is it may require pedestrian and cycle-friendly routes to school to ensure pupil safety [47].

2.5.2.2 Before or After School Sports Clubs and School-linked Community Programmes

Providing before or after school opportunities to be active, where one did not exist

previously, might help children increase MVPA [200]. Before school hours, when parents drop pupils off early, schools can open the school grounds and offer activities for them to increase their MVPA. Schools can also organise after-school programmes with local recreation departments/school-linked community groups for pupils to play informal games or team sports. However, there are barriers, such as transportation, to be overcome. The success of an after-school programme may depend on the availability of transportation for pupils [201]. If parents find that additional transportation is a problem, they may not allow their child to participate in a programme. As a result, it can affect the attendance rate of after-school PA programmes. Jago and Baranowski [201] in 2004 already warned that after-school activity clubs required attention to disincentives for participation. For example, schools may need to provide additional buses for pupils participating in after-school activities or facilitate ride sharing among families.

The other PA opportunities outside school hours mentioned above are also connected to school PA domains and should be considered when assisting pupils to achieve the daily PA guidelines recommended by the World Health Organization [1], [45]. However, they are beyond the scope of this thesis; the reader could consult key literature referenced in the relevant sections for more detail.

Above all, some of the PA domains, such as in-classroom active breaks or ECA sessions during school hours, have limited potential on their own. It seems that a single domain may be insufficient in itself, but accumulating MVPA in different domains during school hours would be useful and might also encourage active habits which persist after pupils' graduate from school longer term. Moreover, it is beneficial to make good use of these modest increases in activity time periods [11] that may not normally be thought of as activity opportunities to attain the daily MVPA recommendation.

To achieve the 30 min/day MVPA school hours benchmark, a combination of PA domains (including structured curriculum PE lessons, and non-curricular time such as recess, in-

classroom active breaks, ECA sessions, and before or after school PA programmes) may be an important consideration. Therefore, to accrue sufficient MVPA to meet the 30-min/day school hours goal for children, a holistic plan to make full use of PA opportunities during school hours may be essential.

2.6 Whole-of-School Approach

Primary pupils' MVPA levels could be raised by adopting a whole-of-school (WOS) approach [202]. The approach can be drawn upon a social-ecological perspective and targets multiple levels of influence when implemented [200]. The WOS approach is used to provide pupils with opportunities and facilities for participating in PA, thus inculcating knowledge, attitudes,and skills conducive to healthy lifestyles. According to the World Health Organization (WHO) Global Action Plan on Physical Activity [49], there is a need to strengthen the implementation of WOS programmes [49] and expand, extend, and enhance the WOS components to improve pupils'physical activity opportunities.

The toolkit, on promoting PA through schools of the WHO [192] defines the WOS approach as:

"An approach that goes beyond the learning and teaching in the classroom to pervade all aspects of the life of a school. It includes teaching content and methods, school governance and cooperation with partners and the broader community, as well as campus and facility management. It is a cohesive, collective, collaborative approach by a school community to improve student learning, behaviour and well-being, and the conditions that support them". [192].

Schools have a role to play in meeting this target by increasing pupils' engagement in physical activity through WOS approach, as suggested in this toolkit [192]. A global action plan published by the WHO in 2018 outlines a wide range of actions across multiple sectors and settings, including schools needed to increase MVPA of children and adolescents.

Among various approaches to PA promotion, WOS PA initiatives have become a widely recognised strategies to help increase PA levels among children and adolescents [202]. Concurrently, there are several established WOS initiatives, such as the Comprehensive School Physical Activity Programme (CSPAP) framework [127], [203] developed by the Centers for Disease Control and Prevention in the United States and the Creating Active Schools (CAS) Framework [204], which is the UK-based WOS PA framework. Both frameworks identify key components and interconnections within a WOS system to support sustainable PA interventions. These frameworks emphasis the role of school ethos and practice, teacher training, and national policies in fostering an environment conducive to PA. They emphasis schools should assume strong leadership roles in promoting PA among children, both during the school day and outside of school [127], [203].

A Comprehensive School Physical Activity Programme (CSPAP) is a multi-component strategy designed to enhance PA both during and beyond the school day by involving policies, environments, and stakeholder engagement, with the aim of developing physically educated pupils [205]. It consists of five components: high-quality physical education (PE), PA during school, PA before and after school, staff involvement, and family and community engagement. The goal is to provide various PA opportunities throughout the school day, ensuring pupils achieve the recommended 60 minutes of daily MVPA [14], and develop lifelong PA habits. Schools can integrate PA through curricular lessons, PE, recess, events, and by promoting active travel, before/after school clubs, and community involvement [206].

The CAS Framework outlines the essential components for implementing WOS PA, including policy, environment, stakeholders, and opportunities [204]. It emphasises the importance of establishing a school-wide ethos for PA through policies that shape beliefs and practices. The framework highlights the significance of the physical environment and the roles of various stakeholders, such as school staff, pupils, parents, and community members, in

influencing PA behaviours [204]. The combination of these factors determines the implementation of PA across various opportunities, including events, recess, PE, curricular lessons, clubs, active travel, and family/community engagement [204].

During school hours, PE and recess are normally the most physically active times. So, the WOS programme can start with these two opportunities and CSPAP and CAS frameworks are consistent with the WHO's toolkit [192]. As outlined by the WHO toolkit quality PE is the first domain that needs attention. Therefore, schools should value PE and not reduce PE time in favour of other subjects, courses, or activities, according to WHO advice [192]. The United Nations Education Scientific and Cultural Organization UNESCO [207] and the Institute of Medicine, USA [18] also recommended that clearer goals and more trained PE specialists are important. They suggested that all schools should provide quality PE as a core part of formal curricula led by appropriately trained teachers [18], [207].

Other than improving the quality of PE lessons, schools should make use of other PA opportunities such as classroom breaks, active ECA programmes during school hours, and recess for pupils' PA promotion. McDonald et al. [208] conducted a systematic review (n=32) to summarise and evaluate specific strategies for the promotion of PA in pupils (aged 3-18). They concluded that multicomponent school-based interventions (among the many approaches) have been most consistently successful in increasing pupils' PA. A number of studies also recommended implementing the WOS programme [202], [209], [210] and Beets et al.[200] suggested expanding, extending, and enhancing PA programmes to provide diverse experiences / varied movement opportunities to help pupils increase MVPA.

It is difficult to compare and generalise international WOS initiatives because each programme is contextualised within the country and the school in which it is actualised [202]. Hence, there are not many research studies detailing the implementation of such initiative. A study in 2015 [209] (with 1031 secondary level pupils) showed that a comprehensive set of PA

practices can result in greater PA levels among middle school students. Another study [210] tested the effectiveness of the WOS approach by using the 4PC model (Active Policy, Active People, Active Programme, Active Place and Active Classroom) in improving PA and reducing SB of schoolchildren in Thailand. A total of 438 pupils (grades 4-6) participated. The result showed that pupils in the intervention group accumulated an additional 19-25 min of MVPA time and experienced a 31-min reduction in sedentary time [210].

A systematic review conducted by Kuhn et al. [211] aimed to examine multicomponent PA interventions in schools by analysing the number and combination of CSPAP components, study characteristics, and primary outcomes. Data from 32 studies were analysed, revealing various combinations of CSPAP components, with most focusing on health outcomes. The results indicate that multicomponent approaches aligned with CSPAPs are effective in promoting PA among children and adolescents in schools. The authors also suggested that future research should explore the effects of different CSPAP components across various outcomes and settings.

Helme et al. [212] conducted a study to evaluate the effectiveness of the CAS on organisational culture for PA in schools and aimed to establish the internal validity and reliability of a school-based organisational capacity questionnaire. The study focused on schools in Bradford, one of the most ethnically diverse cities in the country, with 34% of its neighbourhoods in the lowest tertile of deprivation across the UK. Participating schools (n=57), supported by the in-school CAS, were assessed on school readiness and organisational capacity for PA over a nine-month period (including assessments before engaging with the CAS programme and again at a nine-month follow-up) via a questionnaire. In-school CAS leads completed a 77-item questionnaire assessing changes across 19 domains aligned with the CAS framework over the nine months. Initially, over 70% of schools had inadequate PA provision. After nine months, CAS significantly improved organisational PA, particularly in school

culture, staff involvement, academic and PE lessons, school commutes, and stakeholder behaviour. The findings suggest CAS is effective in promoting system-level changes for PA in schools in deprived, multi-ethnic areas [212]. However, the authors recommended that future studies with controlled designs are needed to confirm these results and to better understand the implementation mechanisms [212].

Overall, this thesis focuses on school hours MVPA, author suggests a 'whole-of-school practice' to combine several PA opportunities during school hours [208]. This approach relies on the willingness of the head teacher and teaching staff to reallocate time in the school schedule and implement the programmes in a cohesive and collaborative way. It includes the teaching content and methods of PE lessons, school governance, and cooperation within the school and the broader community, as well as campus and facility management in planning and arranging PA opportunities for pupils' health and well-being needs [192]. However, an effective, practical sustainable cost-effective WOS PA approach has yet to be found and must rely on future research and practice to collect relevant data.

2.7 Physical Activity/Physical Education/ Recess Contexts in Scottish Primary Schools

2.7.1 Primary School System in Scotland

Children in Scotland complete seven years of primary school, starting in primary one at age 4-5 years, going up to primary 7. The Scottish Government provides a list of links to school term information for all local authorities. Term dates and holidays for independent schools are available from the schools themselves. The usual length of the week for most primary schools is 25 hours [133]. In primary schools, pupils usually have most of their lessons in one classroom, and sometimes learn in the school library, gym, or computer room. They usually have the same teacher most of the time. The school day usually runs from Monday - Friday, usually around 9 am - 3:00 pm, with schools usually open for approximately 190 days per year although every school has its own timetable [133].

2.7.2 Physical Education in the Curriculum for Excellence in Scotland

In Scotland, the Curriculum for Excellence (CfE) [213] is used with the aim of providing a wider, more flexible range of courses and subjects. The Scottish government only sets guidelines about the school curriculum. Schools need not stick to rigid learning paths and can make their own decisions to some extent on what to teach pupils. There are three core subjects that schools should ensure are taught: health and wellbeing, literacy, and numeracy. The government recommends schools deliver at least two hours of PE for all pupils in primary school [214].

2.7.3 The Physical Education and Recess Context in Scotland

According to the CfE, [213] Health and Wellbeing Principles and Practice:

"Regular physical activity is essential for good health. Physical education should inspire and challenge children and young people to experience the joy of movement, to develop positive attitudes both individually and as part of a group and to enhance their quality of life through active living. This will give children and young people an important foundation for participation in experiences in physical activities and sport and in preparation for a healthy and fulfilling lifestyle" [213].

In the Scottish Curriculum for Excellence, Health and Wellbeing (together with numeracy and literacy) is one of the three priority areas [213]. PE is the only subject area within CfE with aspecific timetable target. Also, PE has been housed within the core curriculum area of Health and Well-being which extends beyond specified PE curriculum time. To ensure all children acquire skills to live healthy, happy lives, [213] the health and wellbeing of all pupils should be integrated into a holistic approach, embracing the entire school ethos and the eight main curriculum areas: Expressive Arts, Health and Wellbeing, Language, Mathematics, Religious and Moral Education, Sciences, Social Studies, and Technologies [214]. PE should be viewed in the wider context of Health and Wellbeing, with its six domains, namely, mental, emotional,

social, and physical wellbeing; planning for choices and changes; physical education, physical activity, and sport; food and health; substance misuse and relationships [215]. According to Association for PE Scotland (AfPE) [216], for the age range 7/8 – 14 years old, children and adolescents extend and consolidate their core movement competence, cognitive abilities as well as social and emotional skills in order to apply them in real life contexts such as sport, dance, outdoor and recreation activities [216].

Primary school PE in Scotland is usually conducted by class teachers, as opposed to Hong Kong (all PE classes must be delivered by a trained PE teacher). Many teachers feel inadequately prepared for teaching PE, which is neither their main subject nor one covered in their mainstream teacher training modules [217]. They have little empathy for PE and find little school or parental support for the subject [217]. Some schools hire coaches or experts to help conduct sports, however, they tend to view themselves as service providers for client schools. They seldom build up a rapport with pupils or staff, as they are not there to stay [218]. It might require a fundamental multi-discipline and dimensional pedagogical paradigm shift in view of teaching in both the curriculum and public health context if the recommended 50% of PE lessons in MVPA goal are to be achieved [192].

In Scotland, recess is mandatory and all primary school children have one 15-or 20-minute morning recess period (typically between 10-11 am) per day. Moreover, schools have lunch periods (normally lasting for 45 minutes between 12.15 to 1.00 pm) where children can engage in PA. Lunchtime is an unpredictable combination of time spent queuing for and eating lunch and recess time for whatever children might do.

2.8 Theory and Model of Behaviour Change that Influence Children's Moderate-to-Vigorous Physical Activity Levels in a Primary School Setting.

2.8.1 The Socio-ecological Model

The socio-ecological model (SEM) [219] provides a useful comprehensive framework for

interventions to increase MVPA levels, including for pupils.

There are different levels of influence on children's PA behaviours. Sallis et al. [220] in 2008 stated that SEM is a multifactorial concept that shows that PA behaviours can be influenced by a multiplicity of levels (from the most proximal to the broader settings), including intrapersonal and physiological elements, interpersonal and organisational characteristics, and societal level. The approach highlights the dynamic relationship between intrapersonal, interpersonal, organisational and community levels. The combination of these behavioural constructs and social-ecological frameworks explains and highlights the importance of evidence-based school policies and practices (Figure 1). The SEM helps us understand how each of these layers' influences children's PA behaviours during school hours, including PE and recess. The SEM acknowledges the multifaceted contexts that influence how PA behaviours are shaped and maintained in our daily lives [219]. Salmon and King [221] suggest that application of the social ecological framework appear to have the greatest effect on PA behavioural change, as the approach involve multiple settings and that target multiple levels of influence.

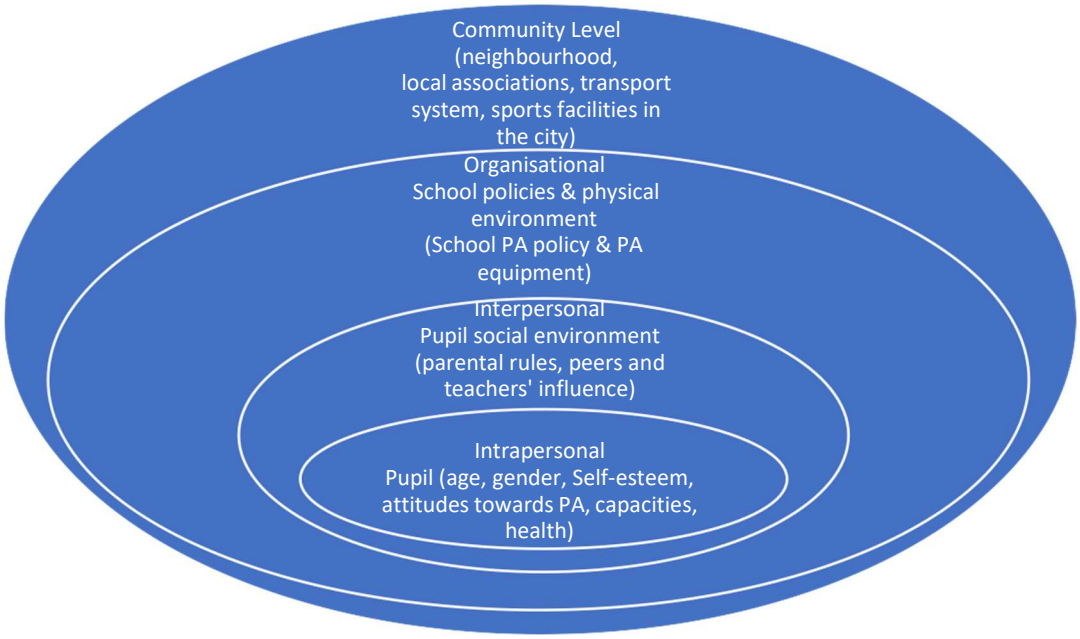

Figure 1. Social-ecological Model for PA Opportunities at School in this Thesis

2.8.2 Theory of Expanded, Extended, and Enhanced Opportunities

Along with the use of the SEM, there are additional approaches with salient features that appear also effective in bringing about pupils' PA behaviour change [200]. Beets et al.[200] provideda common taxonomy, theory of Expanded, Extended, and Enhanced Opportunities (TEO) which offers a new way to understand how interventions might bring about children's and adolescents' PA behaviours across all settings where their PA is intervened upon [202]. In many PA interventions for children and adolescents, the approaches mainly fall into the expansion of opportunities (by the inclusion of a new occasion to be active), as well as the extension and the enhancement of an existing PA opportunity (by increasing the amount of time allocated for that opportunity or through strategies designed to increase PA above routine practice). The theory presents a common taxonomy by which to classify and identify appropriate targets for interventions designed to increase PA [200].

According to Beets et al. [200], expansion of opportunities means introducing a new PA opportunity that serves to broaden pre-existing ones and therefore increase the time allotted for pupils to be physically active. These include introducing PA breaks into a classroom environment, initiating a Daily Mile programme, or adding a PA timeslot in the afternoon during a school week. The extension of opportunities means allocating additional time for an existing PA opportunity. One example is to extend/elongate a 15-minute recess session to 20 or 25 minutes per day. Both expansion and extension serve to replace sedentary behaviours with alternative, more physically active opportunities [200]. The enhancement of opportunities involves modifying an existing PA opportunity to increase the amount of PA accumulated during that occasion. The quality of a PE lesson could be enhanced by making the lessons more active. Other examples include improving playground markings and providing more accessible equipment during recess to maximise the amount of PA that occurs above routine practice [200]. Hence, using the TEO may lead to a greater impact on child and adolescent activity behaviours

than what has been demonstrated in previous studies [200].

As suggested in Section 2.6, schools may adopt a WOS approach by combining PA domains during school hours in a systematic way to increase pupils' MVPA. A combination of the WOS approach and the TEO taxonomy is shown in Figure 2.

Lastly, it is also important that future WOS interventions be of adequate quality and conducted over an appropriate period of time, with repeated measures to ensure intervention sustainability and the generation of evidence-based outcomes.

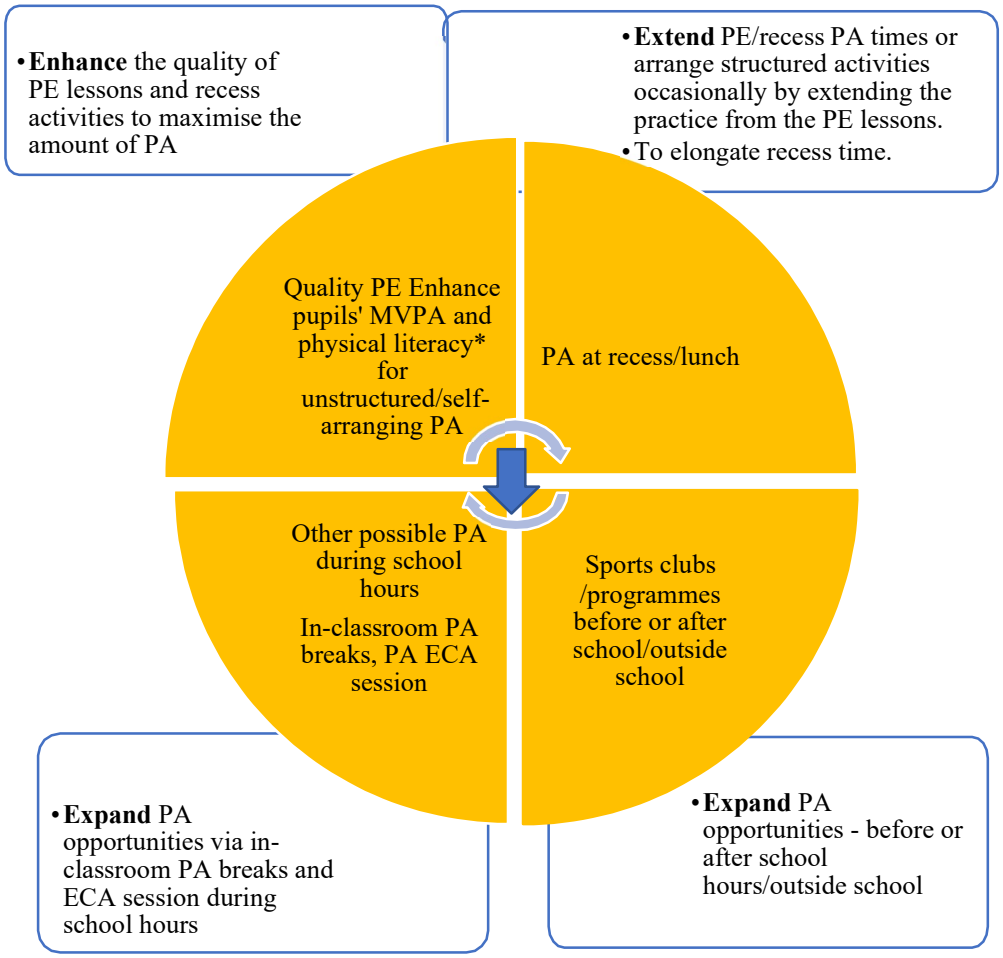

Figure 2. Combination of the Whole-of-school Approach and the Theory of Expanded, Extended, and Enhanced Opportunities (TEO)

2.9 Chapter Conclusions

The information and evidence presented in this chapter provide background to this thesis. The opportunity for PA in school is of utmost importance for children and adolescents PA habits and a healthy lifestyle should be established in early childhood. The overall aim of this PhD thesis is to investigate ways to increase MVPA levels for Scottish primary pupils during school hours.

The lack of participation in MVPA is considered a problem of pandemic proportions. Even though children's current MVPA levels and SB in primary raise concerns [221], the available evidence on intervention research in Scotland regarding school hours MVPA is limited.

This thesis aims to examine school hours MVPA for pupils and propose measures to increase MVPA levels. Risk factors influencing the achieved MVPA will also be explored. The scope of this thesis included identifying interventions to increase MVPA in primary school children's PE lessons, modifying a promising PE intervention to be used in Scottish primary schools, and analysing MVPA levels during school hours and recess (not including lunchtime) for Scottish children aged 10-11. The recess focus of this thesis is confined to morning recess because this is a time of the school day when free play is prioritised over eating lunch. For this reason, the author only included the nationally mandated morning recess in this study for practical considerations. MVPA during lunchtime was not examined and could be a rewarding subject for future research. Further planning may be needed to coordinate/connect all PA opportunities during school hours in a more systematic and cohesive way to improve pupil health-enhancing behaviour and well-being.

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Chapter 3: Interventions to Increase Moderate-to-Vigorous Physical Activity in Elementary School Physical Education Lessons: Systematic Review

3.1 Chapter Overview

Physical Education (PE) is mandatory and valued at all educational levels, with a weekly frequency that contributes to promoting an active and healthy lifestyle. It is also the only school subject that provides pupils with the means to develop the knowledge, skills, and motivation to engage in health-enhancing physical activities for life. However, a review of the literature shows that moderate-to-vigorous physical activity (MVPA) levels in PE lessons are often very low. Therefore, the aim of this chapter was to systematically review the evidence on interventions designed to increase MVPA content of PE lessons for children aged 8-11.

The present systematic review was published in the *Journal of School Health* in August 2021. The paper is presented in the same format as was published in the journal, and the published format is included in Appendix II.

Wong LS was the lead author and led on all aspects of the systematic review. The synthesis was supported by Gibson A-M, Farooq A and Reilly JJ. Reilly JJ assisted in assessing quality, Gibson A-M supported methodology, and Farooq A contributed to the meta-analysis. All authors contributed to the design of the review and participated in the revision and approval of the final manuscript for submission to the *Journal of School Health*.

3.2 Abstract

Background: This systematic review aimed to synthesise recent evidence on interventions to increase Moderate-to-Vigorous Physical Activity (MVPA) content of Physical Education (PE) in children aged 8 to 11.

Methods: A search of 6 databases was conducted in December 2019. Controlled intervention

studies were included so long as they used objective measures of MVPA. Methodological quality was assessed using the appropriate Joanna Briggs Institute (JBI) Checklist. Random effects meta-analysis was used where appropriate.

Results: Of the 5459 records, only five studies met all inclusion criteria, reporting on 1452 participants; three Quasi-Experimental studies and two RCTs. All five eligible studies reported favourable intervention effects. Meta-analysis was possible from 4/5 studies: the mean difference between intervention and control groups at follow-up was +14.3% of lesson time in MVPA (confidence interval [CI] 2.7 to 25.8).

Conclusions: Efforts to increase the MVPA content of elementary school PE are achievable. Two studies employed PE specialist teachers and one study used an expert instructor as their intervention, two studies worked with the class teachers using self-determination theory. All studies focused on health (MVPA) outcomes and included either "fitness infusions" or physically active games to engage students' in physical activities and increase their activity level.

Keywords: Physical education, Moderate-to-vigorous physical activity, Activity level, Fitness, Student.

3.3 Introduction

Regular moderate-to-vigorous physical activity (MVPA) provides a range of benefits for children and young people: physical and mental health [1] and non-health benefits such as cognitive development and educational attainment [2], [3]. Low MVPA among children and young people, plus the growth of sedentary time via social media and advent of more digital platforms and mobile devices is being regarded as the next major global public health issue [4], [5]. A more active lifestyle in childhood is crucial in improving short-term health and wellbeing, as well as reducing risk of many Non-Communicable Diseases (NCD) in later life [6], [7].

According to Metzler et al.[8] physical education (PE) is the only place where children have an opportunity to engage in MVPA, become physically fit, and learn the movement and behavioural skills needed for a lifetime of active, healthy living. Furthermore, all school-age

children spend around half of their days per year at school, making the school environment a strategically important setting for the promotion of MVPA [9]. For example, the United States Centres for Disease Control and Prevention (CDC, USA) [10] and the UK Association for Physical Education (PE) (AfPE, UK) [11] recommend that MVPA levels during elementary school PE lessons should reach 50% of lesson time, a meaningful contribution to the 60 minutes minimum MVPA per day recommended [12]. These also align with "health optimising physical education" (HOPE), the concept that PE should make an important contribution to health-related physical activity and fitness, all students are engaged and active at least 50% of the PE lesson time [9]. Furthermore, PE participation is one of the entry points for students' lifelong participation in MVPA, sports and society at large [13]-[16].

Despite the potential of school PE for increasing MVPA and improving public health, a systematic review carried out by Hollis et al. [17] in 2015 showed MVPA levels during elementary school PE lessons typically do not meet the recommendation of 50% of lesson time. Their findings suggested that interventions to increase the proportion of PE lesson time spent in MVPA were needed.

Lonsdale et al.'s systematic review of PE interventions aimed at increasing MVPA, conducted in 2013 [18], was comprehensive. A total of 14 studies were included, seven of which involved interventions conducted during the primary school years (aged 8-10). Three of these primary school interventions used a theoretical framework based on social learning/cognitive theory. Most of the interventions designed for primary school settings fall into two categories: those targeting teaching strategies and those focusing on fitness.

For those interventions that focused on teaching strategies (n=5 studies), teachers learned methods to promote MVPA through effective activity selection, class organisation and management, and instruction techniques. Examples of interventions that targeted teaching strategies include Child and Adolescent Trail for Cardiovascular Health (CATCH) [19] and Sports, Play and Active Recreation for Kids (SPARK) [20]. There is evidence that these types of

PA programmes have increased the percentage of MVPA during PE lessons [21]. For instance, results from the CATCH intervention showed a 12% increased MVPA [21].

However, fitness interventions have also been reported to show increases in MVPA [22]. Ingico et al.'s [22] intervention used 'fitness infusion' approach, where they incorporated skill development with short bouts of MVPA between practice attempts. Rowlands et al.'s [23]. intervention employed external instructors to teach PE lessons, with the goals of achieving 30 minutes MVPA during each session. The intervention resulted in an absolute increase in MVPA of 12.4% [23].

In summary, Lonsdale et al. [18] reported that interventions designed to increase primary pupils' MVPA during PE lessons, in which teachers supplemented usual PE lessons with high-intensity activities (e.g., jumping, running on spot) provided pupils with more active learning time compared to usual practice. They also suggested that increasing active learning time in PE should be a public health priority [18]. Lastly, Lonsdale concluded that interventions including teacher professional development focused on pedagogy (e.g., lesson preparation and management) and behaviour during PE lessons offered considerable potential for increasing PA in children and adolescents. However, higher quality trials are needed to determine the best methods for promoting MVPA in PE lessons and identifying the most effective and sustainable intervention strategies.

There was a need for a new review to uncover evidence not included in the Lonsdale's review and to examine whether the evidence base has improved in recent years. An update of Lonsdale et al.s' review is needed for the following reasons: a) the most recent eligible study included in that review was over a decade old (eligible studies were published from 1991 to 2008). Since research is quite a busy field, more recent studies may have emerged in the past ten years, b) Lonsdale's review was broad, covering both primary and secondary school levels, whereas the focus of this thesis is on primary level and it was desirable to identify if a bigger evidence base was available from primary school studies, c) the studies included in the Lonsdale review were

mostly from USA — out of 14 eligible studies identified, 10 were from the USA, limiting the generalisability of the findings beyond that country, and it was important to try to identify more generalisable interventions (e.g., from the UK if possible), d) Lonsdale et al. [18] found that many of the eligible studies had limitations (small sample sizes were common, with a median of n=106, and only one school was involved in seven studies), suggesting that the evidence should be considered with caution and there should be a search for higher quality studies than were available to Lonsdale et al. [18].

Across the western world there is now clear evidence that MVPA levels of children are low and in decline before adolescence [24]. Interventions are therefore required pre-adolescence to increase MVPA levels and mitigate this age-related decline [25]. Interventions are therefore required for elementary school children [24], [25]. In the UK, the Medical Research Council Framework on the Development and Evaluation of Complex Interventions [26] recommends that thorough searching of intervention evidence is used to inform intervention development. The present review was intended as the foundation of school PE-based intervention development aimed at increasing MVPA in children (8.0 to 11.9 years) in Scotland and was intended to identify new/existing interventions which might be adapted for use in Scotland. Our intervention development is focused on 8.0 to11.9 year olds and therefore the review focused on intervention strategies for that age group: intervention evidence from younger children and older youth would probably be less generalisable, and so were beyond the scope of the present review.

The primary aim of this study was to systematically review the more recent global evidence, published after Lonsdale's review (which had only 7 eligible older studies in our target age range, 4 from the United States), to identify promising ways to increase MVPA in elementary school PE lessons for children in the upper stages of primary school education in Scotland (age 8.0-11.9 years).

3.4 Methods

3.4.1 Literature Search

This study followed the PRISMA statement for conducting and reporting systematic reviews and meta-analyses. The protocol was registered on PROSPERO on the 11th of November 2019. (http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42019155878).

Up to December 2019, eligible studies were identified in six relevant electronic databases, Scopus, SPORTDiscus, PsycINFO, ProQuest, PubMed and ERIC. The search strategy followed the PICOS (population, intervention, comparison, outcomes, and study design) framework. The inclusion and exclusion criteria are detailed below. The search was limited to 2010-2019 (aimed updating the previous review by Lonsdale et al., 2013), it was also restricted to search for English language studies only due to the impracticalities of translating papers. An example of a search strategy for the Scopus database is provided in Table 1, which was adapted for the five other databases. Hollis's [17] and Lonsdale's [18] citation lists, as well as reference lists of the final included papers, were examined to find any potential eligible studies missed during the database search.

References were imported into endnote and duplicates were removed, at which point one author screened the titles and abstracts with 81 full-text articles were identified. Three authors then screened potentially relevant full-text articles independently based on the inclusion and exclusion criteria. Any disagreement was resolved through discussions among the three authors.

3.4.2 Inclusions/Exclusion Criteria

Population. Studies of apparently healthy elementary school children aged 8.0 to 11.9 years old were included in the present systematic review, with studies excluded if the mean age of study participants was <8.0 or >11.9 years. The reasons of selecting this age range were partly scientific: late childhood/early adolescence = mid-late elementary years represents a fairly homogenous group likely to experience sharply declining MVPA, and partly pragmatic: this review was undertaken in order to help inform development of a PE intervention for 8-11 years

old in Scotland as noted above. Studies of children with any intellectual, physical or cognitive disabilities, which may impair their ability to engage in PA, were excluded.

Intervention. For inclusion in the present review, the interventions had to take place in PE lessons. If the intervention was multi-component, MVPA had to be described as the predominant component in the publication. Interventions which addressed other domains of PA (pre or after school, recess), or which were set in the community or home were excluded.

Comparison. For inclusion in the review, the interventions had to be compared to a comparison or control group, who received either no treatment, another PA intervention, other lifestyle intervention, waitlist control or attentional control. Uncontrolled studies were excluded.

Outcomes. For inclusion, the studies must have had MVPA outcomes measured using an objective method (using an accelerometer or direct observation method). PA outcomes measured using self-report, or questionnaire, or an objective measurement that did not give an intensity (pedometers), or studies that measured a small period of the day other than PE (such as recess interventions) were excluded.

Study design. Studies included in the systematic review had to have intervention and control groups, either quasi-experimental designs (non-randomised experimental studies) or randomised controlled trials (RCT) or cluster randomised controlled trials.

3.4.3 Data Extraction

Data were extracted by one of the authors and checked by a second. In cases where data were missing, or additional information was required for the eligible studies, the study authors were contacted to provide the relevant information. Authors of two of the potentially eligible studies were contacted to determine if the study interventions and designs met the inclusion criteria. One for additional information on the mean (SD) or median (age) of study participants at baseline; the other to clarify the size of the intervention effect in the paper. As one of the authors was unable to provide the details, this paper was not included in the present review. [27]

3.4.4 Data Analysis and Synthesis

A narrative synthesis was conducted on outcomes for each included paper. The outcome of interest was MVPA during PE, and meta-analysis was possible for 4 of the 5 eligible studies, on the mean difference in the MVPA content of PE lesson time at follow-up between intervention vs control groups. Two of the four studies did not provide the standard deviation (SD) for MVPA content of PE, but instead median and inter-quartile range was provided. In these two cases median values were assumed as mean values and SD was estimated using methods described in Wan et al. [28] A random effect meta-analysis was performed for the mean difference and the standardised mean difference with 95% confidence intervals (CI). Heterogeneity across studies was assessed using I^2 statistics (I^2 of 0-40% represents low heterogeneity and 75-100% considerable heterogeneity) [29]. All statistical analyses were performed using metafor package (in RStudio, Version 1.2.5001).

3.4.5 Risk of Bias

Two authors independently assessed the quality of the eligible papers using the quality assessment tool of the JBI Critical Appraisal Checklist for Quasi-Experimental Studies (non-randomised experimental studies) [30] and JBI Critical Appraisal Checklist for Randomized Controlled Trials (RCT) [31], referring to a third author when required. The Checklists were used to assess the methodological quality and to determine the extent to which a study addressed the possibility of bias in its design, conduct, analysis, and reporting.

3.5 Results

3.5.1 Identification and Selection of the Studies

The PRISMA flow diagram [32] is presented in Figure 1. From an initial pool of 5459 records (identified from six databases and 100 records through other sources Hollis's and Lonsdale's citation lists as well as reference lists of the final included papers were examined to find any potential eligible studies missed during the database search), 5200 remained once duplicates were removed. Following the title and abstract review, 81 full-text papers were

retrieved and reviewed for eligibility. Five papers met all the inclusion criteria (Boulley et al., 2018; Fairclough et al., 2016; Powell et al., 2016; Smith et al., 2015 and Telford et al., 2016) [33]-[37] and no further papers were identified when searching references of the five included studies. All study selection discrepancies between the three authors were resolved through discussion.

3.5.2 Characteristics of the Eligible Studies

An overview of the included studies is presented in Table 2. Three studies were conducted in the UK [34], [35], [36], one in France [33] and one in Australia [37]. The eligible studies had a total of 1452 participants (in both intervention and control groups). The duration of the interventions varied from 6 weeks to 4 years, involving elementary children with mean age 9.8 years. Of the five included studies, three of them were quasi-experimental studies (non-randomised experimental studies) and two were RCTs.

A range of PE interventions were utilised in the five included studies-a common feature was either to use specialist PE teachers, an expert instructor or class teachers (provided with relevant program training) to conduct the interventions. Three studies, Boulley et al., [33] Powell et al. [35] and Smith et al. [36] (with mean age 9.3 years) focused on theory-based teaching strategy interventions which supported generalist (class teachers, not PE specialists) teachers [33], [35] or PE specialists [36] in increasing children's MVPA during school PE lessons. Boulley et al.[33] aimed to test the effects of a self-determination theory-based teacher professional development program, on elementary teachers' need-supportive motivating style and their pupils' physical activity (PA) in PE lessons. Class teachers in the intervention group received 12 hours professional development training (separated into four 3-hour workshops over one school year). Students' PA and teachers' motivating style were assessed via accelerometers and direct observation. Results showed that, compared to class teachers in the control group, teachers who attended the professional development training improved their need-supportive motivating style and their students increased their time spent in MVPA. Average percentage of students' PE time

in MVPA in the intervention group was 53% compared with 43% in the control group at the latest complete follow-up.

Powell's study [35] aimed at developing teacher effectiveness through the 'SHARP Principles Model' which involved the following key pedagogical aspects: stretching whilst moving; high repetition of motor skills, accessibility through differentiation, reducing sitting and standing and promoting in-class physical activity. The SHARP Principles Model was grounded in theoretical frameworks namely the self-determination theory, the social ecological model and key components (barrier identification, action planning and providing instruction) from behavior change taxonomy. A set of teaching principles was developed to provide class teachers with key elements to focus on in both the planning stage and the delivery of their PE lessons. Workshops and resource cards illustrating the Model were provided to enhance teacher's pedagogy. According to the qualitative findings of this study, the generalist class teachers became conscious of increasing the opportunities for children to learn skills in a more active way. The proportion of time children were engaged in MVPA during PE lessons in the intervention school increased significantly from baseline (mean 43%) to post-intervention (mean 73%).

Smith et al. [36] aimed to increase MVPA through two pedagogical models; direct instruction (used in the control group) and the tactical games model (used in the intervention group), also based on self-determination theory but delivered by PE specialists. The findings showed that boys in the intervention group displayed significantly higher levels of MVPA in both rugby (55.7% SD 3.9) and football (67.8% SD 7.1) activities in comparison to the control groups in rugby (41.0% SD 5.1) and football activities (54.6% SD 7.3). While girls in the intervention group recorded comparable MVPA levels in the football sessions, they recorded significantly lower MVPA levels in the netball lessons. As regard to the levels of students' self-determined motivation, no significant differences in both boys' and girls' motivation were noted.

Two studies, Telford et al. [37] and Fairclough et al. [34] used PE specialist teachers and an expert instructor respectively to try to increase the MVPA content of PE. Telford's 'Lifestyle of

our Kids' study [37] used a specialist-taught PE program. Two intervention lessons per week were conducted by a PE specialist which amounted to 90 min of the mandatory 150 min per week. The remaining 60 min of required weekly PE was delivered by class teachers. The intervention, comprising of game play, fitness activities, skill practice and core movement, increased student's MVPA significantly during PE lessons by 6.5 min on average. This was attributable largely to longer PE lessons and more physically active lessons delivered by the teachers with training in PE compared to generalist class teachers.

Fairclough et al. [34] was a pilot study, and they used the 'Born to Move' fitness intervention movement (including move, punch, kick, jump, dance, core, games and yoga) categories program to promote PA and fitness for children. The 'Born to Move' program was delivered (by an expert instructor) twice a week alongside one regular PE lesson in the intervention schools. While children in the comparison schools received their regular twice-weekly PE as specified in the curriculum and the lessons were delivered by their regular class teachers. Participants, including students and teachers, found that the aims of enjoyment, engagement, inclusivity and challenge were satisfied. Overall, this 'Born to Move' program engaged children in significantly more 'moderate PA' (MPA) (mean 14 minutes/lesson) than during comparison group PE (8 minutes/lesson), and with a median of 51% of PE lesson time as MVPA in the intervention group vs 32% in the comparison group.

To summarise, the eligible studies generally found positive effects of their interventions on the content of MVPA during PE. Interventions were quite heterogeneous in intervention duration or follow-up, method of measurement of MVPA, age, one was a pilot study, and 3/5 had a theoretical basis (all three based on self-determination theory). Three used self-determination theory to inform interventions and two of them aimed at changing current generalist class teachers' behaviour. Some interventions were less generalisable to the Scottish setting than others, for example the sport-based intervention of Smith et al.[36] would not readily match the Scottish PE curriculum, and both of the Smith's [36] and Telford's [37] interventions depended

on specialist PE teachers which are not available universally in Scotland (where primary school PE depends largely on generalist class teachers).

3.5.3 Meta-analysis

Four of the five eligible studies reported comparable findings [33]-[35], [37] i.e. differences in the MVPA content of PE (as a % of PE lesson time) between intervention and control groups at follow up. These four studies were pooled using random effects meta-analysis, having first estimated the SD in 2/4 studies using metafor package (in RStudio, Version 1.2.5001). Pooled estimates of effect of PE interventions expressed as mean difference between intervention and control on % time in MVPA during PE was +14.3% (CI +2.7 to + 25.8%) significantly favouring interventions. The I^2 statistics of 97.3% confirmed high level of heterogeneity. Funnel plots were created, and Egger tests of asymmetry were performed. Although visual inspection suggested asymmetry, the Egger's test gave a $z = 0.55$, $p = 0.5817$ confirming symmetry, probably due to the small number of included studies.

3.5.4 Risk of Bias of Eligible Studies

Quality assessment of the eligible studies is summarised in Table 3 (for quasi-experimental studies) and Table 4 (for the RCTs). Evidence quality was generally high, with the range of items conducted and reported adequately from 7-8/9 for the quasi-experimental studies [30] and for the cluster RCTs, 9/12 and 7.5/12 items were conducted and reported adequately [31]. One item found typically weak in study reporting was "statistical analysis" in quasi-experimental studies as there were no mention of power and clustering in most cases.

3.6 Discussion

The present review found favorable intervention effects on children's MVPA in all the studies, with a pooled effect of 14.3 % higher lesson time in MVPA in the intervention groups, equivalent to around a 9-minute improvement in MVPA per one hour of PE lesson time. The range was from a 4% to 30% difference in the MVPA content of PE lessons. The present review therefore suggests that interventions to increase the MVPA content of elementary school PE are

worthwhile. School should also protect PE time to ensure that the recommended amount of class time for PE is actually made available. [37] The eligible intervention studies had certain components which may help explain their success in increasing MVPA in PE. Notably, they included: (1) A focus on active learning approaches and health; (2) a theory and evidence-based approach (using the theoretical framework of self-determination theory); (3) emphasis on fitness and enjoyable activities in the intervention lessons to enhance children's motivation and engagement.

The present review aimed to update Lonsdale et al.'s [18] study of elementary or secondary school PE interventions to increase MVPA in 2013, in which they identified studies published up to 2008 [18]. The five eligible studies in the present review were of high methodological quality, though, as in the Lonsdale systematic review, the evidence was entirely from high-income, western countries. With the problem of low MVPA among students all over the world, more intervention studies are needed in other countries. The information learned from successful interventions could have a positive impact on other sociocultural contexts where interests, values and social norms in school and in society are different (such as Singapore, Hong Kong).

Among the five eligible studies, the SHARP principles model (SHARP) developed by Powell et al. to increase PA levels in primary school PE was identified as the most promising for translation to Scotland. This model was originally developed in one region of England [35] and was considered applicable to the Scottish context, partly due to the close cultural and social similarities between England and Scotland. The SHARP model involves modifying existing PE lessons and does not require curriculum changes, making it easily integrated into teachers' current planning. It can potentially be applied to any PE lessons without the need for additional equipment or resources. Moreover, the SHARP principles can be learned by both generalist classroom teachers and specialist PE teachers in a workshop, supported by online materials (such as videos and resources cards), so it does not require PE specialist teachers and does not require extensive retraining for teachers.

Previous systematic reviews [17], [18] have found that MVPA levels in school PE were often quite low and had reported many barriers to higher activity levels in elementary school PE lessons. Among these were policy and infrastructure barriers (such as, did no protection for PE time, low teacher confidence in their PE teaching ability, resulting in limited expertise in teaching active lessons and less MVPA than would be desirable). The present review is consistent with Hollis et al. [17] and Lonsdale et al. [18] in that PE-based interventions or well-designed PE programs (with enjoyable and fitness-based activities) could have a positive influence on the total amount of MVPA children participate in.

3.6.1 Limitations

The methodological quality of all eligible papers was generally high which means the risk of bias in individual studies was low. However, a few limitations of this review must also be acknowledged. Our review only included studies in English language which may have limited the number of included studies. Since there were so few studies, and only two were randomised, there may be a need to evaluate the effects of interventions to increase MVPA level in high-quality cluster RCTs in the future. Outcome measurement was objective in all included studies but 3/5 of these studies used SOFIT which tends to overestimate MVPA [17] so percentage time in MVPA and minutes spent in MVPA during PE lessons in the eligible studies may have been lower than reported.

Publication bias is a concern with intervention studies. A funnel plot was used to test for publication bias in the present study, but this was limited by the small number of eligible studies. While meta-analysis was supportive of benefits to intervention, this conclusion is tentative because the interventions were so heterogeneous - future research is advisable to estimate the magnitude of intervention effects.

Based on the review identifying the SHARP intervention, it is beneficial to inform the next phase of the PhD programme. The first part of the upcoming study will focus on identifying which aspects of the SHARP Principles may need to be refined before being applied in Scotland.

This will involve discussions with the original SHARP model developer, Dr Emma Powell, and some local teachers. After making the necessary refinements, a modified version of the SHARP Principles will be proposed.

In the second part of the study, workshops will be orgainsed to train 2-4 teachers in the SHARP Principles, and these teachers will apply the principles in their PE lessons over the course of one term. A feasibility study on the SHARP Principles approach will be conducted during this period. It is hoped that the main outcome of the study will demonstrate that applying the SHARP Principles is feasible in Scottish primary schools, based on data collection and process evaluation.

3.7 Conclusions

All studies in this review reported a favorable intervention effect upon increasing children's MVPA, suggesting that efforts to increase the MVPA content of elementary school PE are achievable. All studies had a focus on MVPA (health) outcomes and had PE pedagogical objectives to develop teaching effectiveness. Three of the studies used behavioral theory based intervention (2 with class teachers and 1 with PE specialists). The remaining two studies used either an expert instructor or specialist PE teachers. It was important to support teachers to teach and students to learn, by providing interventions based on teacher professional development programs/workshops and on theoretical framework of self-determination theory [33], [35], [36]. One new/existing intervention from England [38], published after the systematic review by Lonsdale et al. was identified as promising and probably generalisable to Scotland, and so potentially useful for our future intervention development in children in upper primary school in Scotland. Since the number of eligible intervention studies in this age group was relatively small and heterogeneous, though of reasonably high-quality, further studies are recommended. Games centred/motivational approaches to enhance children's enjoyment and engagement in PE lessons may be effective ways to increase children's MVPA levels.

3.8 Implications for School Health

PE can play an important role in promoting students' MVPA level in school, but previous studies have shown that this potential is not being realised because PE lessons are typically not as physically active as they could be, and children not as engaged as they could be. The potential of PE to contribute to public health goals by promoting MVPA might be under-appreciated by educators and health policymakers, as schools tend to prioritise other aspects of the curriculum such as literacy and numeracy. Achieving the WHO recommendation of at least 60 mins of MVPA daily will improve public health so the objective of school and PE lessons should be to assist children meet the recommendation by making PE more physically active. Doing so should be equitable since all children attend school. As reflected by Eloise et al. [39] "high-quality physical education" helps students build up the skills and knowledge that they have acquired to participate in and enjoy PA.

Practical lessons from the present study for class teachers, school principals, as well as education and health policymakers are as follows:

(1) Put more emphasis on the public health goals of PE - more active PE delivers health benefits to school students - helps children build a solid health foundation, reduces the risks from infectious diseases, such as the Covid-19 pandemic, and prevents many Non-Communicable Diseases in later life,

(2) The teachers, either PE trained specialists or generalist class teachers, must plan their PE lessons to have more MVPA content such that all children are engaged,

(3) Chose activities that encourage MVPA behavior - fitness infusion activity, competition, modified games,

(4) Provide training and professional development to modify teaching pedagogy to enhance students' motivations to be active in PE, and

(5) Reduce sedentary time by avoiding children standing around, queuing up, listening to long instructions, or selecting games where only a portion of children are active.

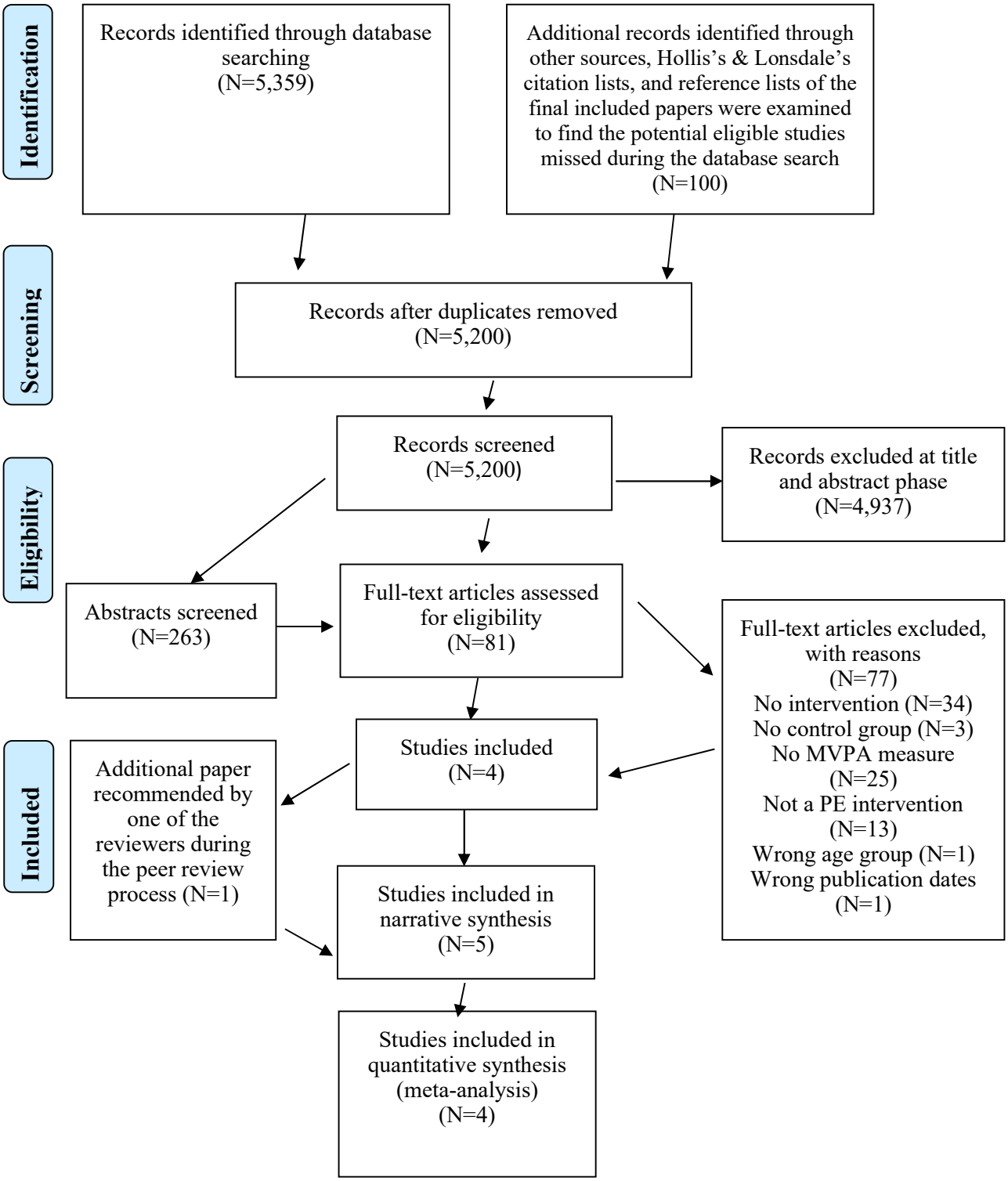

Fig 1. Flow Diagram of Number of Articles Retrieved During the Literature Search and Study Selection.

Table 1 Search Strategy in Scopus

Search Strategy
"physical activit*"
"moderate-to-vigorous-physical activity"
"active learning"
movement
exercise
fitness
"motor activity"
"activity level*"
1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
"physical education"
PE or P.E.
10 or 11
Intervention
experiment
training
compar*
Contrast*
Condition
13 or 14 or 15 or16 or 17 or 18
Student* or pupil
Learner
child* or adolesc*
school*
20 or 21 or 22 or 23
9 and 12 and 19 and 24
limit 25 to English language
limit 26 to yr. = "2010 to current"

The source type was restricted to peer-reviewed journals. Subjects like aging, paediatrics, disability, cancer, employment, religion, older people, college students or surgery were excluded.

Table 2 – Overview of Study Design and Sample Characteristics

Citation	Study Design (Country)	Sample Size Intervention /Control	Age of Students at Baseline	Intervention Duration	MVPA Outcome Measurement	Intervention Details	Comparison or Control Group
Boulley et al. 2018[28]	Cluster RCT (France)	293 students (15 teachers from 13 elementary schools) Eight teachers in control group Seven teachers in intervention group	Mean age = 8.3 (1st to 5th grade)	A school year From Oct to June	Accelerometer (SenseWear®pro2 Armband 6.1 BodyMedia, INC., PA, USA)	A teacher professional development program grounded in self-determination theory to increase generalist teachers' need-supportive motivating style and consequently their students' physical activity during PE lessons	Standard PE (by generalist teachers)
Fairclough et al. 2016[29]	Quasi-Experimental (UK)	139 students Two control schools Two intervention schools	10-11 years (grade 6)	6 weeks	Accelerometers (Actigraph GT9X, ActiGraph LLC, FL)	Twice-weekly 'Born to Move' (BTM) physical activity and fitness intervention alongside a regular PE lesson. BTM element delivered by an expert instructor and regular PE lessons delivered by generalist teachers (3 lessons per week) for intervention group	Children in the 2 comparison schools received their regular twice weekly PE lessons (by generalist teachers)

Powell et al. 2016[30]	Quasi-Experimental (UK)	95 students (with 111 students at based line) One control school and One intervention school	7-9 years (grade 3-4)	I year	SOFIT	Intervention based on self-determination theory and the socio-ecological model. Used the SHARP Principles Model. Delivered by individual generalist teacher, on-going supported by the PE coordinator and the Head Teacher who developed and adapted a PE and PA policy and curriculum map	Standard PE (by generalist teachers)
Smith et al. 2015[31]	Quasi-Experimental (UK)	72 students (42 boys, 30 girls) Two schools (both intervention group and control group in the same school)	11-12 years	12 weeks	SOFIT	Tactical Games Model (TGM) and used Teaching Games for Understanding Approach Delivered by physical education specialists who had experience of the concepts surrounding TGM and had attended a University based training course focused on TGM	Standard PE (by physical education specialists)
Telford et al. 2016[32]	Cluster RCT (Australia)	13 Intervention schools (457 students) 16 Control schools (396 students)	8 years (at based line) to age 12 years	4 years	System for Observing Fitness Instruction Time (SOFIT)	2 PE lessons per week from specialist-trained PE teachers (2 x 45 mins), 90 mins per week and the rest 60 mins was conducted by the generalist teachers to meet the weekly recommendation 150 mins	Standard PE, 2 PE lessons per week (by generalist teachers)

Table 3 – Joanna Briggs Institute Critical Appraisal Checklist for Quasi-Experimental Studies (Non-Randomised Experimental Studies)

	1. Clear Dependent and Independent Variables?	2. Participants Included in Comparisons Similar?	3. Participants Included in Comparisons Receiving Similar Treatment/Care?	4. A Control/Comparison Group?	5. Multiple Measurements of the Outcome both Pre and Post the Intervention?	6. Follow up Complete?	7. Outcomes Measured in the Same Way?	8. Experimental Studies Outcomes Measured in a Reliable way?	9. Appropriate Statistical Analysis?
lough et al. 2016	Yes	Yes	No Control group received less PE	Yes	Yes	Yes	Yes	Yes	Partial; Power limited as this was a pilot study
ll et al. 2016	Yes	Yes	Yes	Yes	Unclear SOFIT	Yes 4 weeks post-intervention using SOFIT	Yes	Yes	Partial; No mention of power and clustering
n et al. 2015	Yes	Yes	Yes	Yes	No	Partial	Yes	Partial SOFIT and accelerometers	Partial; No mention of power and clustering

Table 4 – Joanna Briggs Institute Critical Appraisal Checklist for RCT

/	1. True Randomisation Used?	2. Allocat-ion to Groups Concealed?	3. Groups Similar at the Baseline?	4. Participants Blinded?	5. Were those Delivering Treatment Blinded?	6. Outcomes Assess-ors Blinded?	7. Groups Treated Identically other than Intervene-tion?	8. Follow Up Complete?	9. Participants Analysed in Allocated Groups?	10. Outcomes Measured in the Same Way?	11 Outcomes Measured Reliably?	12. Appropriate Statistical Analysis?	13. Trial Design Appropriate?
ey et al. 2018	Yes	Yes	Yes	Partial	NA	Unclear	No Teachers in the control groups had no TPD	Partial	Yes	Yes	Yes	Yes	Yes
Telford et al. 2016	Yes	Unclear	Yes	No	NA	No	No Standard PE control group less PE lesson	Yes	Yes	Yes	Yes	Partial	Yes

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Chapter 4: Feasibility of Intervention for Increasing Moderate-to-vigorous Intensity Physical Activity (MVPA) in Primary School Physical Education: A Study Protocol

4.1 Chapter Overview

Findings from the systematic review (Chapter 3) identified the SHARP Principles Model as a promising primary school-based PE intervention from England. The aim of this study (Chapter 4) is to test the feasibility of this model and determine whether it increases MVPA during PE classes in primary schools in Scotland. If this intervention is to be used and evaluated in Scotland, it would first need to be adapted (if necessary) and then assessed for feasibility of the 'SHARP Scotland'.

The original plan was to test the feasibility of 'SHARP Scotland' in a Scottish primary school to provide evidence to Scottish Councils of its potential, then do an evaluation with the longer-term aim of adopting and rolling it out across Scotland if it was effective. However, the lockdowns and restrictions associated with COVID-19 at the time made in-person fieldwork impossible, so, the feasibility study could not be conducted during the 2020-2021 school year. Nevertheless, this protocol paper had already established a framework for SHARP Scotland. Although the feasibility study could not be implemented as planned, the paper was published as a protocol for future use by the Physical Activity for Health team at the University of Strathclyde.

The present protocol study was first published first published in *F1000Research* in March 2022. A revised version, incorporating reviewer comments, was republished in February 2023. The paper is presented in the same format as was published in the journal, and the published format is included in Appendix III.

LSW planned the study and was the lead author, responsible for liaising with study participants, coordinating data collection, managing and storing data, and writing (including original draft

preparation and review/editing). EP, LW, FM, JJR oversaw the study and advised on specific aspects, including recruitment, data analysis, and process evaluation procedures. EP and LW provided guidance on conceptualisation and advised on the study design. CS assisted with the design of the intervention. Any changes to the study protocol needed to be discussed before the trial registry could be updated. All authors contributed to the design of the protocol paper, read, and approved the final manuscript.

4.2 Abstract

Background: Most primary school Physical Education (PE) has relatively little health-enhancing moderate-to-vigorous physical activity (MVPA). - A promising theory and evidence-based intervention, the 'SHARP Principles' model, has been effective in making PE lessons more active in one area of England. This protocol paper explains the rationale for use of the SHARP intervention, and the methods used to examine the feasibility and acceptability of a version of SHARP translated for use in Scotland (SHARP Scotland).

Methods: The feasibility of SHARP Scotland will be evaluated by key areas of focus for feasibility studies: Acceptability, Implementation, Integration, Limited Efficacy Testing. A combination of process measures, including observations, session delivery records, accelerometry-data collection, questionnaires, and semi-structured qualitative focus groups with teachers and pupils will be used. The feasibility and suitability of the SHARP Scotland intervention for a future Randomised Control Trial (RCT) will be assessed. The study will involve children from 8-11 years old (Primary 4 to 6) in two schools, one large urban school, and one smaller school; four classes will be randomly assigned to the intervention group, and four classes randomly assigned to the usual-care (standard curriculum) control group. Within the 8-week intervention, MVPA in the intervention group will be targeted by encouraging class teachers to deliver their PE classes in more active ways, following SHARP Principles. A maximum of 64 PE lessons delivered in a SHARP way will be conducted to

assess the effectiveness of the intervention.

Discussion: The outcome of this study will be an assessment of whether applying the SHARP intervention is feasible in Scottish schools. Identification of any modifications to the intervention or evaluation which are required will provide insight for a fully powered effectiveness trial in the future, if appropriate.

Keywords: Moderate-to-vigorous physical activity, Intervention, Primary school, Children, Physical education, Health, Accelerometry-measured, Feasibility.

4.3 Introduction

Moderate-to-vigorous intensity physical activity (MVPA) is very important to the health and well-being of children as it provides both immediate and long-term health and non-health benefits [1]-[4]. Despite these positive impacts, it is estimated that approximately only 20% of children and adolescents globally meet the previous WHO recommendation of 60 minutes of MVPA per day every day [5]. As a result, children's current and future health is at risk [6]. As there is good evidence that PA generally declines by age 6–7 years in the UK and globally [7], future interventions to promote MVPA should start before adolescence [8].

There is high potential for school time to help pupils meet the WHO MVPA recommendation [9]. Schools are an important setting for promoting children's daily PA as pupils from all socio-economic and cultural backgrounds spend around half of their days per year at school [10]. Schools can therefore play a vital role in keeping young people active through all activity opportunities [11], such as morning and lunch breaks, recess, active travel, afterschool activities, play and sports [12], but most importantly in physical education (PE) lessons.

The United States Centers for Disease Control and Prevention (CDC, USA) [13] recommends that MVPA levels during primary school PE lessons should reach 50% of lesson time. The UK Association for Physical Education (AfPE, UK) [14] recommends that children be actively moving

for 50-80% of the available PE learning time. In its health position paper, AfPE also outlines that active learning time is about developing children's physical skills by providing them with the opportunity to practise those skills during lessons in a fun and purposeful learning environment, as PE involves 'learning to move' and 'moving to learn' [14], so PE lessons can enhance MVPA beyond just class time. Nevertheless, most primary school PE lessons globally do not meet recommendations for the MVPA content of class time [15], so there is a need to find more effective and sustainable good practices to increase children's MVPA levels during school time and in PE lessons [16].

In Scotland, there is a great public health need for population-wide interventions to increase Scottish children's PA as few children reach the recommended minimum of 60 minutes of MVPA per day [5], [17]. Scotland faces a crisis arising from unhealthy lifestyles which begin in early childhood: poor diet and low PA or exercise create a massive burden of later heart disease and stroke, diabetes, obesity, and cancers [18]. Hence the Scottish Government is keen to improve children's health and wellbeing as guidelines stated in the national "Curriculum for Excellence [19] that *"Learning in health and wellbeing ensures that children and young people develop the knowledge and understanding, skills, capabilities, and attributes which they need for mental, emotional, social and physical wellbeing now and in the future".*

To find interventions that could increase the MVPA content of school PE, a systematic review was undertaken by the author in 2019 [20]. A literature search of global evidence (within the past decade) on effective interventions to increase MVPA during PE classes in children (8 to 11 years) was conducted. The systematic review identified five eligible intervention studies [21]-[25].

Specific rationale for the choice of SHARP intervention for translation to Scotland

The 'SHARP Principles' [21] model (SHARP) was identified as the most promising for translation to Scotland, among the five eligible studies, from our recent systematic review [20]. This

intervention [21], with a few modifications, now forms the basis of the present feasibility study. On top of the reasons mentioned in the previous chapter discussion, SHARP was chosen for future intervention development and evaluation, starting with the proposed feasibility study as it:

1. had clear evidence of efficacy in increasing MVPA content of PE in children in our target age range. Indeed, there was evidence that the SHARP lessons had a much higher MVPA content than standard (control) PE lessons in the original evaluation studies. SHARP had been tested twice across multiple schools in the West Midlands, England it increased children's MVPA during PE lessons by 30% and 27% respectively [21], [26].
2. had a theoretical basis - the intervention was grounded in a combination of theoretical frameworks namely the Self-Determination Theory (SDT) [27], the Socio-Ecological Model [28], and key components (e.g., barrier identification, action planning, and providing instruction) from Behaviour Change Taxonomy [29]. In the original development of SHARP, SDT was applied to connect the roles of the Head Teachers, PE subject leader, and the individual teachers. The components of SDT were implemented through a supportive autonomous role (autonomy) along with developing teachers' social networks (relatedness) and knowledge (competency). Implementation of the SHARP Principles in Scotland is underpinned through the original SHARP Principles model. It is intended that when the intervention is translated to Scotland teachers have relatedness through the shared aims of PE within the school and their connection with each other as professional practitioners working towards this shared aim, along with the support of their PE subject leader and school leadership team. Moreover, SHARP is applied to teachers' existing planning, so could be applied at little cost, and it ensures that teachers can retain autonomy, hence, it is also faithful to SDT.
3. had the support of readily accessible online resources (e.g., resource cards and videos) for teachers' use [30].

The present study aims to describe how we will test the feasibility of the SHARP intervention in Scotland. We propose this study as the foundation of future research which tests whether the SHARP-Scotland intervention works or not, and how it might be implemented across various parts of Scotland to increase MVPA during PE (two lessons of PE per week are timetabled in Scottish primary schools). The goal of the SHARP lessons is to teach PE in a more active way, increasing pupils' active learning time and, in turn, boosting overall MVPA.

The SHARP lessons had a much higher MVPA outcome than standard (control) PE lessons, as shown in the original evaluation of the two intervention studies conducted across multiple schools in the West Midlands, England. The first small-scale study was a quasi-experimental, non-equivalent groups design involving four classes from two primary schools, with 95 children aged 7 to 9 years, conducted in 2014. The results of the first study showed that the SHARP Principles Model was effective in increasing MVPA in PE (by 30%) [21].

To assess the wider implementation of the SHARP Principles intervention on children's MVPA during primary PE, a quasi-experimental intervention was conducted in nine primary schools involving 10 teachers and 4 coaches as well as 84 aged 5-11 year-old children in the same region of England in 2016. The second study showed that SHARP intervention was an effective teaching strategy for increasing MVPA (by 27%) in primary PE when taught by school-based staff and there was no need for delivery of the intervention by outsourced coaches [26].

The strategy of the SHARP Principles intervention (Stretching while Moving, High Repetition of Skills, Accessibility, Reducing Sitting and Standing, and Promotion of Physical Activity) is based on the findings of previous effective PE interventions which tend to be split into two categories, fitness-based [31], [32] and teaching-based interventions [33]- [36]. The high repetition of skills and promotion of PA demonstrates that active learning time (fitness effect) is integrated into the PE lessons, thereby requiring only low resources [37]. Furthermore, since the

SHARP Principles model is a teaching strategy intervention that targets teachers' behaviour to create an active learning environment embedded in primary PE lessons, it provides regular, structured opportunities for pupils to be active. This approach is likely to be a sustainable way to achieve improvements in PA among children and adolescents [37] .

Moreover, the SHARP intervention had been developed over time, evolving from a small-scale intervention to one that could be replicated on a larger scale across various contexts. The second intervention study concluded that the SHARP Principles are effective when grounded in a supportive organisational culture. Additionally, it appeared that the aim of PE to promote activity while also developing skills became the teachers' main focus as reflected in the teachers' focus group interviews. To help teachers better understand the SHARP Principles and create an active learning environment in PE lessons, materials, such as resources cards and videos were produced and uploaded online for teachers to use.

The SHARP Principles model had been tested twice prior to the work in this thesis, and both intervention studies relied on SOFIT to assess MVPA, which is likely to overestimate MVPA [38]. However, it is evident that the SHARP model has a high potential to increase pupils' MVPA during PE lessons. Therefore, it needs to be modified for the Scottish context and a protocol is needed to develop the modification of SHARP and the evaluation of SHARP in Scotland. The feasibility of SHARP Scotland is intended to assess several key areas of focus for feasibility studies as proposed by Bowen et al. [39], particularly Acceptability, Implementation, Integration, and Limited Efficacy Testing (Table 1).

Table 1- Key areas of focus to be addressed and method to assess that area [39]

Areas of Focus	The feasibility study asks	Method to assess/evaluate
Acceptability	of the intervention	assessed by qualitative methods
Implementation	of the intervention - can it be implemented as planned/what refinements are needed? What adaptations to the intervention might be needed?	assessed by a combination of quantitative evaluation of the number of SHARP sessions delivered and qualitative work
Integration	of the intervention into the new setting - can teachers integrate it into their routine teaching practice?	assessed by qualitative methods
Limited efficacy testing	is there any preliminary evidence of efficacy?	quantitative evaluation (MVPA content of PE lessons by collecting accelerometry data between intervention vs control classes) - the SHARP lessons had higher MVPA content in two previous evaluations in England. Increased children's MVPA during PE lessons by 30% and 27% respectively [21], [26]. Given that these evaluations relied on SOFIT to assess MVPA—resulting in class-level estimates that are likely overestimates and exhibit high between-pupil variation—the efficacy of SHARP for improving child-level MVPA should be interpreted with caution.

4.4 Methods

4.4.1 The Study Sample, Recruitment, Randomisation, and Consent

Children from 8-11 years old (Primary 4 to 6) will be involved from two local authority primary schools in the Glasgow area, characterised for socio-economic status using the Scottish Index of Multiple Deprivation (SIMD) [40]. All class teachers from 18 classes will be invited to take part and we intend to recruit a total of eight classes/class teachers which will then be randomly allocated to four intervention classes and four control classes (standard curriculum, offered the SHARP intervention training after the eight-week intervention, i.e., a wait-list control) by a member of staff from the Mathematics and Statistics Department in our university who is not connected to the study. A total maximum of around 240 children will be involved in this study (the typical class size in Scottish primary schools is 30 pupils).

We have not yet registered this trial because the local authority will only give the agreement in principle until the schools are operating normally post-COVID. We also cannot apply for ethics approval until schools are operating normally post-COVID. When schools will be operating normally is unclear, and the restrictions which might apply to PE classes, or to our research (e.g., access to schools) are unknown at present. Once confirmed, this study will seek ethical approval from the University of Strathclyde's School of Psychological Sciences and Health Ethics Committee. Any amendment to the study protocol will be submitted for ethical approval before implementation. Consent will be obtained from all participating children via parental consent forms. All pupils attending the relevant PE classes will be considered suitable for inclusion, with no exclusions, though if children have health reasons which might impair their ability to take part in PE this will be noted. Teachers will be required to provide informed written consent. Verbal assent will be sought from children before enrolment in the study, and their parents will be required to provide informed written consent.

4.4.2 Teacher Training in the SHARP Intervention

The intervention will be delivered by generalist class teachers and the SHARP Principles (more active approach) will be adopted when they are teaching PE lessons. Teachers of intervention classes will be trained in the SHARP approach (via a workshop) before intervention commencement. They will then be asked to apply the principles in their PE lessons over one school term (eight weeks). The workshop will be delivered by the originator of SHARP (EP) and the PE specialist (CS) involved in translating SHARP Scotland. Existing SHARP resources and training materials are available online [30] and will be used by the teachers involved. Group planning sessions (30 minutes), as required, will be used to help teachers deliver the intervention and intended also to motivate teachers to use the SHARP Principles in their planning and teaching. Training content will be flexible and will depend on what is needed to modify the SHARP Principles according to the curriculum and environment of Scotland. To provide additional motivation for teachers to take part, the training will count towards continuous professional development hours.

(A summary of the intervention description (trial process) is outlined in Figure 1)

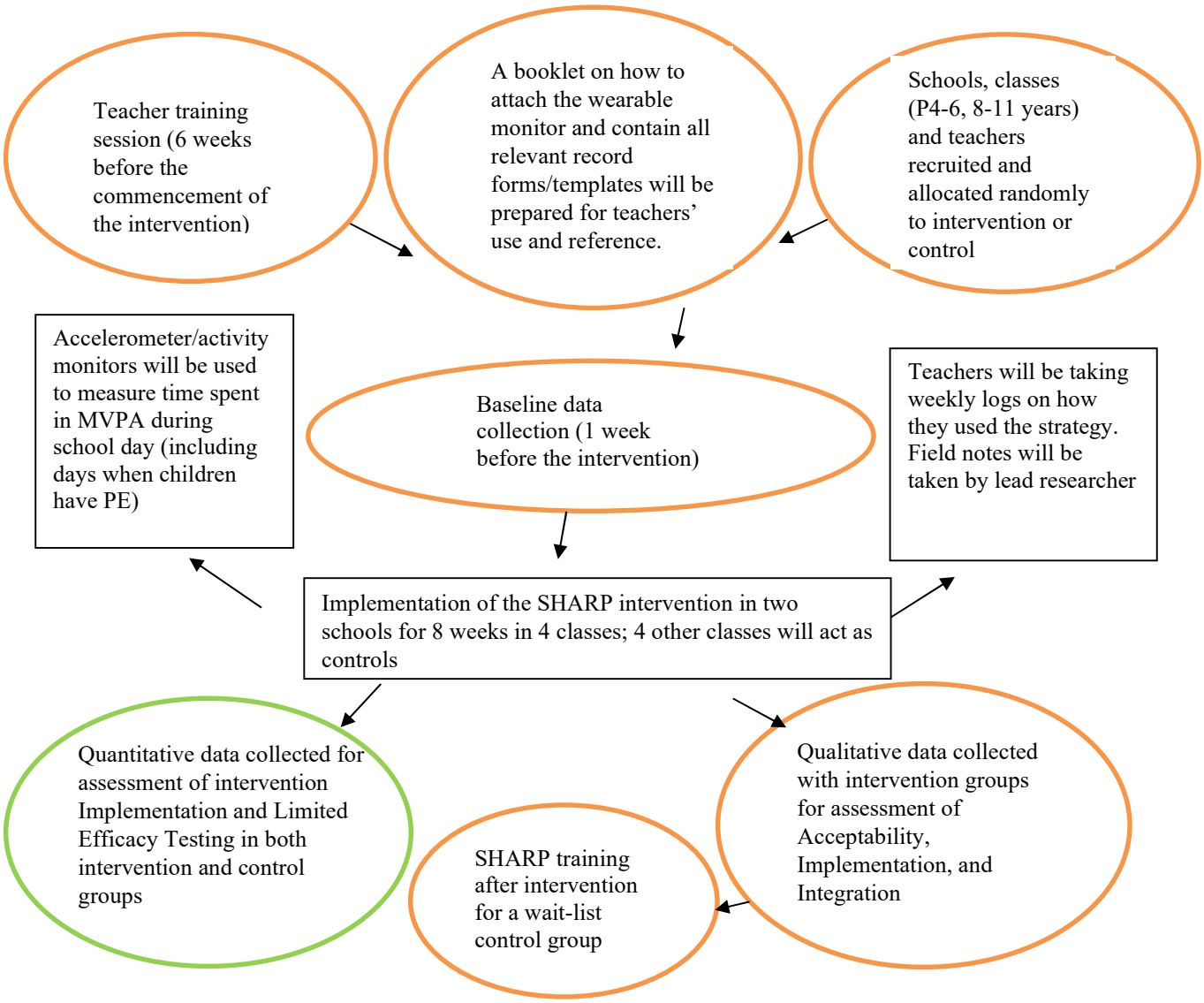

Figure 1 Intervention description

4.4.3 To Apply the SHARP Teaching Principles in the Intervention

The SHARP intervention is based on five teaching principles named 'SHARP Principles' (Stretching whilst moving, High repetition of skills, Accessibility, Reducing sitting and standing, and Promotion of PA [21], [26]). SHARP Principles are designed specifically to help teachers deliver their existing PE classes but to do so in ways that involve more children in the class moving for much more of the class time, to increase MVPA during the lesson. The authors of the present study consist of the original developers of the SHARP intervention in England, a PE

specialist teacher from Scotland, and the researchers responsible for evaluation. We consider that SHARP can be adapted to the Scottish context relatively easily, in part because it does not seek to change what is taught in the class but focuses on how it is taught (in a more active way).

In brief, the SHARP Principles are as follows [30]:

Stretching whilst moving - During the warm-up section of a SHARP PE lesson, activities are to include dynamic movements (such as movements that engage the lower and upper body), and stretches (e.g., side shuffles, jump and twist, high knees, and skipping).

High repetition of motor skills - SHARP increases active learning time by reducing queueing. SHARP can also increase the amount of existing equipment used in each class or increase the number of learning stations.

Accessibility through differentiation - SHARP focuses on setting tasks appropriate to children's physical, cognitive and social development, which will enable them to engage in more active learning time. Teachers can use the 'STEP framework' (space, task, equipment, and people) for more effective differentiation of activities in class [21], [26].

Reducing sitting and standing - SHARP increases teachers' awareness of the amount of time children are sitting and standing during the lesson with knowledge transfer, teacher feedback, and improved organisation of equipment. In a SHARP lesson, teachers should engage children in activity as soon as possible at the start of a lesson, they should not stop the whole class from moving while instructions are being given, they should encourage children to stay active (e.g., by continuing to practice skills) while receiving instructions, and they should organise equipment to minimise queueing.

Promoting in-class physical activity - This principle is based on teachers' encouragement of greater children's in-class PA through positive praise such as 'Great teamwork, keep moving and looking for space'.

4.4.4 Assessment of Feasibility

The Bowen *et al.* Framework [39] (Acceptability, Implementation, Integration, Limited Efficacy Testing) will be used to assess the feasibility of the SHARP intervention and evaluation in Scotland. (Table 1)

Acceptability

Acceptability assessment is an attempt to answer the question framed by Bowen *et al.* but applied to the present study of 'Can SHARP work in Scotland?' [31] Qualitative methods will be used to assess the willingness of school staff to deliver the programme, (e.g., the willingness to be allocated randomly to intervention or control groups, willingness to deliver lessons using the SHARP Principles), and willingness of children to participate. Acceptability of the methods used for measuring the intervention effect in a future evaluation (e.g., whether children find using the accelerometer acceptable) will also be assessed. All qualitative data will be collected via questionnaires and semi-structured focus groups with teachers and pupils on completion of the intervention.

Implementation

Implementation is an assessment of the extent to which the intervention was delivered as planned [39] - can it be implemented as planned/what refinements are needed? The process evaluation will be supported by the Medical Research Council (MRC) guidance on process evaluation of complex interventions [41]. Quantitative methods will be used to assess recruitment and participant attrition rates (class level and individual level), and intervention fidelity. The researcher's observations of the delivery, relevant documentation, and records (such as teachers' logs - teachers will be asked to log each PE lesson delivered and whether they used SHARP Principles and which ones, using a checklist) will enable the researcher to reflect on the appropriate use of and application of behaviour change tools utilised. Qualitative semi-structured

focus groups with the class teachers will be used to identify any refinements to the delivery of the SHARP Scotland intervention which might be required from teachers' perspective.

Integration of the SHARP intervention in the Scottish context (SHARP Scotland)

Integration, as defined by Bowen *et al.* [39] and applied to the present study, is an assessment of the extent to which changes to the school were necessary to integrate SHARP PE lessons (e.g., any changes to timetabling, equipment, unintended teacher impacts such as increased workload). This type of assessment, as framed by Bowen *et al.* [39], is necessary to assess whether the intervention is feasible beyond the counting of the number of sessions delivered. The integration will be assessed by qualitative methods. Semi-structured focus groups with class teachers will be used to identify the changes to the school which were necessary and to identify any unintended consequences if integrating SHARP lessons.

To some extent, the issue of integration of SHARP Principles into the Scottish primary school system has been addressed by cooperation involving the study authors (researchers, original SHARP development team in England, plus primary school PE specialist from Scotland) before the feasibility study. The main outcome of this adaptation was a modified version of the original SHARP Principles intervention (SHARP Scotland). Table 2 outlines the differences between the original SHARP intervention and the translated version of the SHARP Scotland intervention which will be tested for feasibility.

Limited efficacy testing

Bowen *et al.* [39] recommend limited efficacy testing in feasibility studies. Only preliminary evidence of efficacy will be obtained in the present study, and the extent to which the primary outcome of a future evaluation (MVPA content of PE lessons in both the intervention and control groups using accelerometer) can be measured feasibly will be assessed by quantitative methods. We will measure MVPA during PE lessons and the whole school day in all children with hip-

worn Actigraphs. Children will be asked to wear the Actigraph during school time for five days from the beginning to the end of the intervention.

Whole-school day MVPA data will be collected to provide useful contextual information on the amount of MVPA being accumulated during the school day, and because in previous studies we have found that it is more practical to collect accelerometry data during specific periods of the school day (e.g., PE class, recess) if children simply put the Actigraph on at the start of the school day and return it to class teachers at the end of the school day. The feasibility of accelerometry will be assessed as the number of school days with at least 75% of wear time as a percentage of the total number of school days in which children were asked to wear the accelerometers. The teachers in the classes will be shown how to help children put the monitors on /check that they are being worn and worn properly and asked to ensure that the monitors will be put on the consenting participants at the start of the school day and remove just before school finishing. This process of accelerometry data collection also minimises disruption and delay to PE classes (by avoiding the need to distribute accelerometers during the PE class). Teachers will also be asked to record children's PE classes (PE date, day start time, and finish time) in a class diary.

Analyses of between-group differences in the MVPA content of PE (the percentage of time in PE class spent in MVPA), will be preliminary, as the feasibility study is not powered to test for intervention effects. As this is a feasibility study, one of the main objectives is to collect appropriate data to inform a power calculation for a future Randomised Control Trial (RCT). Therefore, no sample size calculation was undertaken for this feasibility study, but the samples will be sufficient to measure important feasibility parameters, notably accelerometer loss, accelerometer data loss, and our ability to identify and extract accelerometer data from PE classes. The analyses will inform a future full-scale trial if feasibility is high.

Table 2 - The differences between the original SHARP intervention and the translated version of SHARP Scotland intervention

Original SHARP Principles Model Duration – 1 school year Population: Primary school children (year 3 and 4 (aged 7 to 9 years)/ year 1 to year 6 (aged 5 to 11) [21, 26]		Adapted "SHARP Scotland" Intervention: Duration – 8 weeks (1 school term in Scotland) Population: Primary school children (P4 to P6, aged 8 to 11 years)	
Components	Details		Details
Teacher training	• Support by head teachers at the organisational/policy levels, PE coordinators, and other staff members in the use of the SHARP Principles during PE lessons • Joint planning sessions (30 minutes)		• Four teachers provided with a "3-hour workshop". Aimed to get teachers on board, motivate them with initiate peer group support among trained teachers, and empower them with the knowledge and skills to deliver the SHARP. • Arranged with ongoing support plus online communication to provide instant feedback if required. • Group planning sessions (30 minutes).
Provision of materials and equipment	• Pedagogical guidelines for teachers to consider during the planning and delivery stage of their PE lessons • Provide the SHARP Principles instruction and resources cards	⇨	• Pedagogical dialogue on what and how to modify the SHARP Principles Model according to the curriculum and environment of Scotland. • Provide the SHARP Principles instruction and resources cards and an overview video resource & SHARP PE lessons – for example, video resource. • Online communication to provide instant feedback if required.
Teaching content	• A minimum of two different activity areas of the primary PE National Curriculum (e.g., dance, gymnastics, games, athletics, and adventure activities), joint planning • Content aligned with the National Curriculum for England.		• Co-production approach to the translation of SHARP to Scotland (input of PE coordinator and relevant class teachers will be needed via online if necessary) has already taken place. • Minimal modifications made to original SHARP intervention content and training materials as it was felt that SHARP Principles can be applied to existing PE lessons. Teachers will be using their normal PE curriculum but delivering the lesson in a SHARP (more active) way. • Contents align with the Curriculum for Excellence in Scotland as based on existing PE classes
Nature of intervention	• A quasi-experimental, non-equivalent group design intervention	⇨	• A feasibility study

Theoretical constructs of the SHARP Principles model are not affected by curriculum activity type or teaching style.	• Self Determination Theory • Behaviour Change Taxonomy • Social-Ecological Components • (Specifically directed at teachers)		• Self Determination Theory – (Teachers' competence relatedness and autonomy) • Behaviour Change Taxonomy • Social-Ecological Components (Teachers' individual level, interpersonal level, organisational level)
Measurement tools	• SOFIT, (pre-and post-direct observation, training provided to observers) • Semi-structured teachers interview during the post-intervention		• Accelerometer/activity monitor used during PE lessons and whole school day • Quantitative evaluation of SHARP PE lesson delivery • Semi-structured teachers/pupil focus groups
Others			• Pre-school visit/observation • Talk to school health staff, if appropriate. • City Council meeting.

Dissemination

Findings of the study will be disseminated via publications in peer-reviewed journals, conference presentations, and lay summary reports/presentations which will be given to parents and primary school teachers who participate in the study.

Data management

Paper-format documents (e.g., field notes) will be kept locked in filing cabinets. All electronic data will be stored in the University of Strathclyde's centralised secure data storage system. Only the immediate research team will have access to raw data and will be kept for five years before being destroyed. Participants' information will also be given codes and will not be referred to by name in published documents. Only the researchers will have access to the codes and their relating participant names. Consent forms will be stored separately from participant data. Teachers' and pupils' questionnaires will be kept by the researchers after completion. After the transcription, data from interviews will be deleted immediately from voice recorders, with

pseudonyms used in all reports in place of participants' names. All data collection and storage procedures will be general data protection regulation compliant.

Safety procedures

Every primary school has its health and safety policies, which the SHARP Scotland feasibility study will not breach. In the event of an accident occurring as a direct consequence of participation in the study (no high-risk activities were identified by risk assessment during ethics application) primary school teachers will report this to the research team and appropriate measures will be taken according to existing policies. The researchers will adhere to any Covid-19 safety requirements in place at the time of the study.

Data analysis

A descriptive analysis will summarise the findings of the feasibility and acceptability parameters of interest such as the proportion of children measured at baseline and follow-up to calculate recruitment and attrition rates. Accelerometer data (primary outcome MVPA during PE lessons) will be used to estimate differences in the MVPA content of school PE between intervention and control groups and it is useful for planning future trials. Qualitative interviews/focus groups will be audio-recorded, transcribed verbatim, and thematically analysed. Due to the small sample size, anticipating these analyses will be exploratory and will be used to inform a future trial rather than to draw definitive conclusions regarding the effectiveness of the intervention.

Study status

Teacher training in the intervention is currently scheduled for summer 2022 (at the end of the 2021-2022 school year in Scotland) and the feasibility study itself is intended to begin later in 2022, ideally towards the start of the school year in 2022-23 (August-October, 2022), but with

precise timing depending on how the COVID-19 pandemic is affecting schools in Scotland at the time.

4.5 Discussion

While concerns about insufficient MVPA in childhood have focused on the impact on their physical and mental health, low MVPA also impairs cognitive function and academic attainment in children [1], [42]. Only a small proportion of Scottish children are achieving the recommended minimum of 60 minutes of MVPA daily [43], [44] and so a simple school-based intervention could provide an effective measure in childhood for increasing MVPA. Therefore, it is hoped that the outcome of this study will be a demonstration that applying the SHARP Principles intervention is feasible in Scottish schools. An intervention that is translated so that it fits the Scottish context well could produce much more active PE lessons and consequently help large numbers of children achieve the MVPA recommendations.

This paper describes the protocol for the SHARP Scotland intervention feasibility study. As noted above, the original SHARP Principles intervention studies [21], [26] were successful in improving MVPA significantly in school PE lessons in the Midlands of England. Adapting successful interventions for use in other settings should be more efficient than developing entirely new interventions. Using existing interventions means that intervention evaluation does not need to start at the beginning of the process described by the UK MRC [41]. To translate an existing intervention from one setting to the other, context-specific modifications might need to be made to ensure the intervention can function as intended while still meeting its desired aims. The study outlined in this protocol aims to test whether the SHARP Scotland intervention is both feasible and acceptable in the Scottish primary schools while it follows along with the intervention development and evaluation pathway described by the UK MRC Framework [41].

Strengths and limitations of this study

There are some strengths to this study. First, it is a translation of a previously successful intervention (SHARP Principles Model) to be used in another setting (SHARP Scotland) and the feasibility testing is a low-cost, culturally relevant school-based intervention with great public health potential [21], [26]. Furthermore, both quantitative (accelerometry data; process evaluation logs; recruitment data) and qualitative (interviews/focus groups) approaches are utilised to test feasibility in the present study, so the data are complementary and can be triangulated. Lastly, information on the feasibility of the SHARP intervention and SHARP evaluation in Scotland will be useful to provide insight for a fully powered effectiveness trial in the future.

However, there are also limitations to the study. Firstly, in this study, we are only dealing with one part of the school day, PE lessons. However, PE lessons are an important part of school day MVPA since they can both increase MVPA directly (MVPA during PE time, 2 lessons per week in Scotland), and indirectly (e.g., by enhancing motor competence, physical fitness, and/or physical literacy). The MVPA accumulated in the whole school day is crucial, but it is the result of a complex system made up of many other elements e.g., influences on what children do during recess, lunchtime, and whether they have active breaks at other times. A whole school day MVPA intervention will probably be required to achieve desired population levels of MVPA but is beyond the scope of the present study. This study will be focused on one element of the whole-school complex system, but future studies will have to build on it and address the other parts of the school system. The present study is restricted to the issue of enhancing existing PE lessons through teaching strategies designed to increase PA above routine practice [45]. Secondly, as a small-scale pilot and feasibility study, the generalisability of this study may be limited due to its short duration and small sample size. However, the feasibility study is required to develop and

evaluate the intervention on a larger scale in the future - it is a foundation for future evaluation research. Thirdly, since the feasibility study may be carried out during the COVID-19 pandemic in 2022, an unstable education environment might cause research delays and modifications may be required to the proposed intervention or feasibility evaluation.

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Chapter 5: Moderate-to-Vigorous Intensity Physical Activity During School Hours in a Representative Sample of 10–11-Year-Olds in Scotland

5.1 Chapter Overview

After identifying the intervention strategies for increasing pupils' MVPA during PE lessons and proposing an adaptation for a feasibility study to be used in Scotland, this chapter aims to provide a clear picture and understanding of the situation regarding Scottish primary pupils' MVPA levels. It explores the MVPA levels of Scottish pupils (aged 10-11 years) during school hours and the factors affecting the accrued levels. The objectives were to examine the percentage of pupils who met the global recommendation of 30 minutes of MVPA during school hours and to identify key risk factors for not meeting this goal.

This chapter contains a peer-reviewed article titled "Moderate-to-vigorous intensity physical activity during school hours in a representative sample of 10–11-year-olds in Scotland"published in the *Journal of Science and Medicine in Sport* in February 2023. The paper is attached in its published format and is included in Appendix IV.

Lan S. Wong was responsible for data management and analysis, data interpretation, conceptualization, writing the original draft, and writing the review and editing. **John J. Reilly** provided scholarly views, data interpretation, and writing for review and editing. **Paul McCrorie** supported data management and analysis, as well as writing for review and editing. **Deirdre M. Harrington** assisted in data analysis and interpretation, and writing for review and editing.

All authors contributed significant intellectual content and approved the final version of the manuscript.

5.2 Abstract

Objectives: Growing concern about children and adolescent physical inactivity has made the promotion of PA a public health priority. International recommendations suggest children should accumulate at least 30 minutes of moderate-to-vigorous physical activity (MVPA) during school hours. This study assessed levels of device measured MVPA in a large nationally representative sample of Scottish children aged 10-11. Risk factors for not meeting the school-hours MVPA recommendation were examined.

Design: Cross-sectional

Methods: Mean time spent in MVPA during school hours across five weekdays was measured using Actigraph accelerometry (May 2015-May 2016). Binary logistic regression, presented as odds ratio (O.R.) and confidence intervals (C.I.), explored associations between meeting/not meeting the recommendation by sex, socioeconomic status (SES), season, and urban/rural residence in 2022.

Results: Valid data were obtained from 773 children (53.9% girls, 46.1% boys) from 471 schools. Mean daily school-hours MVPA was 29 (SD 11) minutes; 42.7% of children reached the recommendation. The odds of girls (O.R. 0.43; C.I. 0.32, 0.57) meeting the recommendation was significantly lower ($p<0.001$) compared to boys. Children living in rural areas had higher odds (O.R. 1.49; C.I. 1.04, 2.15) of meeting the recommendation compared with those in urban areas ($p=0.032$). No significant differences in meeting the recommendation by SES ($p=0.700$). The overall trend for season was significant ($p<0.001$), with lower odds of meeting the recommendation in winter compared to summer.

Conclusions: Most Scottish children aged 10-11 did not meet the 30 minutes MVPA recommendation. Interventions to increase MVPA during school hours are essential to promote public health.

Keywords: physical activity, prevention, health, accelerometer, primary school time, children

5.3 Introduction

Physical activity is important for children as it improves both short-term and long-term health and wellbeing [1]. Specifically, World Health Organization (WHO) guidelines state that achieving an average of 60 minutes per day of moderate-to-vigorous intensity physical activity (MVPA) provides children and adolescents with a wide variety of health benefits [2]. Most children and adolescents globally have low levels of MVPA and do not meet the previous WHO recommendations (i.e. achieving at least 60 minutes MVPA daily) [3]. Children spend a large part of their day at school, and the school setting is a significant contributor to MVPA [4]. MVPA recommendations during school hours from the American Heart Association [5] and the UK Government [6] state that children should achieve at least 30 minutes of MVPA during school hours.

A recent systematic review [7] on PA levels during school hours found only three studies [8]-[10] that analysed the extent of achieving the school-based MVPA recommendation of 30 minutes using the most valid method of measuring MVPA objectively accelerometry. These studies, which included PA opportunities during different time periods at school, involved small samples [8], [9] and only one sample was representative [10]. Van Stralen et al.'s [8] and Hubbard et al.'s [9] study showed that only 7%-8% of European and American elementary school students (aged 7-12) met the recommendation for 30 min of school-hours MVPA, while Grao-Cruces et al.'s study [10] indicated that in Spanish 8-year-old children, 24% of boys and 8% of girls met the recommendation. If low MVPA during school hours is widespread, then school-based strategies to further increase PA will need to be implemented [11].

Development of strategies to increase school-hours MVPA will be informed by understanding risk factors for low MVPA while at school. Only two studies [8], [9] have

considered the risk factors associated with not meeting the 30 minutes daily school-hours MVPA recommendation. These two studies found very limited information, for example, it is not clear whether season and urban or rural residency are risk factors for achieving the recommendation. In summary, there is a dearth of evidence from representative samples using objective measures of MVPA, and limited evidence on risk factors for insufficient school-hours MVPA in primary schoolchildren. We, therefore, aimed, in a large nationally representative sample of Scottish children aged 10-11 years, to (a) assess the prevalence of meeting the school-hours MVPA recommendation, and (b) identify risk factors for not achieving the recommendation.

5.4 Methods

This present study used the data from the "Studying Physical Activity in Children's Environments across Scotland" (SPACES) study (see http://spaces.sphsu.mrc.ac.uk/home) which was carried out during school terms between May 2015-May 2016 [12]. SPACES participants were recruited from the Growing up in Scotland (GUS) study, a nationally representative longitudinal cohort study originating in 2005 (https://growingupinscotland.org.uk/). Of a possible 2404 children (aged 10/11 years old) who had participated in the GUS interview conducted between September 2014 to February 2015, 2162 parents consented to be contacted by the SPACES staff. They were sent SPACES study information, registration documents, and consent forms by post. There were 1096 children who took part and both child and parent were required to sign consent forms. Data were received for this present analysis in 2022. Variables such as sex, socioeconomic status (SES), season, and urban or rural residence were obtained as part of the GUS Study, and weightings were included. These variables were also used as the potential risk factors in the present study.

An accelerometer [13], [14] (ActiGraph GT3X+) was used to measure school-hours MVPA. Accelerometer data were processed using ActiLife software (v6 ActiGraph Inc, USA).

The acceleration signal was extracted from the x-axis, digitised and stored as 'count', and raw data was processed into 10-s epochs. Non-wear time periods (60 consecutive minutes of zero acceleration were recorded by the device) were removed from analyses. and the Accelerometry values ≥ 2296 per minute (cpm - count per minute) defined children's MVPA as this is commonly used to estimate MVPA, supported in the calibration study of Evenson et al. (2008) [15]. We used minimum wear criteria of ≥ three days lasting ≥ 4 hours/ during school hours/day (4 hours is two-thirds of a 6-hour school day or contains at least 70% of a full school daytime) [16].

School hours are not the same across Scotland, for the present study, school start and end times (range 9.00 am – 3.00 pm /8.45 am – 3.15 pm) were identified by using the primary schools' online handbooks for 2015-2016 school year found on the school's or the local authority website. School hours for each child were then identified and extracted manually from the individual accelerometry data by referring to the times from the school's handbook. The total time spent in MVPA of children was measured, and their MVPA data was extracted for school hours only.

Other than the sex/gender, potential risk factors also included SES, season, and urban or rural setting. Students' SES was defined using the Scottish Index of Multiple Deprivation (SIMD) [17], a composite area-based measure (not based on the individual child/family) of relative social, economic, environmental, and health circumstances which are used and accepted widely in health inequality research and policy in Scotland. SIMD rank scores were grouped into 5 quintiles where 1 represented the most deprived area and 5 represented the least deprived area [12].

Season of data collection - a four-level categorical variable (spring, summer, autumn, and winter) was used to classify the season of measurement and indicated the data collection period when each participant wore the activity monitors.18 Regarding the urban or rural setting, children were classified according to their residency in urban or rural areas, with a standard classification method used in Scotland.12 Population size between 3000 to ≥125,000 was classified as urban

and if <3000 was classified as rural [12].

For statistical analysis, as SPACES data were collected to be nationally representative, a weighting variable was applied ahead of the analysis. Data were weighted to compensate for potential bias to ensure the sample matched the population, and then to provide a representative sample [12], [19] - to correct the over-representation of children with higher SES in the sample. Continuous variables were presented as means and standard deviations (SD) and categorical variables are presented as numbers and percentages of the overall sample and for boys/girls separately. Binary logistic regression was used to estimate the odds (odds ratio: O.R.) of meeting the 30-minute MVPA recommendation (the dependent variable). All other variables were analysed and included in the logistic models. Models were run separately for each explanatory variable so the associations of each risk factor could be ascertained separately to check if it would be an actual risk factor for not meeting the school hours MVPA recommendation or not. P values for the overall trend and confidence intervals (C.I.) for each category of explanatory variables are presented (Table 3 in the results). Reference categories for each explanatory variable are also identified. It would be difficult to control schools in the analysis with a small number of children (only 1-2 children) recruited from each school. Out of a total of 471 schools, 306 provided one participant each; 94 schools had two participants, and 71 schools had three or more participants. The low number of children sampled from each school restricted exploration of school-level variance (random effects). To minimise school-level effects and achieve a nationally representative sample, multilevel logistic regression was used to analyse the variables. Data was analysed with SPSS Statistics (IBM Corp, Chicago, IL; version 26). The level of significance was set at $p<0.05$.

5.5 Results

Out of 1096 participants, 774 (417 girls and 357 boys aged 10 to 11 years old) provided

the required accelerometry data to be included in the final SPACES study dataset. [12] For the present analysis, one participant had only 1 day of wear time data, so this participant was excluded from the data set (the total number of students was reduced to 773 from 774 included in the original SPACES study of overall MVPA). A total of 97 non-valid days (2.5% of total days measured from 89 participants) were identified and removed. So, there were 3768 valid days of accelerometry data during school days included in the present analysis (mean valid school days 4.9 per child for the 773 children).

Table 1 presents demographic data and exploratory variable data from 773 children (mean age 11.1 years, 53.9% girl, and 46.1% boy) from 471 schools. The percentage (n) of children who met the 30-minute school-hours MVPA/day recommendation was 42.7% (n=329/770 bases weighted; Table 2). Mean time spent in MVPA was 29 minutes (SD 11) for the overall sample; with 26 minutes (SD 10) accumulated for girls and 32 minutes (SD 11) for boys. Figure 1 shows a more concrete picture of the distribution between girls and boys in MVPA in schools. A higher percentage of girls achieved between 10 to 30 mins MVPA, while a higher percentage of boys accrued more than 30 minutes of MVPA during school hours.

Table 1. Participant characteristics (n(%) unweighted) split by sex and for the overall sample

	Girls (n=417)	Boys (n= 356)	All (n=773)
Sex			
Girls	-		417 (53.9%)
Boys	-	-	356 (46.1%)
SES – using SIMD quintile			
1 (most deprived)	35 (8.4)	29 (8.1)	64 (8.3)
2	55 (13.2)	43 (12.1)	98 (12.7)
3	96 (23.0)	73 (20.5)	169 (21.9)
4	110 (26.4)	97 (27.2)	207 (26.8)
5 (least deprived)	121 (29)	114 (32)	235 (30.4)
Season of data collection [a]			
Winter	89 (21.3)	74 (20.8)	163 (21.1)
Spring	46 (11)	47 (13.2)	93 (12)
Summer	74 (17.7)	61 (17.1)	135 (17.5)
Autumn	207 (49.6)	175 (49.2)	382 (49.4)
Urbanicity			
Urban	313 (75.1)	254 (71.3)	567 (73.4)
Rural	104 (24.9)	102 (28.7)	206 (26.6)
MVPA minutes in school-time[b]	26 (SD 10)	32 (SD 11)	29 (SD 11) out of 369 mins of mean accelerometer wear time during school hours

Note: categorical variables are presented as numbers with percentages in parenthesis. The continuous variable of MVPA is presented as mean with standard deviation in parenthesis.
SIMD: Scottish Index of Multiple Deprivation; SD: standard deviation.
[a] Winter is from late Dec to mid-March, Spring is from mid-March to mid-June, Summer is from mid-June to late Sept, and Autumn is from late Sept to late Dec.
[b] For MVPA the total sample (weighted) is 770 (415 girls and 355 boys).

Regarding factors associated with meeting/not meeting the 30 minutes MVPA per school hours recommendation, Table 2 and Table 3 present the numbers and percentages of meeting the 30-min goal and the results of the logistic regression for each risk factor, respectively. The odds of girls (O.R. 0.43; C.I. 0.32, 0.57) meeting the recommendation was significantly lower ($p<0.001$) compared to boys. Despite a higher number of children from the upper quintiles, there were no significant differences in meeting the recommendation by SES as there were no statistically significant differences between quintiles of SIMD when C.I. were compared or the overall ($p=0.700$) analysis by SIMD quintiles. The overall trend for seasonal influence was significant ($p<0.001$). Those with spring (O.R. 1.54; C.I. 0.93, 2.56), and summer data collection showed higher odds (O.R. 1.98; C.I. 1.26, 3.11) and autumn data collection showed lower odds (O.R. 0.71; C.I. 0.49, 1.03) of meeting the recommendation compared to the winter reference group. There were significantly ($p=0.032$) higher odds (O.R. 1.49, C.I. 1.04, 2.15) of children who lived in rural areas meeting the recommendation compared with those living in urban areas.

For the contribution of school hours MVPA to overall daily MVPA, we compared the 29 minutes of school hours' MVPA with an average of 76 minutes per weekday (school-hour and non-school-hour) in the previous study in the same sample,12 and found that around 38% of students' total daily MVPA on weekdays (school days) occurred during school hours.

Table 2. Weighed number (n) and percentages (% in parenthesis) meeting the school-based MVPA guidelines) for each risk factor

30 min MVPA/day during school hours	No	Yes	Total bases weighted	Total unweighted
Sex Girls	277 (66.7%)	138 (33.3%)	415	417
Boys	164 (46.2%)	191 (53.8%)	355	356
Total	441 (57.3%)	329 (42.7%)	770	773
SES – using SIMD quintile 1 (Most deprived)	96 (58.5%)	68 (41.5%)	164	64
2	77 (56.6%)	59 (43.4%)	136	98
3	80 (55.9%)	63 (44.1%)	143	169
4	88 (53%)	78 (47%)	166	207
5 (Least deprived)	99 (61.5%)	62 (38.5%)	161	235
Total	440	330	770	773
Season Winter	100 (58.1%)	72 (41.9%)	172	163
Spring	45 (47.9%)	49 (52.1%)	94	93
Summer	58 (40.6%)	85 (59.4%)	143	135
Autumn	237 (65.7%)	124 (34.3%)	361	382
Total	440	330	770	773
Urbanicity Urban	367 (59.6%)	249 (40.4%)	616	567
Rural	74 (48.1%)	80 (51.9%)	154	206
Total	441	329	770	773

Note: Total weighted number of participants used in the calculation of proportions is represented by total bases weighted. The total number of participants measured is represented by total unweighted.

Table 3. Odds ratios (OR) (95% C.I.) for meeting 30-min recommendation of MVPA during school hours.

	Meeting 30 mins MVPA during school hours
Sex	
Boys	1.00 reference
Girls	**0.43 (0.32, 0.57)**
P value	<0.001
SES – using SIMD quintile	
5 (least deprived)	1.00
4	1.40 (0.89, 2.15)
3	1.24 (0.78, 1.97)
2	1.25 (0.79, 2.00)
1 (most deprived)	1.25 (0.79, 1.96)
P value	0.700
Season of data collection	
Winter	1.00
Spring	1.54 (0.93, 2.56)
Summer	**1.98 (1.26, 3.11)**
Autumn	0.71 (0.49, 1.03)
P value	<0.001
Urbanicity	
Urban	1.00
Rural	**1.49 (1.04, 2.15)**
P value	0.032

Note: All models control for school number; bolded category is significant at p=0.003.

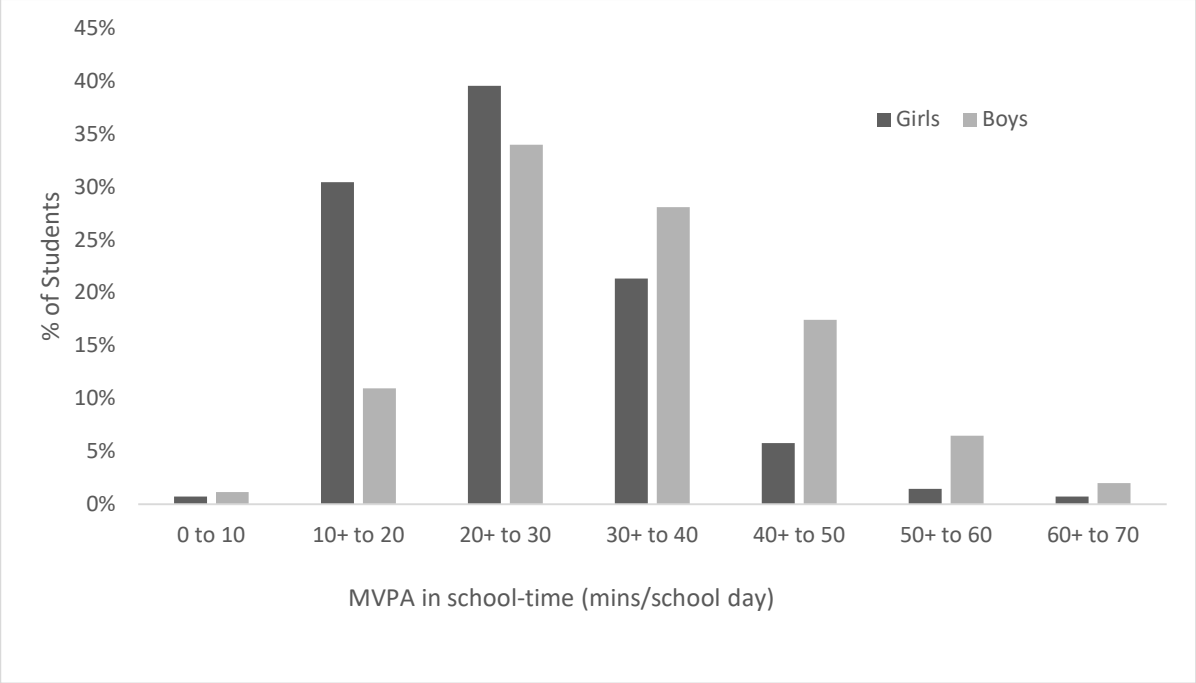

Fig. 1. The percentage of children (with boys and girls separately) accumulating MVPA in school-time per 10-minute increment.

5.6 Discussion

The main findings showed that only 42.7% of children accumulated ≥30 minutes/day of MVPA during school hours in this large sample, representative of 10- to 11-year-olds in Scotland. Gender, season, and urban/rural status were all associated with the probability of meeting the recommendation to accumulate at least 30 minutes MVPA per day during school hours. School hours provided an average of 29 minutes of MVPA per day in the present study.

While previous nationally representative studies of accelerometer measured school-hours MVPA in primary school-age children have been limited, the present study was consistent with previous findings in Europe [8], [10] and the USA [9] that girls were less active and more sedentary during school hours than boys. Rooney et al.[20] found that boys (8-11-year-olds) physical education lessons and recess (break and lunch time) provided important occasions for children to be engaged in PA. Bailey et al. [21] suggested that boys' PA may typically be greater

during PE. Some similar studies [7], [22] suggested that girls are typically less active than boys due to socio-ecological factors at the individual, family, school, and environmental levels. This is possibly due to the persistence of sex/gender stereotypes [7]. Consequently, opportunities for physical activities offered by schools and communities may typically be more attractive to boys than girls [22].

We found that SES was not a significant predictor of meeting the school-hours MVPA recommendation, consistent with Hubbard et al.'s study [9]. In Scotland, the school environment and PA provision should vary little by SES. Almost all Scottish children and adolescents attend the public school system, and schools follow the same national curriculum [23] with similar levels of funding (in fact additional funding per student for schools in lower SES areas). Consequently, schools may have similar opportunities and capacity to engage all children in MVPA broadly and equally during school hours.

The reasons for rural settings being associated with higher school-hours MVPA than urban schools are unclear, but rural schools may have more space for outdoor PA than urban schools [18]. The seasonal difference in school-hours MVPA in the present study may be explained by the fact that in Scotland primary schools tend to keep children inside during recess and lunchtimes when it is windy or rain heavily, which happens less often during summer. Ridgers et al. [24] and Harrison et al.[25] found that temperature [24] and rainfall [25] are negatively associated with PA.

The present study provides support for the concept that schools need to develop a whole-school approach to promoting health-enhancing MVPA, via a combination of PE lessons, recess, [20] more active classroom breaks [26], and greater use of outdoor space [27] with covered playgrounds in cold and wet seasons. As suggested by Harrison et al. [25] a focus on encouraging indoor physical activities in wet weather may help children remain active during school hours

[25]. While Zahi-Thanem et al. [28] indicated that increased outdoor time increases MVPA and Telford et al. [22] recommended that opportunities for MVPA should be tailored to the preferences of boys and girls.

The MVPA accrued during school hours in the present study, while lower than recommendations, was higher than from other European countries [8], [10]. The differences may be partially explained by using different accelerometry cut points to classify PA intensities, as well as due to the differences in the educational system and weather conditions. The 2296 count per minute Actigraph cut-off used to define MVPA provides a conservative threshold for estimating time spent in MVPA - if the appropriate cut-point to classify MVPA in children is higher than this, then the prevalence of meeting the 30-minute recommendation will be even lower than observed in the present study [29].

The present study had some strengths. First, the dataset used was from a large representative sample of children across Scotland - few other international studies of school hours MVPA have been based on large nationally representative samples [7]. Second, MVPA was measured objectively by using accelerometers - accelerometry is a valid method for measuring actual levels (intensity) of PA [13]. Third, few previous studies addressed factors influencing MVPA accumulated during school hours [7].

There were also a few limitations in this study. A total of ninety-seven non-valid days across the entire study were identified because eighty-nine participants provided invalid accelerometer data on some days. However, compared with a total of 3768 valid days of data, the percentage (2.5% of non-valid days) was small and should not make much difference to the estimates of time spent in MVPA in the sample. Second, we were limited to a small number of individual and family-based potential risk factors for not meeting the school-hours MVPA recommendation (sex, SES, season, and urban or rural residence) available in the original SPACES dataset [12].

Other potential risk factors for insufficient MVPA (such as the number and arrangement of break times, and the amount of MVPA provided during school PE lessons) were not collected in SPACES study. Third, the participants were restricted to children aged 10-11, the findings may not be generalisable to younger children or older youths. Fourth, the present study examined school-hours MVPA and not where that came from, for example, recess, PE lessons, or class time.

5.7 Conclusions

This present study demonstrated that a relatively high proportion (around 57%) of children (regardless of sex, SES, season, or urban/rural setting) did not meet the 30-minute MVPA recommendation during school hours. School is a valuable setting to prevent chronic disease as it creates a unique opportunity to reach children across the population, and during a critical period in establishing health behaviours [30]. A careful examination of the school's role in contributing to their students' daily MVPA is essential. Further studies on how to promote PA within school hours and settings with a whole school approach are recommended.

5.8 Practical Implications

Schools could promote optimal MVPA for students as suggested below:

- A careful examination of the school's role in contributing to their student's daily MVPA.
- A whole-school approach to promoting health-enhancing MVPA, via a combination of PE lessons, active breaks, and recess.
- More active PE and recess, active classroom breaks, greater use of outdoor space, and use of covered playgrounds or school halls in cold and wet seasons.
- MVPA opportunities tailored to the preferences of both boys and girls are needed.

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Chapter 6: Physical Activity Levels During School Recess in a Nationally Representative Sample of 10-11-Year-Olds

6.1 Chapter Overview

Recess provides an important and valuable opportunity for pupils to be active on a regular basis, as all Scottish schools offer recess daily. Physical activity (PA) during recess can help pupils reach their daily activity levels. Therefore, before using recess to promote PA among pupils during school hours, it is important to understand their current levels of planned vigorous physical activity (PVPA). The aim of this study is to examine pupils' MVPA levels during morning recess and to determine how many of them met the benchmark of at least 40% of recess time spent in MVPA.

This chapter contains a peer-reviewed article titled "Physical Activity Levels During School Recess in a Nationally Representative Sample of 10- to 11-Year-Olds." It was first published online on July 24, 2023, and later published in *Pediatric Exercise Science* in January 2024. The paper is presented in the same format as it was published in the journal (included in Appendix V); therefore, the referencing order/system (the reference list presented at the end of this chapter) follows the alphabetical order of the authors' surnames, which is not the same as that used in the other chapters of this thesis.

Wong LS contributed to data management and analysis, data interpretation, conceptualization, writing the original draft, and writing the review and editing. **Reilly JJ** provided scholarly insights, data interpretation, and writing the review and editing. **McCrorie P** supported data management and analysis, as well as writing the review and editing. **Harrington DM** assisted with data analysis and interpretation, writing the review and editing. All authors provided intellectual content and approved the final version of the manuscript.

6.2 Abstract

Purpose: School recess provides a valuable opportunity for children's daily moderate-vigorous intensity physical activity (MVPA). This study aimed to quantify MVPA during school recess in a representative sample of Scottish children, and examine if recess MVPA varied by gender, socioeconomic status, season, urban/rural residency, and recess length.

Method: Five-day accelerometry MVPA data were analysed from 773 children (53.9% girls, 46.1% boys, 10–11-year-olds) from 471 schools. Binary logistic regression explored associations between meeting /not meeting the recommendation to spend 40% of recess time in MVPA and the aforementioned risk factors. Descriptive recess data were also analysed.

Results: Participants spent an average of 3.2 minutes (SD 2.1) in MVPA during recess. Girls engaged in 2.5 minutes (SD 1.7) of MVPA compared to 4.0 minutes (SD 2.2) for boys. Only 6% of children met the recess MVPA recommendation. The odds of girls (O.R. 0.09; C.I. 0.04, 0.25) meeting the recommendation was lower ($p<0.001$) compared to boys. No statistically significant differences were observed in meeting the recommendation for the other risk factors.

Conclusion: Levels of MVPA during school recess are very low in Scottish children and interventions aimed at increasing MVPA during recess are needed.

Keywords Moderate-to-vigorous-intensity physical activity, Health, accelerometer, School recess, Primary school children

Childhood PA is associated with positive physical, developmental, and psychological health [12], [14] and helps prevent non-communicable diseases [50], which means a lower risk of cardiovascular disease, hypertension, diabetes, and many cancers, later in life. Low PA in children is one of the most important public health issues in the 21st century [23]. The World Health Organisation (WHO) recommended that school-age children engage in moderate-to-vigorous PA (MVPA) for an average of at least 60 min per day [51]. However, many children

globally do not meet the recommendation [13],[50]. School is a key environment where children accumulate MVPA [41] on around half of all days (allowing for weekends and school holidays). There are recommendations in the USA [25] and in the UK [6] that children and adolescents should achieve 30 min of MVPA daily during school hours. Weaver et al. [49] found that most children (in grades 1-3) were not accumulating 30 min/day of MVPA during school hours. Grao-Cruces et al.'s systematic review [11] showed that less than a quarter of children reached the 30 min MVPA recommendation during school hours.

The PA Guidelines for Americans [7] suggested that, as part of the school strategy to increase MVPA, school day segments (such as physical education and recess) are opportunities for providing MVPA [7]. School recess is an essential school experience that has developmental [27] and behavioural [3] benefits. Recess also serves as a necessary break from the rigors of academic challenges [29]. This is particularly important now as Kharel et al.'s systematic review [15] has shown that since the start of the COVID-19 pandemic, children and adolescents typically spend less time in MVPA and more time on screens [15]. It is crucial to examine how active children are during recess and what factors are associated with MVPA at recess, so that interventions aimed at improving recess MVPA can be optimized. In 2005, Ridgers and Stratton [35] suggested that children should engage in MVPA for at least 40% of recess time. This benchmark has been accepted by many researchers since [30]. Despite this specific MVPA recommendation, few studies have examined children's compliance with MVPA during recess. The Sanchez and Gallego systematic review [41] found only two studies [1],[22] of children's compliance with the recess MVPA recommendation. Furthermore, the sample sizes of these two studies were small (n=135 and n=379), and there was a lack of studies using accelerometers in large, nationally representative samples. Additionally, a number of factors (such as gender, climate, and recess length), that may affect children's recess MVPA have been reported [32],[36],[43]. To date, no

large-scale, nationally representative, accelerometry studies have explored the possible influence of these factors on children's activity levels. Therefore, this study aimed to a) examine how much MVPA is accumulated during recess and the percentage of recess time spent in MVPA; and b) explore the risk factors for low recess MVPA including gender, socioeconomic status (SES), season, urban/rural residency, and recess length on recess MVPA, in a representative sample of 10-11-year-olds in Scotland.

6.3 Methods

6.3.1 Participants and Study Design

The present study used data from the SPACES (Studying Physical Activity in Children's Environments across Scotland) study (19) conducted during the school year between May 2015 and May 2016. Both children (n=1096) and their parents were required to sign consent forms before participating. (More details of the SPACES study can be found in supplementary materials).

6.3.2 Instruments

Measurements of MVPA during recess

ActiGraph GT3X+(Actigraph Inc). In the SPACES study [19] accelerometry data were collected using the ActiGraph GT3X+ (Actigraph Inc, USA) worn on a belt around the waist. Children were asked to wear the device for 8 consecutive days (with a minimum of 10 hours on a weekday/school day) during waking hours [19] [38].

ActiLife software (version 6, Actigraph Inc). In the present study, accelerometry data were considered valid with a minimum of 4 hours per day over 3 school days [31]. To ensure the sample was broadly representative of the Scottish population, the sample was weighted to compensate for potential bias [5],[19]. Non-wear time periods (if 60 consecutive minutes of strings of zero counts acceleration were recorded by the device) were removed from further

analyses. ActiLife software (version 6, Actigraph Inc, USA) was used to download, clean, and analyse data. Once downloaded, data files (.agd) were reintegrated from the original 10-second epoch to a 60-second to establish the pupil's recess time. To define children's MVPA, the commonly used cut-points (values ≥ 2296 counts per minute) from Evenson et al. [9] were used to define MVPA levels from the accelerometer count data.

6.3.3 Procedures

Definition and Identification (Extraction) of Recess Time.

Recess time was defined as the timetabled 15- or 20-minute (typically between 10 to 11 am) morning break that primary school children have during school days in Scotland. Time spent in MVPA was extracted for this morning recess only from each day of data. Each child's morning recess time was identified by using the primary schools' online handbooks for the 2015-2016 school year and extracted manually from the individual accelerometry data by matching the child to their school's recess time. Accelerometry counts from each day of each pupil were visually checked to verify that the counts increased at the expected start of the recess interval, and whether the counts decreased at the expected end of recess for each day. MVPA values are reported as the percentage of the length of recess time (i.e., time available) to control for varying durations of school and recess (using mean minutes, and percentage per day in the statistical analysis).

Definition of the Explanatory Variables.

The widely used Scottish Index of Multiple Deprivation (SIMD) [42], a composite area-based measure (not based on the individual child/family) of relative social, economic, environmental, and health circumstances, was used to define children's SES. SIMD rank scores were grouped into 5 quintiles where 1 represented the most deprived area and 5 represented the least deprived area [19]. Season of data collection when each participant wore the accelerometer was a four-level categorical variable (spring, summer, autumn, and winter) [20]. Children's urban

or rural residency was defined using their home address combined with a standard classification method used in Scotland that recognises settlement size (population between 3000 and ≥125,000 was urban and <3000 was rural) [19].

6.3.4 Data Analysis

Continuous variables were presented as means and standard deviations (SD) and categorical variables were presented as numbers and percentages of the overall sample and for boys/girls separately. Binary logistic regression analyses were used to examine the association between the risk factors (independent explanatory variables) and meeting the 40% recess time MVPA (the dependent variable – based on the benchmark suggested by Ridgers and Stratton [35]. Models were run for each explanatory variable (with reference categories identified) separately. We did not produce a combined model with all risk factors included simultaneously because we found that only one of the factors was associated with meeting the recess MVPA guideline in initial analyses. It would be difficult to control for school in the analysis due to a small number of children (only 1-2 children) recruited from each school. Out of a total of 471 schools, 306 provided one participant each; while 94 schools had 2 participants, and 71 schools had 3 or more participants. The low number of children sampled from each school restricted the exploration of school-level variance (random effects); therefore, multilevel logistic regression was used to analyse the variables. *P*-values for the overall trend, odds ratio (O.R.), and confidence intervals (C.I.) for each category of explanatory variables are presented. All models controlled for the number of schools involved. Significance was set at $p<0.05$. Data were analysed with SPSS Statistics (version 26) in July 2022.

6.4 Results

6.4.1 Characteristics of Participants

Of 2162 parents who had consented to be contacted for SPACES, 1096 (50.7%) children

took part in data collection. Of those, 859 (78.4% of those who participated) children provided data but only 774 (70.6% of those who participated; 417 girls and 357 boys aged 10 to 11 years) provided sufficient (defined as at least 4 weekdays and 1 weekend day) data for inclusion in the SPACES dataset [19]. One participant did not meet the minimum inclusion criterion enabled for the present analysis (3 school days with at least 4 h/day) and was removed from the present study data set. A small number of non-valid recess periods (132 periods representing 3.5% of the total recess periods) were removed because only zero counts could be found during recess time in a valid school day. The final analytical sample comprised 773 children across a mean of 4.8 days of data per participant. Valid data from 3733 recess periods were included in the analyses. Table 1 presents the descriptive characteristics (mean, SD) of the sample. Overall, 773 children (mean age 11.1 years, 53.9% girls, and 46.1% boys). Mean daily recess length was 16.1 (SD 2.2) minutes.

6.4.2 Prevalence of Meeting 40% of Recess Time in MVPA Recommendation

Only 6% (1% of girls and 11% of boys) of children spent at least 40% of their recess time in MVPA. Table 1 shows that mean MVPA during recess was 3.2 minutes (SD 2.1), equating to 20% of recess time on average for the entire sample (mean minutes of recess MVPA (3.2 mins) divided by mean recess time (16.1 mins)*100). Girls engaged in 2.5 minutes (SD 1.7) compared to 4.0 minutes (SD 2.2) for boys. This equated to 16% and 25% of recess time in MVPA, for girls and boys, respectively.

6.4.3 Risk factors for Not Meeting 40% of Recess Time in MVPA Recommendation

Table 2 and Table 3 present the weighted number, percentages/results of the logistic regression, and the odds ratios (95% confidence intervals (C.I.)) for meeting the 40% MVPA recommendation during recess. Odds of meeting the recommendation was significantly lower in girls (O.R. 0.09; C.I. 0.04, 0.25; $p<0.001$) than in boys. SES was not related to meeting the

recommendation. There was no statistically significant relationship for the overall SIMD [42] factor (p=0.29), nor differences between quintiles and the reference category (least deprived) of SIMD with all confidence intervals overlapping 1.0. The overall trend for seasonal influence was also not significant (p=0.25). No differences in compliance were found between urban or rural residency and when the length of recess time (15 mins vs. 20 mins) was compared (both factors $P = 0.91$).

6.5 Discussion

This study revealed that most children spent very little time (an average of 20% recess time) in MVPA at morning recess. In Scotland, schools have lunch periods where children can/may be active as well. However, lunchtime is an unpredictable combination of time spent queuing for, and eating lunch and recess time for play, so we only counted the nationally mandated morning recess for practical considerations. None of the risk factors for low recess MVPA (SES, season, urban/rural residency, and recess length), other than gender, influenced the odds of meeting the recommendation.

Our evidence of lower compliance with the recess recommendation in girls than boys was consistent with older accelerometry studies from Bailey et al. [1] and Nettlefold et al. [22] though we found lower compliance in the present analysis. Bailey et al. [1] used RT3 triaxial accelerometers as measurement device, with MPA (970-2332 cpm) and VPA (≥2333 cpm) as cut- points. They found that 28% of girls and 60% of boys aged 10-14 years met the recess MVPA recommendation. In contrast, Nettlefold et al. [22], used the ActiGraph GT1M device with age-specific cut points [48] to classify PA intensity and reported that 16% of girls and 34% of boys aged 8-11 years were compliant with recess recommendations. Differences in compliance between the studies may relate to measurement devices and the cut points used, the time period of measurement, the age range of the samples, or the length of recess time. Our findings concerning

activity levels are similar to those found in the UK-based study by Ridgers and Stratton [35] (4.3% of girls and 14.9% of boys of 5-10-year-old met the 40% value) and are consistent with other studies (i.e., ~20% of recess spent engaged in MVPA) [17],[39],[44]. The reasons for gender differences in recess MVPA may be attributable to the social context[1], [41], the structure of the playground environment, and differences in the behaviors that boys and girls typically engage in during recess. Pawlowski et al. [26] indicated that girls tend not to be interested in competitive sport-based activities and they like socialising with friends during recess [26]. Saint-Maurice and colleagues [40] reported that boys prefer to engage more in team sports activities, and this may be due to gender stereotype/socialisation [10],[18]. The absence of an association between SES and meeting the recess MVPA recommendation in our results is consistent with Tercedor et al. [47]. Taylor et al. [46] found that school environments provide the opportunity for the influence of SES during school hours to be minimised as all children are exposed to similar environmental context regardless of individual circumstances [46]. However, some studies either reported that children with higher SES spend more time in MVPA [21] or that children from lower-income families in America are least likely to have recess [4].

In Scotland, recess is mandatory and all primary school children receive one 15-or 20-minute morning recess period per day. Moreover, schools have similar capacity (fixed equipment) and funding (in fact additional funding per pupil for schools in lower SES areas) to engage all children in MVPA broadly equally during recess. Since no comparable studies currently exist exploring links between urban or rural residency and MVPA during recess, no direct comparisons are possible. As our results showed no significant difference between urban and rural residency influencing the recess MVPA, potentially this might demonstrate the similar school environments across Scotland. Our finding of no seasonal influence on recess MVPA is contrary to some studies which reported that children are more active in spring compared to autumn or winter [40]

or in cooler compared to warmer months [34]. The seasonal variability between the studies may be due to differences in sample size, the number of recesses included, and geographical locations. There is some evidence that the impact of short term changes in the weather (e.g., rain or temperature during recess) might have more of an impact than seasons [16].

Results from the present study showed no association between the length of the recess and compliance with the recommendation. This result is different from those found by Suga et al. [45]45] and Ridgers et al. [37]: their studies reported that a longer duration of recess was associated with increased PA in the playground. Stanley et al. indicated that length of recess time was found to positively facilitate interventions in school recess time PA [43]. When checking the pupils' individual accelerometer data in the present study, their MVPA typically did not appear until around 5-8 minutes into recess time, suggesting that higher MVPA levels may be more possible in a longer recess length.

Recess is a valuable opportunity for all children to increase their PA [33]. Erwin et al. [8] argued that the potential of recess for MVPA accumulation is undervalued especially for inactive children [8]. Schools should, therefore, carefully consider the time available for breaks and work to ensure that pupils in schools have adequate breaks in the day for them to play and socialise with peers [2]. Pfledderer et al. [28] suggested altering or adding playground markings and utilizing zonal design along with the markings indicating the types of activities that might be performed in that area to suit the needs of boys and girls. Parrish et al. [24] suggested that longer-term plans, which incorporate changes to interventions over time may assist in maintaining children's interest, and so promote sustained increases in PA during recess. Schools need to create strategies that are not only gender-equal [18] and feasible but more importantly, strategies that cater specifically for different pupils' needs should be developed.

Our study had a number of strengths, notably the large representative sample with

accelerometry measures of MVPA. Few other international studies have been based on large nationally representative samples with accelerometry measures of MVPA which are considered more valid and reliable tools to assess MVPA than self or proxy reports [32]. Few studies have examined the proportion of children meeting the benchmark of 40% recess time in MVPA [35].

There were some limitations in this analysis. Despite the very large sample size relative to the previous studies, the low MVPA may have limited our ability to assess potential risk factors for not meeting the recommendation. Second, as this is a secondary data analysis, accelerometer data were extracted to fit this study's purpose. Actual recess time was not measured, also whether the recess periods reported aligned with movement/activity could not be verified. To analyse the data, we reintegrated from the original 10-second epoch to a 60-second and if MVPA is being accumulated in very short and sporadic bursts the epoch of 60 seconds is likely to reduce the apparent time spent in MVPA. Third, the potential risk factors for not meeting the recess MVPA recommendation were limited to those factors available in the original SPACES dataset [19], other potentially important factors, such as teachers or peer influence, and the context of the playground, were not available. It would be difficult to control for school in the analysis due to the small number of children (only 1-2 children) recruited from each school which aimed to minimise school-level effects and achieve a nationally representative sample. Fourth, the focus of the present study was purely on the morning recess period because this is a time of the school day when free play is prioritised over waiting and eating lunch. Hence, MVPA during lunchtime was not examined and could be considered in future research. Finally, the results of this study were restricted to children aged 10-11 years old, and not necessarily generalisable to younger children or older youths.

6.6 Conclusions

Recess can make a worthwhile contribution to school children's daily MVPA. However,

levels of MVPA during school recess are low in Scottish children aged 10-11. Despite small gender differences in reaching MVPA recess goals, recess-based interventions are recommended for both boys and girls for the benefit of public health.

Table 1. Participant Characteristics (n (%) Unweighted) Split by Gender and for the Overall Sample

	Girls (n=417)	Boys (n= 356)	All (n=773)
Gender			
Girls	-	-	417 (53.9%)
Boys	-	-	356 (46.1%)
SES – using SIMD quintile			
1 (most deprived)	35 (8.4)	29 (8.1)	64 (8.3)
2	55 (13.2)	43 (12.1)	98 (12.7)
3	96 (23.0)	73 (20.5)	169 (21.9)
4	110 (26.4)	97 (27.2)	207 (26.8)
5 (least deprived)	121 (29)	114 (32)	235 (30.4)
Season of data collection [a]			
Winter	89 (21.3)	74 (20.8)	163 (21.1)
Spring	46 (11)	47 (13.2)	93 (12)
Summer	74 (17.7)	61 (17.1)	135 (17.5)
Autumn	207 (49.6)	175 (49.2)	382 (49.4)
+			
Urban	313 (75.1)	254 (71.3)	567 (73.4)
Rural	104 (24.9)	102 (28.7)	206 (26.6)
MVPA minutes /school recess [b]	2.5 (SD 1.67)	4.0 (SD 2.17)	3.2 (SD 2.05)
Proportion of MVPA during recess (%) (recess MVPA/Mean recess length in minutes)	15.7% (2.5/16.1 mins)	24.8% (4.0/16.1 mins)	19.9% (3.2/16.1 mins)
Recess time contributed to school hours MVPA (%)[c]	8.6% (2.5/29.0 mins)	13.8% (4.0/29.0 mins)	11% (3.2/29.0 mins)

Note: categorical variables are presented as numbers with percentages in parenthesis. The continuous variable of MVPA is presented as mean with standard deviation in parenthesis.
SIMD: Scottish Index of Multiple Deprivation; SD: standard deviation.
[a] Winter is from late Dec to mid-March, Spring is from mid-March to mid-June, Summer is from mid-June to late Sept, and Autumn is from late Sept to late Dec.
[b] For MVPA the total sample (weighted) is 770 (415 girls and 355 boys)
[c] An average of 29 minutes was found during school hours in the previous study (Wong et al. 2023 Feb issue of J Sci Med Sport [52]) in the same sample.

Table 2. Weighed Number (n) and Percentages (% in parenthesis) Meeting the Recess MVPA Recommendation) for Each Potential Risk Factor

	No	Yes	Total bases weighted	Total unweighted
Gender				
Girls	410 (98.8%)	5 (1.2%)	415	417
Boys	315 (88.7%)	40 (11.3%)	355	356
Total	725 (94.2%)	45 (5.8%)	770	773
SES – using SIMD quintile				
1 (Most deprived)	159 (96.4%)	6 (3.6%)	165	64
2	121 (89%)	15 (11%)	136	98
3	136 (95.1%)	7 (4.9%)	143	169
4	155 (93.4%)	11 (6.6%)	166	207
5 (Least deprived)	154 (95.7%)	7 (4.3%)	161	235
Total	725	46	771	773
Season				
Winter	160 (93.6%)	11 (6.4%)	171	163
Spring	86 (91.5%)	8 (8.5%)	94	93
Summer	135 (94.4%)	8 (5.6%)	143	135
Autumn	344 (95%)	18 (5%)	362	382
Total	725	45	770	773
Urbanicity				
Urban	582 (94.5%)	34 (5.5%)	616	567
Rural	143 (92.9%)	11 (7.1%)	154	206
Total	725	45	770	773
Length of recess				
15 mins	581 (94.6%)	33 (5.4%)	614	609
20 mins	140 (92.1%)	12 (7.9%)	152	161
25 mins	1 (100%)	0	1	1
30 mins	3 (100%)	0	3	2
Total	725	45	770	773

Note: Total weighted number of participants used in the calculation of proportions is represented by total bases weighted. The total number of participants measured is represented by total unweighted.

Table 3. Odds Ratios (OR) (95% C.I.) for Meeting the 40% Recommendation of MVPA during Recess

	Meeting 40% of recess time in MVPA
Gender	
Boys	1.00 reference
Girls	0.09 (0.04, 0.25)
P value	<0.001
SES – using SIMD quintile	
5 (least deprived)	1.00
4	1.55 (0.70, 3.44)
3	1.09 (0.44, 2.71)
2	2.39 (0.97, 5.86)
1 (most deprived)	2.11 (0.70, 6.42)
P value	0.294
Season of data collection	
Winter	1.00
Spring	0.75 (0.28, 2.04)
Summer	0.93 (0.41, 2.10)
Autumn	0.51 (0.25, 1.05)
P value	0.245
Urbanicity	
Urban	1.00
Rural	1.04 (0.51, 2.13)
P value	0.91
Length of recess time	
15 minutes	1.00
20 minutes	1.29 (0.65, 2.58)
P value	0.915

Note: All models control for school number; bolded category is significant at p=0.003.

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Chapter 7: Discussion and Conclusions

7.1 Chapter Overview

The aim of this final chapter is to summarise the key findings from the four original studies in the thesis as well as consider implications for the primary school as a setting to promote increased MVPA. Future research directions are suggested, and strengths and limitations are outlined. Lastly, overall thesis conclusions are presented.

7.2 Thesis Findings and Contribution to Knowledge in the Context of School-based Intervention Literature and Practice

7.2.1 Summary of Findings: Chapter 3 (Study 1)

PE classes are regular, structured, and compulsory time periods that provide a context for PA participation in the school curriculum for all pupils. It represents the main societal context for the promotion of PA [1], [2]. For many children and adolescents, PE is the first structured introduction to movement skills and experiences. Therefore, before looking at other avenues of increasing PA during school hours, it is important that the school subject (PE) that most assume would generate maximum PA be considered first.

The aim of the systematic review in Chapter 3 was to identify effective interventions that can increase MVPA levels for pupils (aged 8 to 11 years) during school PE lessons. Previous studies showed that MVPA (being the most health-enhancing intensity and the only intensity that has guidelines at present) levels in PE lessons are often very low [3], [4]. So, the research question of this chapter was "How can children's and adolescent's MVPA levels be increased in PE lessons?"

The findings of this systematic review showed that efforts to increase the MVPA content of primary school PE are achievable. The pooled effect of an approximately 9-minute

improvement in MVPA in each hour of PE lesson shows that these efforts can make a meaningful contribution to pupils' daily MVPA goals. The review also suggested that pedagogical objectives to develop teaching effectiveness are necessary, highlighting the importance of giving more support to teachers in the planning of PE lessons.

The other specific contribution of Chapter 3 to this thesis was that one existing intervention [5] (the SHARP Principles Model) from England was identified as promising and probably generalisable to Scotland. Therefore, this led to a plan for Study 2, which was to use the SHARP Model in Scottish primary schools.

7.2.2 Summary of Findings: Chapter 4 (Study 2)

A study protocol was used, aiming to test the feasibility of the 'SHARP Principles Model'[5] (which is a promising theory and evidence-based intervention and is being considered as the most promising intervention strategy for translation to Scotland) to see whether it is practical. If practical, future research could test whether this intervention achieves the goal of increasing MVPA during PE classes in primary schools in Scotland.

If this intervention were to be used and evaluated in Scotland, it would first have to be adapted (if required) and then assessed for feasibility. The SHARP Model was therefore modified for the Scottish context with the support of the original developer in England and inputs from a local primary school PE specialist teacher. A 'SHARP Scotland' model ready for feasibility testing was created. The advantage of this adaptation was that the intervention would be implemented within the normal national school curriculum, without extra resources, personnel, or extra costs.

The original plan was to test the feasibility of 'SHARP Scotland' in a Scottish primary school. However, the lockdowns and restrictions associated with COVID-19 at the time made in-person fieldwork impossible, so, a test for this feasibility study could not be conducted (refer

to Plan C in the COVID-19 impact statement). Nevertheless, the protocol paper had already provided a framework for SHARP Scotland, it was still hoped that the outcome of this study could answer the research question: "Is the 'SHARP Model' feasible in Scottish primary schools? / Can this Model be translated to other school settings?" In addition, if the translated intervention fits the Scottish context well, then it might produce much more active PE lessons and consequently help large numbers of pupils achieve increased school hours MVPA and possibly achieve the MVPA recommendations.

The modification and adaptation of activities were conducted with the assistance of Dr Emma Powell (from Newman University, Birmingham). Having conducted two SHARP research interventions in one region/one council area in England [5], [6], her contribution to the adaptations of 'SHARP Scotland' was valuable. In addition, the involvement of a local Scottish PE Specialist in translating SHARP Scotland provided practical inputs and suggestions.

Though a test for the feasibility study could not be implemented as planned, the paper was published as a protocol. This protocol could be used by others in future, including by the Physical Activity for Health team at the University of Strathclyde. It was felt that the plan for a feasibility study would still be useful for future use of SHARP intervention in Scotland.

This study protocol has now been used by researchers from Physical Activity for Health with Dundee City Council who provided funding for a small feasibility study in one local school as part of their child's healthy weight plan. This feasibility test was conducted in Spring 2023 with two classes (Primary 2 and Primary 4) from one school for five weeks. Full SHARP training was delivered online to two generalist teachers and one PE coordinator. The results have been analysed for inclusion in funding applications and have been accepted in abstract format at the UK Society for Behavioural Medicine annual scientific meeting (Glasgow, Spring

2024). So, this protocol paper has moved finally into a feasibility testing phase, though the results and outcomes are too late for inclusion in this thesis. In conclusion, without the work, research, and effort made in choosing and adapting this protocol paper, this research in Dundee could not have been conducted and implemented so quickly with few changes.

7.2.3 Summary of Findings: Chapter 5 (Study 3)

In Chapters 3 and 4, intervention strategies for increasing pupils' MVPA at school and teaching approaches to make for more active PE lessons were presented (Chapter 3). Adaptation and feasibility testing of an existing effective intervention was outlined for use in primary schools in Scotland (Chapter 4). To have a real picture and understanding of the situation regarding Scottish primary pupils' MVPA levels, Chapter 5 tried to explore the research question: "How much MVPA do Scottish primary pupils get and how many of them meet the 30-minute MVPA benchmark during school hours?"

This is an analysis of novel and high-quality (accelerometer-measured) data from a large, nationally representative, sample of pupils from Scotland. The objectives were to examine the percentage of pupils who met the national benchmark of 30-minute MVPA during school hours [7], [8] and identify key risk factors for not meeting this goal. Up to now, this evidence, of great importance to public health, has been lacking in Scotland. This chapter was based on secondary data analysis by using the SPACES (Studying Physical Activity in Children's Environments across Scotland) study [9] which was carried out between May 2015 and May 2016.

Based on the data analysis of 773 participants (10- to 11-year-olds) from around 471 primary schools, it was found that Scottish pupils engaged in an average of 29 minutes in MVPA during school hours with 43% of them reaching the 30-min MVPA school hours benchmark. This result also demonstrated that a relatively high proportion did not meet the

recommendation. The odds of girls meeting the recommendation was significantly lower compared to boys. Pupils living in rural areas had higher odds of meeting the recommendation than those living in urban areas. Measured during the summer season, pupils had higher odds of meeting the school hours' MVPA recommendation than those measured in the winter season.

The results from this chapter provided evidence that time in MVPA during a typical primary school day in Scotland was low. It is therefore vital to find ways to improve pupils' MVPA as pupils spend a significant amount of time in school. According to evidence from Study 1 (Chapter 3), it was obvious that PE lessons are typically not as physically active as they could be. Therefore, to improve pupils' MVPA during school hours, we cannot solely rely on PE lessons. This chapter's findings point to the possible need to promote MVPA within the other domains of PA in school hours and adopt a more holistic approach in order to have a more sustainable effect.

7.2.4 Summary of Findings: Chapter 6 (Study 4)

Recess is a critical component of the school day and one of the key opportunities for PA across the primary school day. It provides an important and valuable opportunity for pupils to be active on a regular basis as all Scottish schools provide recess periods daily. The study of Verstraete et al. [10] also suggested that stimulating PA during recess can contribute to reaching the daily activity levels recommended for good health [10].

Before making recess an opportunity to promote MVPA for pupils during school hours, it is worth knowing what pupils' present MVPA levels are during recess. The research question for this chapter was therefore "How much MVPA do Scottish primary pupils get during school recess and how many of them meet the generally accepted benchmark of at least 40% of recess time MVPA goal?" Risk factors for not meeting the benchmark were also examined. Furthermore, up to now, this evidence, of great importance to children's and adolescents'

health, has been lacking in Scotland.

Based on the five-day accelerometry data of 773 participants (same SPACES dataset), levels of MVPA during school recess were very low among Scottish primary pupils. They spent an average of 3.2 minutes (SD 2.1) in MVPA out of an average of 16.1-minute recess. Only 6% of pupils met the recess MVPA goal. The odds of girls meeting the threshold was lower ($p < .001$) compared with boys. No statistically significant differences were observed in meeting the goal for the other risk factors including socio-economic status, seasons, urban/rural residency, and recess length.

7.3 Learnings from the Thesis

MVPA levels of primary pupils during school hours and recess had never been investigated in Scottish schools before. The findings of this thesis show that MVPA levels during recess and overall school hours are low in Scottish children aged 10-11. The results (Chapter 6) reveal that, on average, recess lasts 16.1 minutes, contributing only 11% to school-hours MVPA and typically less than the recommended 40% of recess time in MVPA. Results (Chapter 5) also indicate that less than half (43%) of pupils averaged at least 30 minutes of MVPA during school hours, with the overall average being 29 minutes. As reflected in the systematic review (Chapter 3), studies showed that pupils' MVPA during PE lessons was lower than recommended [4], [11] often falling below the 50% of PE time as MVPA target [12], [13]. Pupils' PA levels during school hours are crucial, as these hours provide an excellent opportunity for a population-based approach to increasing MVPA among pupils and helping them meet PA guidelines [14], [15], which is essential for improving both individual and public health [15]. Kristiansen et al.'s study [14], involving 291 pupils (aged 12), found that school hours PA possesses an unrealised potential to significantly increase pupils' weekly PA.

School settings have been identified as key targets for reducing sedentary time and

promoting PA while providing inclusive and equitable education for all children worldwide [16]. Figure 1 illustrates the PA context in schools, which encompasses time before, during, and after school hours, where MVPA can be accumulated across various domains. This thesis focuses on three aspects of in-school MVPA: the total time spent in MVPA during school hours (Chapter 5), increasing active learning time to enhance MVPA during both PE lessons (Chapters 3 and 4), and recess (Chapter 6). The goal is to ensure that pupils accumulate at least 30 minutes of MVPA per day in school.

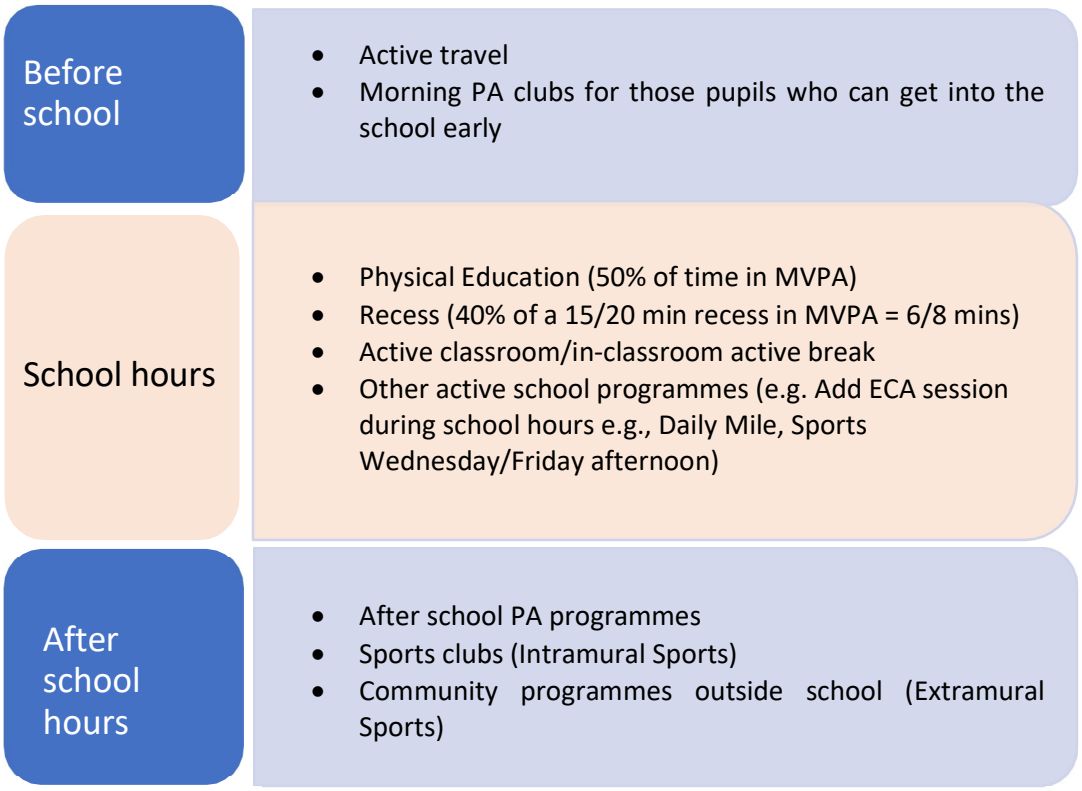

Figure 1. Adapted Model of the Physical Activity Context in Schools (from Beets, 2012.)

Quality PE is a key component of various PA guidelines and programmes, [15]-[18]. Reflecting on the findings from the systematic review (Chapter 3), it was shown that teaching strategies, pedagogy, and curriculum planning for PE lessons can play a significant role in increasing children's MVPA levels. Regular PE lessons, supplemented with high-intensity activity or fitness infusion, along with teacher professional development focused on organisation, management, and instruction, were effective strategies for increasing MVPA during PE lessons (as detailed in Chapter 2, Section 2.4.3). However, as reported by Lonsdale et al.'s review [3], most PE interventions to date have not been sustainable. Therefore, they suggested that higher-quality trials are needed to identify the most effective and sustainable intervention strategies [3].

PE curricula are structured to provide developmentally appropriate experiences that build the motor skills and self-efficacy needed for lifelong participation in health-enhancing PA [15]. To offer enhanced PE that increases the time pupils spend in MVPA during lessons, it is crucial to implement instructional practices that promote significant levels of MVPA, more likely when PE is taught by certified PE teachers [15]. Consequently, when PE is delivered by a non-PE specialist or classroom teacher, it is important to improve the teacher's subject knowledge and teaching strategies to ensure effective and safe PE instruction for pupils [15].

One of the key contributions of this thesis was the development of a novel plan in Chapter 4, which involved adapting practices to create a feasibility study protocol aimed at increasing MVPA levels during PE lessons for Scottish pupils. Following a small feasibility test (conducted by other researchers in the same department) in Dundee, preliminary data suggested that implementing SHARP PE lessons, led by a sports leader, nearly doubled the levels of MVPA during PE. The researchers suggested that this preliminary study will contribute to the development of teaching interventions designed to enhance PA levels in children during PE.

Therefore, it is worth exploring further opportunities for broader implementation.

Results from Chapter 5 indicated that school hours provided pupils with 29 minutes of MVPA daily, accounting for around 38% of their total daily MVPA. Additionally, 57% of pupils did not meet the 30-minute per day MVPA school-hour benchmark. However, this could be seen as a positive sign, as it shows that around 40% of pupils did meet the benchmark, demonstrating that the target is achievable. Scottish primary schools may only need to make a small additional effort to help more pupils aged 10–11 to meet the target. The findings also revealed that gender, seasons, and urban/rural residency were significant factors affecting pupils' school-hour MVPA. These findings suggest that schools should develop and promote policies that prioritise MVPA, ensuring all pupils have access to opportunities for movement throughout the day.

School recess is a mandatory part of the primary school day in Scotland [19], [26], [27]. Chapter 6 reported that MVPA during recess contributed 11% to the total school-hour MVPA, less than recommended and consistent with previous studies [20]-[22].

To improve MVPA during recess, several strategies were identified in systematic reviews [23], [24], [25], including playground markings, the demarcation of physical activity zones, group activities, the availability of sports and loose equipment, as well as perceived encouragement, all of which have the potential to increase PA levels during recess periods. However, Parrish and colleagues [25] found that despite the implementation of intervention strategies in many studies (38 out of 43 eligible intervention studies), no consistent effects on pupils' school recess MVPA levels were observed (details mentioned in Chapter 2, Section 2.4.5). Reilly et al. [26] also concluded in their systematic review (n=24 eligible studies) that recess typically makes only a small contribution to daily MVPA in children aged 6-11.

Although Chapter 6 found that recess length was not a significant factor in pupils achieving

the recess MVPA benchmark, findings showed that pupils accrued more MVPA time during a 20-minute recess (24% of recess time spent in MVPA) compared to a 15-minute recess (19% of recess time spent in MVPA). This result is consistent with some systematic reviews [23], [27] which demonstrated that pupils are likely to achieve more minutes of MVPA during a longer recess.

The above findings regarding Scottish primary pupil's school hour and recess MVPA, as well as associated risk factors were based on a nationally representative sample. The data can assist policymakers and schools in planning future initiatives to increase MVPA levels among primary pupils in Scotland. Despite evidence of some beneficial effects on MVPA, interventions have been introduced piecemeal into PE lessons or recess periods. These effects of these interventions, however, tend not to be sustained beyond the intervention study [28]. Moreover, conclusions from other systematic reviews and meta-analyses [29], [30] are more pessimistic, suggesting smaller and/or less sustainable effects of interventions aimed at increasing MVPA in school-aged children.

For example, Metcalf et al. [29] reviewed 30 studies involving 6,153 children (average age 9.8 years) and found only small improvements in MVPA, about 4 extra minutes of walking or running per day. Love et al.'s [30] systematic review (n=25 studies, participants aged 6-18) and meta-analysis of school-based PA interventions found little to no increase in children's daily MVPA levels, with strong evidence that current efforts are ineffective. Hartwig et al. [31] reviewed 6,621 children and adolescents (aged 4-18) from 20 trials and concluded that school-based interventions do not benefit all subpopulations equally. They recommended focusing on more vigorous PA and developing targeted strategies for different groups of pupils. While Jones et al. [32] reviewed 57 studies (ages 5-11), finding that 82% of studies that expanded PA opportunities reported positive effects on MVPA: multicomponent interventions, which combine

PA expansion and enhancement, were moderately successful in increasing MVPA.

Results of Chapter 3 and 6 showed that PE lessons or recess alone might not be enough to help large numbers of pupils meet the daily 30 minutes of school-hour or 60 minutes of MVPA recommendations. Therefore, PE and recess probably need to be part of a more comprehensive approach to increasing MVPA. For instance, the Comprehensive School Physical Activity Program (CSPAP) [17] or Creating Active Schools (CAS) [18] programmes, which are examples of a "whole-of-school" approach to PA promotion [33] may be more likely to be effective at increasing MVPA sustainably and at a larger scale than simply focusing on recess or PE alone. These programmes align with the WHO's call for systems thinking to create sustainable changes to PA provision across the whole school [16]. As introduced in Section 2.6, both CSPAP and CAS aim to institutionalise PA within the school environment. As contemporary whole-school approaches, they have gathered attention for their high potential for implementation and impact, utilising a comprehensive multi-level approach that involves multiple stakeholders, from governing bodies to organisational change and PA provision, extending the impact of efforts to increase MVPA beyond school-hours, e.g., by using after school clubs and active commuting to increase MVPA. There is a need to understand how to design and implement such interventions to achieve system-level change for PA from a whole-systems perspective. [36]-[38].

A recent concern is the evidence of a decline in MVPA during the COVID-19 lockdowns and the post-COVID-19 period. There is evidence that the pandemic has affected children's MVPA in both the short and long term [34]. Neville et al. [35] reported that global data revealed that boys and girls of all ages and baseline activity levels experienced reductions in daily PA during COVID-19. The lockdown restrictions led to the loss of accrued benefits from regularly engaging in PA for people of all ages, and these newly established lower levels of MVPA will

be difficult to change [35].

Jago et al.'s [34] study reported that levels of MVPA in England have returned to pre-pandemic levels since most restrictions were lifted, while sedentary time remains higher than before. Even with this recovery, many children have lower levels of MVPA than recommended, so there is a need to increase MVPA, especially among those who are typically less active [34]. Thus, there is an urgent need to find new ways to develop strategies to manage sedentary behaviours and to increase the MVPA levels of primary school-aged children.

Studies [36], [37] also reported that multicomponent, multimodal, and multi-outcome interventions work best to promote PA and maintain consistency in practice during childhood [36], [37]. To sustain effects throughout the day, studies [18], [38], [39] concluded that multidimensional intervention strategies are probably required, and the contribution of different components within such strategies needs to be carefully considered and evaluated to maximise effectiveness and cost-effectiveness. Details of a whole-of-school approach will be described later in Section 7.5.

7.4 Theoretical Application in Planning Interventions to Increase Pupils' School Hours MVPA

In planning interventions to increase pupils' school-hours MVPA, models and theoretical frameworks can provide rich sources of ideas. The concepts of the Social Ecological Model (SEM) [40] framework and the Theory of Expanded, Extended, and Enhanced Opportunities (TEO) [41] were introduced in Chapter 2, Sections 2.8.1 and 2.8.2, respectively. An integrated approach to increasing pupils' school-hours MVPA, which combines SEM, TEO, and the Whole-of-School Approach (WOS), is presented in Figure 2.

The Social-Ecological Model (SEM) provides a useful framework for public health interventions that target health behaviour change within the population [42]. Interventions

aimed at promoting MVPA levels among school pupils tend to be more effective when they target multiple layers of the SEM for Health [42]. The SEM is recommended for planning interventions that address community, organisational, interpersonal, and intrapersonal factors [43] to promote MVPA during school hours. This model emphasises the importance of addressing multiple levels of influence to effectively increase PA opportunities for pupils.

The TEO mechanism is a simple, direct, and immediate application across different settings and contexts [41]. It offers a new way to understand the PA behaviours of children and adolescents and provides a common taxonomy that interventionists can use to identify appropriate targets for interventions across various settings [41]. Through the TEO perspective, PA opportunities can be expanded, extended, or enhanced to increase children's participation. Expanding involves adding new opportunities for pupils to be physically active; extending entails lengthening the time allocated to existing opportunities; and enhancing requires improving the quality of existing opportunities to maximise participation. The application of these strategies—expanding, enhancing, and extending PA opportunities—will be explained in greater detail later in this discussion. The TEO approach to increasing pupils' PA aligns with the goals of CSPAP and have the potential to facilitate pupils in meeting the target of 30 minutes of MVPA during school hours each day.

The application of theoretical constructs in school-based PA interventions is organised according to the layers of the SEM: intrapersonal, interpersonal, organisational, and community. A detailed application of these layers, along with the TEO mechanism, will be integrated into the following discussion.

7.5 A Whole-of-school PA Promotion by Integrating Multiple Levels of Influence and Opportunity

Overall, how the findings of individual studies relate to current and future research and

practice should be carefully considered. To achieve sustained intervention effects, a more comprehensive and systematic approach, such as a whole-school approach, is recommended for increasing pupils' MVPA.

Studies have shown that CSPAP and CAS are established initiatives proven to be effective in promoting PA and other positive outcomes for pupils [38], [39]. To align with the multiple levels of influence and opportunity within the CSPAP and CAS frameworks, and with reference to the theoretical frameworks (both SEM and TEO), schools can take the following steps to implement a whole-school approach as illustrated in Figure 2:

7.5.1 Establish a Whole-of-school PA Practice and Ethos at the Organisational Level

As referenced in the Social Ecological Model for Health Promotion [40]. Based on shared beliefs and customs [18], this approach helps drive internal school policy and vision. This can likely be achieved by engaging relevant stakeholders—such as school leaders, teachers, other staff, pupils, parents/guardians, and broader community members (e.g., local organisations and clubs)—and by creating a facilitative social and physical environment [18], [39]. This environment could include green spaces, playgrounds, and school halls, aimed at enhancing the quality, quantity, and variety of school spaces.

7.5.2 Combine the Environment and Key Stakeholders to Provide Effective PA Opportunities:

To ensure that all pupils have access to PA opportunities throughout the day, schools should integrate their environment with key stakeholders across various contexts [18] (e.g., curriculum lessons, PE, recess/in-classroom breaks, school PA events, and broader family and community engagement) to provide PA programmes both inside and outside of school.

7.5.3 Physical Activity Opportunities During School Hours

Based on the findings of this thesis and in alignment with the multicomponent approaches

of the CSPAP [33] and CAS [18] initiatives, , the following steps are proposed for schools to implement and organise PA opportunities during school hours. It may be more feasible to start with two key opportunities — PE and recess — before incorporating additional opportunities to expand, enhance, and extend PA. Schools can take several steps:

7.5.3.1 Enhance PE lessons

Evidence from Chapters 3 and 4 highlights that teaching strategies and a diverse PE curriculum, including a wide range of activities such as fitness infusion games, are important for increasing MVPA during PE and fostering pupils' interest and competence in PE lessons. Teachers conducting PE lessons should adopt active teaching strategies to enhance MVPA outcomes [1], [5], improving classroom instruction and increasing pupils' motivation to move and learn. Well-trained teachers tend to manage and organise PE classes more effectively, accommodating pupils by adjusting activities to meet their needs, providing positive feedback, setting tasks [1], and grouping pupils according to their abilities. Additionally, providing more equipment encourages active participation [5], [6], thereby boosting pupils' intrinsic motivation. In the UK, primary PE lessons are typically conducted by class teachers. Therefore, ongoing professional development — through workshops, seminars, and online courses — can enhance teachers' knowledge and skills, ultimately benefiting pupil learning and achievement [15], [16].

7.5.3.2 Expand and Extend PA Opportunities by Providing PA Interspersed Throughout the School Day.

Examples of PA during school hours include:

- **Providing/extending daily recess:** The outcomes from Chapter 6 recommend that schools implement recess policies and facilitate playground environments to help pupils accrue sufficient MVPA during recess. Schools could provide written

guidelines and programmes for both structured and unstructured activities during recess to maintain pupils' interest and increase PA [25]. Recess offers pupils the opportunity to apply the skills and knowledge they have acquired in PE to participate in and enjoy PA, while also supplementing the PA time accumulated during PE classes [25]. From a practical point of view, organising recess sessions that are tied to PE content might be relatively easily implemented since the equipment is available, and it does not require schools to change their time schedules [44] [45]. One study [46] showed that organised recess sessions were highly beneficial for girls since their MVPA values almost doubled during organised parkour recess compared with traditional recess [46].

Schools could design playgrounds with clear markings to encourage PA and ensure that other facilities, such as gyms, playgrounds, and outdoor spaces, are well-maintained and accessible [47]. Schools should also provide a variety of equipment that encourages different types of PA, catering to the diverse interests and abilities of both boys and girls, as Chapters 5 and 6 reflect that gender significantly influences the accumulation of MVPA during school hours and recess. Alternatively, as suggested earlier in the thesis schools could extend recess periods by increasing the duration [23], [48] (e.g., changing a 15-minute recess to 20 minutes in Scotland) or by adding an additional recess period each day or on alternate days to provide more opportunities for MVPA [49].

- **Incorporating short in-classroom PA breaks (3–5 minutes):** Short (3-5 minute) classroom PA breaks during lesson time could be introduced, during which pupils engage in moderately intense activities, such as marching in place, under the direction of the classroom teacher. These activity breaks can positively impact on

the total MVPA levels by modestly increasing activity during times not typically considered opportunities for movement [1]. These breaks can also contribute to enhanced concentration, improved attention to tasks, and better classroom behaviour [1]. There is also an educational implication in incorporating (PA) opportunities into curriculum learning time. Previous studies reported that a classroom-based PA programme was effective in increasing daily in-school PA and improving on-task behavior during academic instruction [50]. The systematic review (n= 50 studies) by Raspberry et al. [51], found that PA positively influences cognitive skills, attitudes, and academic behaviour. The review indicates that maintaining or increasing time for PE supports academic performance without negatively affecting it. Incorporating movement and PA breaks in classrooms can enhance pupil performance and the classroom environment. Therefore, school personnel can confidently provide regular PA breaks/recess, which benefits academic behaviour, supports social development, and promotes health. These strategies enable schools to help pupils meet national PA recommendations without compromising academic outcomes [51].

- **Organising school-wide sports afternoons for co-curricular activities:** Co-curricular activities can be used to integrate PA throughout the school day, such as sports activities on Wednesday or Friday afternoons. Programmes like the Daily Mile can provide children with an additional opportunity to accumulate MVPA. Evidence shows that taking part in sport provides greater self-esteem and confidence with direct cognitive benefits [52], [53].

7.3.3.3 Expanding and Fostering Partnership Opportunities with Community and Non-Profit Organisations:

It is likely to be useful to foster partnerships between schools and community or non-profit organisations to enhance PA opportunities for pupils. These partnerships can serve as valuable resources for joint-use agreements [15] that facilitate PA programming for pupils in their communities outside of school hours. They can help provide diverse activities, especially for less active children, through resources such as primary school PE hubs, Boys and Girls Clubs, YMCA/YWCA, universities, and off-site activities. By collaborating with local sports clubs and community organisations, schools can potentially increase MVPA for pupils during and outside of school hours [41], [54].

Besides, it must be recognised that the school is not the only setting needed to increase MVPA, though it is an important one. Attention should also be paid to out-of-school activities, such as active travel to and from school, organised programmes for pupils to participate in before and after school, as well as weekend activities. Since children spend only a limited portion of their waking hours at school on weekdays, and out-of-school activities play a crucial role in complementing in-school activities to contribute to pupils' total MVPA minutes throughout their school years. If schools can collaborate with community partners to increase MVPA opportunities for pupils outside of school hours, it can help pupils achieve sufficient MVPA levels during non-school hours [55].

Research by Mackintosh and colleagues [55] involving 810 English children (ages 10-11) found that the most active children maintained their sedentary time and PA levels at weekends, whereas among less active peers, their weekend sedentary time and PA at all intensities was lower. Therefore, weekend intervention strategies are likely to be most beneficial for less active children [55]. Schools can implement weekend or holiday PA programmes, such as sports clubs

and outdoor activities, to help all pupils, particularly the less active ones, achieve adequate MVPA levels and that would in turn improve their overall fitness and well-being.

To incorporate the Social Ecological Model for Health Promotion [40] into the PA planning process, policymakers should consider the interrelationships between individuals and the social, physical and policy environment. As mentioned above, they could develop school and community partnerships available during school hours and leverage all PA opportunities including those in the home, neighborhood practices, and organisational settings. Both policymakers and teachers should consider various factors that influence PA at both intrapersonal and interpersonal levels. At the intrapersonal layer, they should account for the varying interests of boys and girls, as well as their needs and preferences [43] regarding PE learning and recess-time behaviours. For instance, PE lessons can aim to develop pupils' knowledge, competence, and confidence in skill acquisition. While the interpersonal layer of the SEM includes both formal and informal social networks and systems, which encompass relationships (family) and friendship networks (peers) [43]. Teachers play a crucial role in providing ongoing support, including fostering physical skills and relationship-building for pupils. They also contribute to the development of pupils' social environments by involving them in group work, fostering peer support networks, and ensuring that pupils have the skills, abilities, and motivation to consistently engage in PA during both PE and recess.

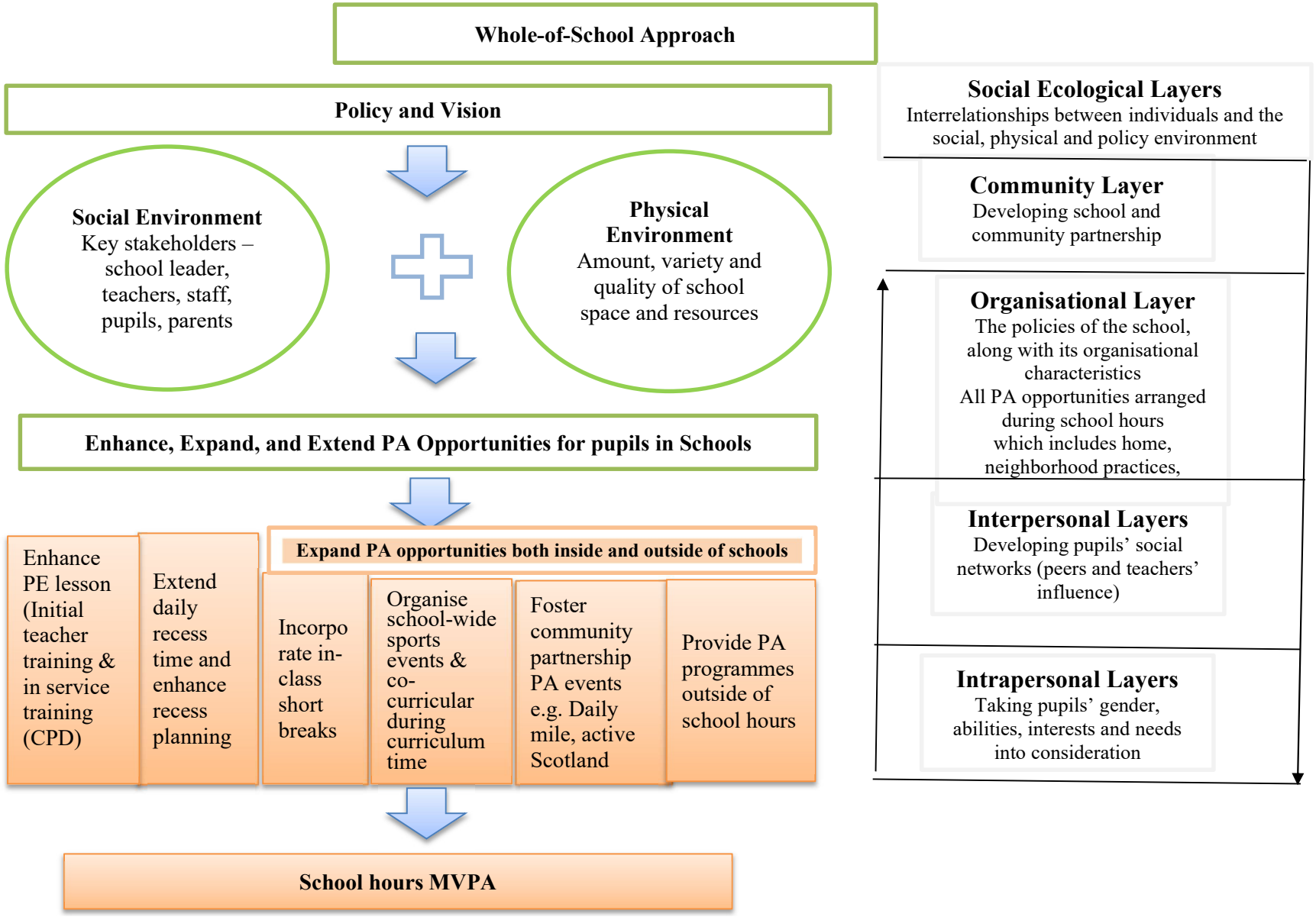

Figure 2. Whole School Practice and Ethos to Increase Pupils' School Hours MVPA - to strengthen the implementation of WOS programmes and expand, extend, and enhance the WOS components to improve pupils' PA opportunities.

7.6 Implications

Research shows that children are not engaging in enough MVPA during school hours, which has serious consequences for their health. This thesis addresses important issues related to this topic and provides key considerations and recommendations for increasing pupils' MVPA during school hours. Implications for policy, practice, and research are discussed in the following sections.

Implications for Policy

School leadership probably plays a critical role. When school governance bodies value PA, they are probably more likely to implement policies that prioritise it, which is crucial for both health and academic performance. Prioritising PA within schools depends on leadership commitment, resources, and infrastructure [1], [15]. Schools should integrate the strategies outlined in Section 7.5 into their unique contexts by incorporating them into both the curriculum and the overall school environment. These strategies should align with the concepts of CSPAP, CAS, SEM, and the TEO, adapting them to the specific needs of each school. This approach would foster a more physically active culture which should motivate pupils to engage in regular PA, leading to long-term increases in MVPA levels [16].

It is crucial to make good use of the two key PA opportunities (PE and recess) during school hours. Effective PE, ideally delivered by specialists, is essential [15]. Therefore, government should focus on teacher training, both in initial training and continuing professional development (CPD), as these are central to enhancing the capability and motivation of PE teachers to promote PA effectively [18]. Colleges and universities should prioritise training future teachers to integrate teaching strategies and active learning, and the delivery of evidence-based PE and health programmes [56]. Additionally, student teachers should understand pupils' physical and mental development, motor skills, and health. Teacher education programmes could be improved by shifting the primary focus from sports to a

broader emphasis on health and PA [57], addressing the issue of low childhood MVPA.

Implications for Practice

The aim of the work described in this thesis is to provide evidence which might help sustainably promote PA in schools through improved teaching, the use of existing resources, and evidence-based practices. The strategies outlined focus on integrating PA into the curriculum and school environment as follows:

- **Improving pedagogy and the PE curriculum**: Schools should focus on enhancing the quality of PE teaching. Addressing the shortage of PE specialists can be achieved through teacher training, partnerships with universities, and ongoing professional development. These efforts should help classroom teachers maximise MVPA during PE classes.
- **Optimising existing structures**: Rather than introducing new programmes, schools might usefully maximise the use of current resources to increase MVPA [4]. Research shows that enhancing existing programmes [58] can be more cost-effective and impactful in promoting PA. For example, instead of extending recess or PE time, schools could focus on improving the quality of PE teaching and recess arrangements to help pupils meet the recommended 30 minutes of daily MVPA. Teachers could first demonstrate the effectiveness of their PE lessons [4] and recess PA programmes to secure further support from the school to sustain PA and recess interventions.

Implications for Research

The approach of this thesis provides an overview of the multiple components that need to be considered when recommending schools in the design, delivery, and evaluation of future PA interventions during school hours. This approach ensures that PA is not only valued but also integrated into the daily life of the school and the wider school community [18]. Based on this whole-school approach, it is hoped that schools can create supportive environments

for PA in Scotland and potentially extend this to other places. However, the local variables related to pupils and the contextual factors influencing changes in pupils' MVPA in Scotland and other countries and regions require further exploration to better understand improvements in children's PA during school hours. Interventions to increase MVPA during school hours and overall levels of MVPA will likely be necessary in both research and policy/practice applications in Scotland. Future research directions are suggested in the following section.

7.7 Future Research Directions: Proposed Next Steps for this Research Area

1) This thesis proposes that interventions are likely to be needed to increase MVPA during time spent in school through school hours total MVPA (Chapter 5), PE lessons (Chapters 3 and 4) and recess (Chapter 6). The thesis offers an approach to increase pupils' school hours MVPA (Figure 2) for other researchers and practitioners to work from or evaluate its usefulness. There are a number of other components of the school day where changes could be made to increase MVPA. One next step would be to identify other datasets with representative samples that allow for analysis of MVPA during PE lessons, before and after school, and the total school time MVPA.
2) There is a lot of evidence, that supports the efficacy of individual components such as PE programmes/lessons [3], [4], [5], recess [23], [24], active classrooms [59], [60], [65] and after-school PA programmes [61] as mentioned in the previous chapters. Their effectiveness has mostly been examined in isolation, that is the effects of interventions on specific domains such as recess or PE. However, there is a lack of research investigating the implementation of comprehensive programmes at multiple levels and with different stakeholder's effectiveness [62]. As suggested by McDonald et al. [63][63], school PA programmes which combine several PA opportunities across the school, have been most consistently successful in increasing pupils' PA and have been demonstrated to be sustained in the long-term [64]. More research is needed to prove

how successful and sustainable comprehensive school-based PA programmes work in terms of increasing pupils' PA.

3) A protocol for testing the feasibility of SHARP is proposed in Chapter 4. This has been used to run a small-scale feasibility study funded by Dundee City Council as a test-of-change - part of their systems-approach to child healthy weight. Guided by the recently updated MRC Framework for intervention development and evaluation [65] the next step would be a pilot study leading to a full randomised controlled trial to test effectiveness of SHARP in the UK. A funding application to do this just has been submitted by the author's supervisor and the SHARP developers at Newman University.

4) The SPACES data are now 8 years old so one next step for research would be to do a follow-up study of those children – they would now be about 18/19, an ongoing SPACES Longitudinal Study may address this as data collection in Scotland is just about complete and/or collect updated data with a sample of younger children, as things may have changed in schools in Scotland in the past 8 years.

5) A unique contribution based on methods used in this PhD thesis was the identification of school hours and recess time for each individual participant. These data (derived school hours and recess time variables) have been given to the MRC Unit to be added to the SPACES dataset for other analysis on school hours or recess time to be done.

7.8 Strengths and Limitations of the Research

Strengths and limitations to this research should also be acknowledged, and specific limitations to each study are discussed within the published papers/individual thesis chapters. Some over-arching strengths and limitations are also included below.

7.8.1 Strengths

1) Results in this thesis are novel. The thesis provides the first report on the MVPA levels of a nationally representative sample of Scottish pupils during school hours and recess

periods. For the first time using accelerometry (in a large and nationally representative sample, the extent to which MVPA levels fall short of commonly used benchmarks) for both school hours and recess has been identified.

2) There is importance to results in this thesis. Identifying the low MVPA levels during school's hours, and potential risk factors, can help with intervention development in future, and should prompt greater emphasis on interventions to maximise MVPA during school hours MVPA in future.

3) The methods used have generate derived variables for other researchers to use. As noted above, in order to answer the research questions the author has derived new variables to be added to the original SPACES dataset i.e., school time, and school recess time for all of the 773 participants. The updated dataset has been deposited with the MRC Unit as mentioned above and there are plans for further secondary analysis of the updated dataset in 2024.

4) While it was disappointing not to collect primary data as part of this thesis, it is a strength that the thesis could capitalise on a government funded dataset for two of the chapters. The more value that can be derived from our large national datasets the better.

5) The use of the SPACES dataset has opened further opportunities for publications between the MRC Unit and University of Strathclyde.

6) The dissemination of the findings from Chapters 3 and 4 allowed a new relationship to develop between Dundee City Council and the University of Strathclyde.

7.8.2 Limitations of this Thesis

1) This thesis focuses solely on MVPA which is one intensity-related-behaviour on an intensity continuum. The focus on MVPA rather than light intensity PA, sleep, or sedentary behaviour was partly for practical reasons, but also because both the World Health Organization (WHO) and the UK health departments have MVPA guidelines but

no light intensity PA or sleep guidelines for school-age children, and no guideline for time spent on sedentary behaviours (including screen time). However, some countries do have evidence-based guidelines for 24-hour movement behaviours for school-age children and adolescents, notably Canada [66] and Australia [67]. These relatively new international guidelines for children's PA, sedentary behaviours, and sleep cover the 24-hour period [66], [67]. This new paradigm of movement behaviours does not mean that MVPA should be ignored, but rather seen as part of a continuum of movement behaviours. The 24-hour movement behaviours paradigm was largely beyond the scope of this thesis, but the thesis might help to contribute to future thinking about the MVPA component of school day movement behaviours. Since the thesis focused on school hours there was less relevance to some of the components of the 24-hour movement behaviours such as sleep and screen-time.

2) Sub-groups of children considered seldom heard or at high risk of low MVPA, such as, those with disabilities or with long-term conditions were not represented within the SPACES dataset since this dataset did not include these groups.

3) The interpretations of results from Studies 3 and 4 are restricted to 10–11-year-olds only and may not be generalisable to other age groups.

4) The generalisability / applicability of the findings to modern children in 2024 must be questioned. SPACES data were collected 8 years ago. Covid-19 changed circumstances and the MVPA levels of boys and girls went down as noted above. However, the SPACES data was still useful and generalisable to Scotland and the sample size was large and the sample representative. The Daily Mile[68], [69] is a useful addition to school hours PA since the original SPACES Study but most evidence suggests that it will not add very much more MVPA per school day [69] we can't say that Daily Mile has solved the problem of low schoolhours MVPA since the time of the SPACES Study for example.

7.9 Overall Thesis Conclusions

Primary schools are a well-established setting for MVPA promotion. This thesis identified the problem of low MVPA across school hours among Scottish 10-11-year-olds. While the data employed is not completely up to date, the representative nature of the dataset and the objective measure of PA gives cause for concern. A simple and cheap evidence-based intervention for increasing MVPA during PE lessons (one key part of school hours) is proposed (SHARP intervention). A cohesive approach combining policy, curriculum, and school environmental changes should also help promote MVPA during school hours, (but would need to be evaluated to confirm effectiveness).

The integration of efforts to increase MVPA in most or all possible school-level domains may improve children's MVPA, and academic attainment as well as decrease the risk of adverse health conditions linked to low activity. School can be an important contributor to public health.

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APPENDICES

Appendix I: Most Cited Award Certificate

WILEY

Top Cited Article 2021-2022

Congratulations to:

Lan Sum Wong

whose paper has been recognized as a top cited paper* in:

JOURNAL OF SCHOOL HEALTH

Interventions to Increase Moderate-to-Vigorous Physical Activity in Elementary School Physical Education Lessons: Systematic Review

**Among work published in an issue between 1 January 2021 – 15 December 2022.*

Appendix II: Published format of Study 1

JOURNAL OF SCHOOL HEALTH

American School Health Association

RESEARCH ARTICLE

Interventions to Increase Moderate-to-Vigorous Physical Activity in Elementary School Physical Education Lessons: Systematic Review

LAN S. WONG, MEd[a] ANN-MARIE GIBSON, PhD[b] ABDULAZIZ FAROOQ, MSc, MPH[c] JOHN J. REILLY, PhD[a,d]

ABSTRACT

BACKGROUND: This systematic review aimed to synthesize recent evidence on interventions to increase moderate-to-vigorous physical activity (MVPA) content of physical education (PE) in children age 8 to 11.

METHODS: A search of 6 databases was conducted in December 2019. Controlled intervention studies were included so long as they used objective measures of MVPA. Methodological quality was assessed using the appropriate Joanna Briggs Institute (JBI) Checklist. Random effects meta-analysis was used where appropriate.

RESULTS: Of the 5459 records, only 5 studies met all inclusion criteria, reporting on 1452 participants; 3 quasi-experimental studies and 2 RCTs. All 5 eligible studies reported favorable intervention effects. Meta-analysis was possible from 4/5 studies: the mean difference between intervention and control groups at follow-up was +14.3% of lesson time in MVPA (confidence interval [CI] 2.7 to 25.8).

CONCLUSIONS: Efforts to increase the MVPA content of elementary school PE are achievable. Two studies employed PE specialist teachers and 1 study used an expert instructor as their intervention, 2 studies worked with the class teachers using self-determination theory. All studies focused on health (MVPA) outcomes and included either "fitness infusions" or physically active games to engage students' in physical activities and increase their activity level.

Keywords: physical education; moderate-to-vigorous-physical activity; physical activity; activity level; fitness; student.

Citation: Wong LS, Gibson A-M, Farooq A, Reilly JJ. Interventions to increase moderate-to-vigorous physical activity in elementary school physical education lessons: systematic review. J Sch Health. 2021; 91: 836-845. DOI: 10.1111/josh.13070

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Regular moderate-to-vigorous physical activity (MVPA) provides a range of benefits for children and young people: physical and mental health[1] and nonhealth benefits such as cognitive development and educational attainment.[2,3] Low MVPA among children and young people, plus the growth of sedentary time via social media and advent of more digital platforms and mobile devices is being regarded as the next major global public health issue.[4,5] A more active lifestyle in childhood is crucial in improving short-term health and wellbeing, as well as reducing risk of many noncommunicable diseases (NCD) in later life.[6,7]

According to Metzler et al.[8] physical education (PE) is the only place where children have an opportunity to engage in MVPA, become physically fit, and learn the movement and behavioral skills needed for a lifetime of active, healthy living. Furthermore, all school-age children spend around half of their days per year at school, making the school environment a strategically important setting for the promotion of MVPA.[9] For example, the United States Centers for Disease Control and Prevention (CDC, USA)[10] and the UK Association for Physical Education (PE) (AfPE, UK)[11] recommend that MVPA levels during elementary school PE lessons should reach 50% of lesson time, a meaningful

[a]Doctoral Student, (lan.wong@strath.ac.uk), University of Strathclyde, Graham Hills Building, 50 George Street, Glasgow, G1 1QE, UK.
[b]Lecturer, (Ann-Marie.Gibson@acu.edu.au) Australian Catholic University, Strathfield Campus, Sydney, Australia, 2135, UK.
[c]Epidemiologist, (mohammed.farooq@aspetar.com) Research and Scientific Support Department, Aspetar Orthopaedic and Sports Medicine Hospital, P. O. Box 29222, Doha, Qatar
[d]Professor, (john.j.reilly@strath.ac.uk) University of Strathclyde, Graham Hills Building, 50 George Street, Glasgow, G1 1QE, UK.
Address correspondence to: Lan Sum Wong, Doctoral Student, (lan.wong@strath.ac.uk), University of Strathclyde, Graham Hills Building, 50 George Street, Glasgow, G1 1QE, UK.

contribution to the 60 minutes minimum MVPA per day recommended.[12] These also align with ''health optimizing physical education'' (HOPE), the concept that PE should make an important contribution to health-related physical activity (PA) and fitness, all students are engaged and active at least 50% of the PE lesson time.[9] Furthermore, PE participation is one of the entry points for students' lifelong participation in MVPA, sports, and society at large.[13-16]

Despite the potential of school PE for increasing MVPA and improving public health, a systematic review carried out by Hollis et al.[17] in 2015 showed MVPA levels during elementary school PE lessons typically do not meet the recommendation of 50% of lesson time. Their findings suggested that interventions to increase the proportion of PE lesson time spent in MVPA were needed. The systematic review of PE interventions aimed at increasing MVPA by Lonsdale et al.[18] in 2013 was comprehensive, but the most recent eligible study included in that review is now over a decade old (published in 2008). Moreover, the Lonsdale et al. review was wide-ranging, including both children and adolescents, and identified 14 eligible studies, most (10/14) from the United States, with potentially limited generalizability beyond the United States. Lonsdale et al.[18] found that many of the eligible studies were quite limited (small sample sizes were common) and the evidence should be considered with caution. Overall, they concluded that PE-based interventions could increase MVPA content of PE lessons by up to about 24% compared with usual practice.[18] They also concluded that professional learning focused on PE teacher pedagogy offered considerable potential for increasing PA in children and youth, but higher quality trials were needed to determine how best to promote MVPA in PE lessons, and to determine the most effective and sustainable intervention strategies. Since the review by Lonsdale et al. included evidence across elementary (7 out of 14 eligible studies), middle, and high schools, their eligible evidence was largely from the United States, from studies published over a decade ago, and from a somewhat limited evidence base, there was a need for a new review to examine whether the evidence base had improved in recent years.

Across the western world there is now clear evidence that MVPA levels of children are low and in decline before adolescence.[19] Interventions are therefore required pre-adolescence to increase MVPA levels and mitigate this age-related decline.[20] Interventions are therefore required for elementary school children.[19,20] In the United Kingdom, the Medical Research Council Framework on the Development and Evaluation of Complex Interventions[21] recommends that thorough searching of intervention evidence is used to inform intervention development. The present review was intended as the foundation of school PE-based intervention development aimed at increasing MVPA in children (8.0 to 11.9 years) in Scotland, and was intended to identify new/existing interventions which might be adapted for use in Scotland. Our intervention development is focused on 8.0 to 11.9 year olds and therefore the review focused on intervention strategies for that age group: intervention evidence from younger children and older youth would probably be less generalizable, and so were beyond the scope of the present review.

The primary aim of this study was to systematically review the more recent global evidence, published after Lonsdale's review (which had only 7 eligible older studies in our target age range, 4 from the United States), to identify promising ways to increase MVPA in elementary school PE lessons for children in the upper stages of primary school education in Scotland (age 8.0-11.9 years).

METHODS

Literature Search

This study followed the PRISMA statement for conducting and reporting systematic reviews and meta-analyses. The protocol was registered on PROSPERO on November 11, 2019 (http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42019155878).

Up to December 2019, eligible studies were identified in 6 relevant electronic databases, Scopus, SPORTDiscus, PsycINFO, ProQuest, PubMed, and ERIC. The search strategy followed the PICOS (population, intervention, comparison, outcomes, and study design) framework. The inclusion and exclusion criteria are detailed below. The search was limited to 2010 to 2019 (aimed updating the previous review by Lonsdale et al., 2013), it was also restricted to search for English language studies only due to the impracticalities of translating papers. An example of a search strategy for the Scopus database is provided in Table 1, which was adapted for the 5 other databases. Hollis et al.'s[17] and Lonsdale et al.'s[18] citation lists, as well as reference lists of the final included papers, were examined to find any potential eligible studies missed during the database search.

References were imported into endnote and duplicates were removed, at which point 1 author screened the titles and abstracts with 81 full-text articles were identified. Three authors then screened potentially relevant full-text articles independently based on the inclusion and exclusion criteria. Any disagreement was resolved through discussions among the 3 authors

Inclusions/Exclusion Criteria

Population. Studies of apparently healthy elementary school children aged 8.0 to 11.9 years old were

Table 1. **Search Strategy in Scopus**

Search Strategy
"physical activit*"
"moderate-to-vigorous-physical activity"
"active learning"
movement
exercise
fitness
"motor activity"
"activity level*"
1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
"physical education"
PE or P.E.
10 or 11
Intervention
experiment
training
compar*
Contrast*
Condition
13 or 14 or 15 or16 or 17 or 18
Student* or pupil
Learner
child* or adolesc*
school*
20 or 21 or 22 or 23
9 and 12 and 19 and 24
limit 25 to English language
limit 26 to yr. = "2010 to current"

The source type was restricted to peer-reviewed journals. Subjects like aging, pediatrics, disability, cancer, employment, religion, older people, college students or surgery were excluded.

included in the present systematic review, with studies excluded if the mean age of study participants was <8.0 or >11.9 years. The reasons of selecting this age range were partly scientific: late childhood/early adolescence = mid-late elementary years represents a fairly homogenous group likely to experience sharply declining MVPA, and partly pragmatic: this review was undertaken in order to help inform development of a PE intervention for 8 to 11 years old in Scotland as noted above. Studies of children with any intellectual, physical or cognitive disabilities, which may impair their ability to engage in PA, were excluded.

Intervention. For inclusion in the present review, the interventions had to take place in PE lessons. If the intervention was multicomponent, MVPA had to be described as the predominant component in the publication. Interventions which addressed other domains of PA (pre or after school, recess), or which were set in the community or home were excluded.

Comparison. For inclusion in the review, the interventions had to be compared to a comparison or control group, who received either no treatment, another PA intervention, other lifestyle intervention, waitlist control or attentional control. Uncontrolled studies were excluded.

Outcomes. For inclusion, the studies must have had MVPA outcomes measured using an objective method (using an accelerometer or direct observation method). PA outcomes measured using self-report, or questionnaire, or an objective measurement that did not give an intensity (pedometers), or studies that measured a small period of the day other than PE (such as recess interventions) were excluded.

Study design. Studies included in the systematic review had to have intervention and control groups, either quasi-experimental designs (nonrandomized experimental studies) or randomized controlled trials (RCT) or cluster randomized controlled trials.

Data Extraction

Data were extracted by one of the authors and checked by a second. In cases where data were missing, or additional information was required for the eligible studies, the study authors were contacted to provide the relevant information. Authors of 2 of the potentially eligible studies were contacted to determine if the study interventions and designs met the inclusion criteria. One for additional information on the mean (SD) or median (age) of study participants at baseline; the other to clarify the size of the intervention effect in the paper. As one of the authors was unable to provide the details, this paper was not included in the present review.[22]

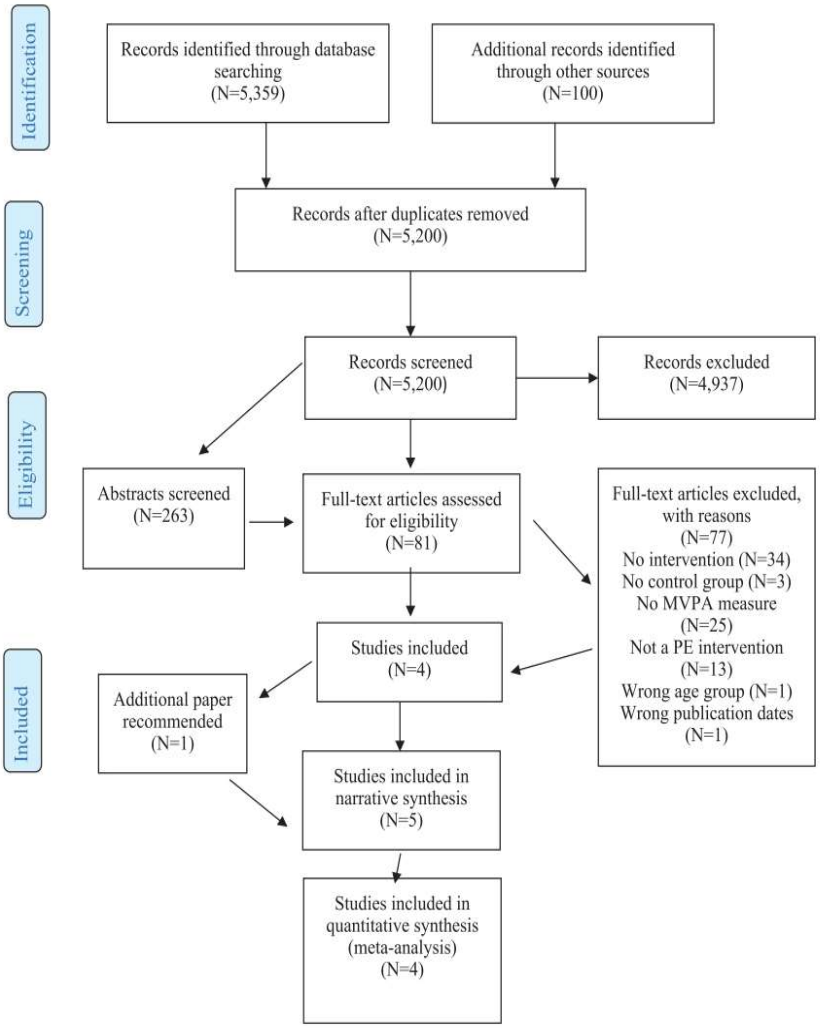
Data Analysis and Synthesis

A narrative synthesis was conducted on outcomes for each included paper. The outcome of interest was MVPA during PE, and meta-analysis was possible for 4 of the 5 eligible studies, on the mean difference in the MVPA content of PE lesson time at follow-up between intervention vs control groups. Two of the 4 studies did not provide the SD for MVPA content of PE, but instead median and inter-quartile range was provided. In these 2 cases, median values were assumed as mean values and SD was estimated using methods described in Wan et al.[23] A random effect meta-analysis was performed for the mean difference and the standardized mean difference with 95% confidence intervals (CI). Heterogeneity across studies was assessed using I^2 statistics (I^2 of 0-40% represents low heterogeneity and 75-100% considerable heterogeneity).[24] All statistical analyses were performed using metafor package (in RStudio, Version 1.2.5001).

Quality Assessment

Two authors independently assessed the quality of the eligible papers using the quality assessment tool of the JBI Critical Appraisal Checklist for Quasi-Experimental Studies (nonrandomized experimental studies)[25] and JBI Critical Appraisal Checklist

Figure 1. **Flow Diagram of Number of Articles Retrieved During the Literature Search and Study Selection**



for RCT,[26] referring to a third author when required. The Checklists were used to assess the methodological quality and to determine the extent to which a study addressed the possibility of bias in its design, conduct, analysis, and reporting.

RESULTS

Identification and Selection of the Studies

The PRISMA flow diagram[27] is presented in Figure 1. From an initial pool of 5459 records (identified from 6 databases and 100 records through other sources), 5200 remained once duplicates were removed. Following the title and abstract review, 81 full-text papers were retrieved and reviewed for eligibility. Five papers met all the inclusion criteria (Boulley et al., 2018; Fairclough et al., 2016; Powell et al., 2016; Smith et al., 2015 and Telford et al., 2016)[28-32] and no further papers were identified when searching references of the 5 included studies. All study selection discrepancies between the 3 authors were resolved through discussion.

Characteristics of the Eligible Studies

An overview of the included studies is presented in Table 2. Three studies were conducted in the United Kingdom,[29-31] 1 in France,[28] and 1 in Australia.[32] The eligible studies had a total of 1452 participants (in both intervention and control groups). The duration of the

Table 2. **Overview of Study Design and Sample Characteristics**

Citation	Study Design (Country)	Sample Size Intervention/Control	Age of Students at Baseline	Intervention Duration	MVPA Outcome Measurement	Intervention Details	Comparison or Control Group
Boulley et al.[28]	Cluster RCT (France)	293 students (15 teachers from 13 elementary schools) Eight teachers in control group Seven teachers in intervention group	Mean age = 8.3 (1st to 5th grade)	A school year From October to June	Accelerometer (SenseWear®pro2 Armband 6.1 BodyMedia, INC., PA, USA)	A teacher professional development program grounded in self-determination theory to increase generalist teachers' need-supportive motivating style and consequently their students' physical activity during PE lessons	Standard PE (by generalist teachers)
Fairclough et al.[29]	Quasi-experimental (UK)	139 students Two control schools Two intervention schools	10-11 years (grade 6)	6 weeks	Accelerometers (Actigraph GT9X, ActiGraph LLC, FL)	Twice-weekly 'Born to Move' (BTM) physical activity and fitness intervention alongside a regular PE lesson. BTM element delivered by an expert instructor and regular PE lessons delivered by generalist teachers (3 lessons per week) for intervention group	Children in the 2 comparison schools received their regular twice weekly PE lessons (by generalist teachers)
Powell et al.[30]	Quasi-experimental (UK)	95 students (with 111 students at based line) One control school and One intervention school	7-9 years (grade 3-4)	1 year	SOFIT	Intervention based on self- determination theory and the socio-ecological model. Used the SHARP Principles Model. Delivered by individual generalist teacher, on-going supported by the PE coordinator and the Head Teacher who developed and adapted a PE and PA policy and curriculum map	Standard PE (by generalist teachers)
Smith et al.[31]	Quasi-experimental (UK)	72 students (42 boys, 30 girls) Two schools (both intervention group and control group in the same school)	11-12 years	12 weeks	SOFIT	Tactical Games Model (TGM) and used Teaching Games for Understanding Approach Delivered by physical education specialists who had experience of the concepts surrounding TGM and had attended a University based training course focused on TGM	Standard PE (by physical education specialists)
Telford et al.[32]	Cluster RCT (Australia)	13 Intervention schools (457 students) 16 Control schools (396 students)	8 years (at based line) to age 12 years	4 years	System for Observing Fitness Instruction Time (SOFIT)	2 PE lessons per week from specialist-trained PE teachers (2 x 45 minutes), 90 minutes per week and the rest 60 minutes was conducted by the generalist teachers to meet the weekly recommendation 150 minutes	Standard PE, 2 PE lessons per week (by generalist teachers)

interventions varied from 6 weeks to 4 years, involving elementary children with mean age 9.8 years. Of the 5 included studies, 3 of them were quasi-experimental studies (nonrandomized experimental studies) and 2 were RCTs.

A range of PE interventions were utilized in the 5 included studies-a common feature was either to use specialist PE teachers, an expert instructor or class teachers (provided with relevant program training) to conduct the interventions. Three studies, Boulley et al.,[28] Powell et al.,[30] and Smith et al.[31] (with mean age 9.3 years) focused on theory-based teaching strategy interventions which supported generalist (class teachers, not PE specialists) teachers[28,30] or PE specialists[31] in increasing children's MVPA during school PE lessons. Boulley et al.[28] aimed to test the effects of a self-determination theory-based teacher professional development program, on elementary teachers' need-supportive motivating style and their students' PA in PE lessons. Class teachers in the intervention group received 12 hours professional development training (separated into 4 3-hour workshops over 1 school year). Students' PA and teachers' motivating style were assessed via accelerometers and direct observation. Results showed that, compared to class teachers in the control group, teachers who attended the professional development training improved their need-supportive motivating style and their students increased their time spent in MVPA. Average percentage of students' PE time in MVPA in the intervention group was 53% compared with 43% in the control group at the latest complete follow-up.

Powell et al.'s study[30] aimed at developing teacher effectiveness through the ''SHARP Principles Model'' which involved the following key pedagogical aspects: stretching while moving; high repetition of motor skills, accessibility through differentiation, reducing sitting and standing, and promoting in-class PA. The SHARP Principles Model was grounded in theoretical frameworks namely the self-determination theory, the social ecological model and key components (barrier identification, action planning, and providing instruction) from behavior change taxonomy. A set of teaching principles was developed to provide class teachers with key elements to focus on in both the planning stage and the delivery of their PE lessons. Workshops and resource cards illustrating the Model were provided to enhance teacher's pedagogy. According to the qualitative findings of this study, the generalist class teachers became conscious of increasing the opportunities for children to learn skills in a more active way. The proportion of time children were engaged in MVPA during PE lessons in the intervention school increased significantly from baseline (mean 43%) to postintervention (mean 73%).

Smith et al.[31] aimed to increase MVPA through 2 pedagogical models; direct instruction (used in the control group) and the tactical games model (used in the intervention group), also based on self-determination theory but delivered by PE specialists. The findings showed that boys in the intervention group displayed significantly higher levels of MVPA in both rugby (55.7% SD 3.9) and football (67.8% SD 7.1) activities in comparison to the control groups' in rugby (41.0% SD 5.1) and football activities (54.6% SD 7.3). While girls in the intervention group recorded comparable MVPA levels in the football sessions, they recorded significantly lower MVPA levels in the netball lessons. As regard to the levels of students' self-determined motivation, no significant differences in both boys' and girls' motivation were noted.

Two studies, Telford et al.[32] and Fairclough et al.[29] used PE specialist teachers and an expert instructor respectively to try to increase the MVPA content of PE. Telford's ''Lifestyle of our Kids'' study[32] used a specialist-taught PE program. Two intervention lessons per week were conducted by a PE specialist which amounted to 90 minutes of the mandatory 150 minutes per week. The remaining 60 minutes of required weekly PE was delivered by class teachers. The intervention, comprising of game play, fitness activities, skill practice and core movement, increased student's MVPA significantly during PE lessons by 6.5 minutes on average. This was attributable largely to longer PE lessons and more physically active lessons delivered by the teachers with training in PE compared to generalist class teachers.

Fairclough et al.[29] was a pilot study and they used the ''Born to Move'' fitness intervention movement (including move, punch, kick, jump, dance, core, games, and yoga) categories program to promote PA and fitness for children. The ''Born to Move'' program was delivered (by an expert instructor) twice a week alongside 1 regular PE lesson in the intervention schools. While children in the comparison schools received their regular twice-weekly PE as specified in the curriculum and the lessons were delivered by their regular class teachers. Participants, including students and teachers, found that the aims of enjoyment, engagement, inclusivity, and challenge were satisfied. Overall this ''Born to Move'' program engaged children in significantly more ''moderate PA'' (MPA) (mean 14 minutes/lesson) than during comparison group PE (8 minutes/lesson), and with a median of 51% of PE lesson time as MVPA in the intervention group vs 32% in the comparison group.

To summarize, the eligible studies generally found positive effects of their interventions on the content of MVPA during PE. Interventions were quite heterogeneous in intervention duration or follow-up, method of measurement of MVPA, age, 1 was a pilot study, and 3/5 had a theoretical basis (all 3

based on self-determination theory). Three used self-determination theory to inform interventions and 2 of them aimed at changing current generalist class teachers' behavior. Some interventions were less generalizable to the Scottish setting than others, for example, the sport-based intervention of Smith et al. would not readily match the Scottish PE curriculum, and both of the Smith's and Telford's interventions depended on specialist PE teachers which are not available universally in Scotland (where primary school PE depends largely on generalist class teachers).

Meta-analysis

Four of the 5 eligible studies reported comparable findings[28-30,32]; ie, differences in the MVPA content of PE (as a % of PE lesson time) between intervention and control groups at follow up. These 4 studies were pooled using random effects meta-analysis, having first estimated the SD in 2/4 studies using metafor package (in RStudio, Version 1.2.5001). Pooled estimates of effect of PE interventions expressed as mean difference between intervention and control on % time in MVPA during PE was +14.3% (CI +2.7 to +25.8%) significantly favoring interventions. The I^2 statistics of 97.3% confirmed high level of heterogeneity. Funnel plots were created and Egger tests of asymmetry were performed. Although visual inspection suggested asymmetry, the Egger's test gave a $z = 0.55$, $p = 0.5817$ confirming symmetry, probably due to the small number of included studies.

Quality Assessment of Eligible Studies

Quality assessment of the eligible studies is summarized in Table 3 (for quasi-experimental studies) and Table 4 (for the RCTs). Evidence quality was generally high, with the range of items conducted and reported adequately from 7 to 8/9 for the quasi-experimental studies[22] and for the cluster RCTs, 9/12 and 7.5/12 items were conducted and reported adequately.[23] One item found typically weak in study reporting was ''statistical analysis'' in quasi-experimental studies as there were no mention of power and clustering in most cases.

DISCUSSION

The present review found favorable intervention effects on children's MVPA in all the studies, with a pooled effect of 14.3% higher lesson time in MVPA in the intervention groups, equivalent to around a 9 minute improvement in MVPA per 1 hour of PE lesson time. The range was from a 4% to 30% difference in the MVPA content of PE lessons. The present review therefore suggests that interventions to increase the MVPA content of elementary school PE are worthwhile. School should also protect PE

Table 3. Joanna Briggs Institute Critical Appraisal Checklist for Quasi-Experimental Studies (Nonrandomized Experimental Studies)

Study	1. Clear Dependent and Independent Variables?	2. Participants Included in Comparisons Similar?	3. Participants Included in Comparisons Receving Similar Treatment/Care?	4. A Control/ Comparison Group?	5. Multiple Measurements of the Outcome both Pre and Post the Intervention?	6. Follow Up Complete?	7. Outcomes Measured in the Same Way?	8. Experimental Studies Outcomes Measured in a Reliable way?	9. Appropriate Statistical Analysis?
Fairclough et al. 2016	Yes	Yes	No Control group received less PE	Yes	Yes	Yes	Yes	Yes	Partial: Power limited as this was a pilot study
Powell et al. 2016	Yes	Yes	Yes	Yes	UnclearSOFIT	Yes 4 weeks postintervention using SOFIT	Yes	Yes	Partial: No mention of power and clustering
Smith et al. 2015	Yes	Yes	Yes	Yes	No	Partial	Yes	Partial SOFIT and accelerometers	Partial: No mention of power and clustering

Table 4. **Joanna Briggs Institute Critical Appraisal Checklist for RCT**

Study	1. True Rando-mization Used?	2. Allocation to Groups Concealed?	3. Groups Similar at the Baseline?	4. Participants Blinded?	5. Were those Delivering Treatment Blinded?	6. Outcomes Assessors Blinded?	7. Groups Treated Identically other than Intervention?	8. Follow Up Complete?	9. Participants Analyzed in Allocated Groups?	10. Outcomes Measured in the Same Way?	11. Outcomes Measured Reliably?	12. Appropriate Statistical Analysis?	13. Trial Design Appropriate?
Boulley et al. 2018	Yes	Yes	Yes	Partial	NA	Unclear	No Teachers in the control groups had no TPD	Partial	Yes	Yes	Yes	Yes	Yes
Telford et al. 2016	Yes	Unclear	Yes	No	NA	No	No Standard PE control group less PE lesson	Yes	Yes	Yes	Yes	Partial	Yes

time to ensure that the recommended amount of class time for PE is actually made available.[32] The eligible intervention studies had certain components which may help explain their success in increasing MVPA in PE. Notably, they included: (1) a focus on active learning approaches and health; (2) a theory and evidence-based approach (using the theoretical framework of self-determination theory); (3) an emphasis on fitness and enjoyable activities in the intervention lessons to enhance children's motivation and engagement.

The present review aimed to update Lonsdale et al.'s study of elementary or secondary school PE interventions to increase MVPA in 2013, in which they identified studies published up to 2008.[18] The 5 eligible studies in the present review were of high methodological quality, though, as in the Lonsdale systematic review, the evidence was entirely from high-income, western countries. With the problem of low MVPA among students all over the world, more intervention studies are needed in other countries. The information learned from successful interventions could have a positive impact on other sociocultural contexts where interests, values and social norms in school and in society are different (such as Singapore, Hong Kong).

Previous systematic reviews[17,18] have found that MVPA levels in school PE were often quite low, and had reported many barriers to higher activity levels in elementary school PE lessons. Among these were policy and infrastructure barriers (such as did no protection for PE time, low teacher confidence in their PE teaching ability, resulting in limited expertise in teaching active lessons and less MVPA than would be desirable). The present review is consistent with Hollis et al.[17] and Lonsdale et al.[18] in that PE-based interventions or well-designed PE programs (with enjoyable and fitness-based activities) could have a positive influence on the total amount of MVPA children participate in.

Limitations

The methodological quality of all eligible papers was generally high which means the risk of bias in individual studies was low. However, a few limitations of this review must also be acknowledged. Our review only included studies in English language which may have limited the number of included studies. Since there were so few studies, and only 2 were randomized, there may be a need to evaluate the effects of interventions to increase MVPA level in high-quality cluster RCTs in the future. Outcome measurement was objective in all included studies but 3/5 of these studies used SOFIT which tends to overestimate MVPA[17] so percentage time in MVPA and minutes spent in MVPA during PE lessons in the eligible studies may have been lower than reported.

Publication bias is a concern with intervention studies. A funnel plot was used to test for publication bias in the present study, but this was limited by the small number of eligible studies. While meta-analysis was supportive of benefits to intervention, this conclusion is tentative because the interventions were so heterogeneous—future research is advisable to estimate the magnitude of intervention effects.

Conclusions

All studies in this review reported a favorable intervention effect upon increasing children's MVPA, suggesting that efforts to increase the MVPA content of elementary school PE are achievable. All studies had a focus on MVPA (health) outcomes and had PE pedagogical objectives to develop teaching effectiveness. Three of the studies used behavioral theory-based intervention (2 with class teachers and 1 with PE specialists). The remaining 2 studies used either an expert instructor or specialist PE teachers. It was important to support teachers to teach and students to learn, by providing interventions based on teacher professional development programs/workshops and on theoretical framework of self-determination theory.[28,30,31] One new/existing intervention from England,[33] published after the systematic review by Lonsdale et al. was identified as promising and probably generalizable to Scotland, and so potentially useful for our future intervention development in children in upper primary school in Scotland. Since the number of eligible intervention studies in this age group was relatively small and heterogeneous, though of reasonably high-quality, further studies are recommended. Games centered/motivational approaches to enhance children's enjoyment and engagement in PE lessons may be effective ways to increase children's MVPA levels.

IMPLICATIONS FOR SCHOOL HEALTH

PE can play an important role in promoting students' MVPA level in school, but previous studies have shown that this potential is not being realized because PE lessons are typically not as physically active as they could be and children not as engaged as they could be. The potential of PE to contribute to public health goals by promoting MVPA might be underappreciated by educators and health policymakers, as schools tend to prioritize other aspects of the curriculum such as literacy and numeracy. Achieving the WHO recommendation of at least 60 minutes of MVPA daily will improve public health so the objective of school and PE lessons should be to assist children meet the recommendation by making PE more physically active. Doing so should be equitable since all children attend school. As reflected by Eloise et al.[34] "high-quality physical education" helps students build up the skills and knowledge that they have acquired to participate in and enjoy PA.

Practical lessons from the present study for class teachers, school principals, as well as education and health policymakers are as follows:

1. Put more emphasis on the public health goals of PE—more active PE delivers health benefits to school students—helps children build a solid health foundation, reduces the risks from infectious diseases, such as the Covid-19 pandemic, and prevents many NCD in later life;
2. The teachers, either PE-trained specialists or generalist class teachers, must plan their PE lessons to have more MVPA content such that all children are engaged;
3. Choose activities that encourage MVPA behavior—fitness infusion activity, competition, modified games;
4. Provide training and professional development to modify teaching pedagogy to enhance students' motivations to be active in PE; and
5. Reduce sedentary time by avoiding children standing around, queuing, listening to long instructions, or selecting games where only a portion of children are active.

Human Subjects Approval Statement

As a literature review not involving original research on human subjects, this study did not require review by an institutional review board.

Conflicts of Interest

The authors declare no conflicts of interest.

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Appendix III: Published format of Study 2

STUDY PROTOCOL

REVISED Feasibility of an intervention for increasing moderate-to-vigorous intensity physical activity (MVPA) in primary school physical education: a study protocol [version 2; peer review: 1 approved]

Lan Sum WONG[1], Fiona Muirhead[1], Emma Powell[2], Lorayne A Woodfield[2], Cameron Stewart[3], John J Reilly[1]

[1]Physical Activity for Health Group, School of Psychological Sciences and Health, University of Strathclyde, Graham Hills Building, 5/F., 50 George Street, Glasgow, G1 1QE, UK
[2]Faculty of Education, Newman University, Genners Lane, Bartley Green, Birmingham, B32 3NT, UK
[3]Department of Education, East Renfrewshire Council, 211 Main Street, Barrhead, G78 1SY Scotland, UK

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Abstract

Background: Most primary school Physical Education (PE) has relatively little health-enhancing moderate-to-vigorous physical activity (MVPA). - A promising theory and evidence-based intervention, the 'SHARP Principles' model, has been effective in making PE lessons more active in one area of England. This protocol paper explains the rationale for use of the SHARP intervention, and the methods used to examine the feasibility and acceptability of a version of SHARP translated for use in Scotland (SHARP Scotland).
Methods: The feasibility of SHARP Scotland will be evaluated by key areas of focus for feasibility studies: Acceptability, Implementation, Integration, Limited Efficacy Testing. A combination of process measures, including observations, session delivery records, accelerometry-data collection, questionnaires, and semi-structured qualitative focus groups with teachers and pupils will be used. The feasibility and suitability of the SHARP Scotland intervention for a future Randomised Control Trial (RCT) will be assessed. The study will involve children from 8-11 years old (Primary 4 to 6) in two schools, one large urban school, and one smaller school; four classes will be randomly assigned to the intervention group (will be taught by class teachers with SHARP approach training), and four classes randomly assigned to the usual-care (standard curriculum) control group (taught by class teachers without SHARP training). Within the 8-week intervention, MVPA in the intervention group will be targeted by encouraging class teachers to deliver their PE classes in more active ways, following SHARP Principles. A maximum of 64 PE lessons

Open Peer Review

Approval Status ✓

	1
version 2 (revision) 17 Oct 2022	
version 1 02 Mar 2022	✓ view

1. **Freya MacMillan**, Western Sydney University, Campbelltown, Australia

Any reports and responses or comments on the article can be found at the end of the article.

delivered in a SHARP way will be conducted to assess the effectiveness of the intervention.
Discussion: The outcome of this study will be an assessment of whether applying the SHARP intervention is feasible in Scottish schools. Identification of any modifications to the intervention or evaluation which are required will provide insight for a fully powered effectiveness trial in the future, if appropriate.

Keywords
Moderate-to-vigorous physical activity, Intervention, Primary school, Children, Physical education, Health, Accelerometry-measured, Feasibility.

This article is included in the Sociology of Health gateway.

Corresponding author: Lan Sum WONG (lan.wong@strath.ac.uk)

Author roles: WONG LS: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Software, Supervision, Validation, Writing – Original Draft Preparation, Writing – Review & Editing; **Muirhead F**: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Resources, Supervision, Validation, Writing – Review & Editing; **Powell E**: Conceptualization, Methodology, Resources, Supervision, Validation, Writing – Review & Editing; **Woodfield LA**: Conceptualization, Resources, Supervision, Validation, Writing – Review & Editing; **Stewart C**: Conceptualization, Investigation, Methodology, Project Administration, Software, Writing – Review & Editing; **Reilly JJ**: Conceptualization, Data Curation, Methodology, Resources, Supervision, Validation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

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REVISED **Amendments from Version 1**

We add the URI address for one of our co-authors John J Reilly

In response to the reviewer's comments, we made the following changes.

1. We concisely mentioned in the abstract too that the teachers delivering the intervention (taught by class teachers with SHARP approach training) are not the same teachers taking the control classes (taught by class teachers without SHARP training).
2. We deleted the term 'non-health' and replaced the word with 'other'.
3. We updated the reference with the current WHO recommendation i.e., an average of at least 60 minutes of MVPA per day. Relevant change has also been made on reference list no.5.
4. The word 'accelerometry' has been replaced by 'accelerometers' in the 2nd sentence of the 'limited efficacy testing' section.

Any further responses from the reviewers can be found at the end of the article

List of abbreviations

MRC: Medical Research Council
MVPA: Moderate-to-vigorous physical activity
PA: Physical activity
PE: Physical education
RCT: Randomised Control Trial
SHARP: Stretching whilst moving, High repetition of skills, Accessibility, Reducing sitting and standing, and Promotion of physical activity
UK: United Kingdom
USA: United States of America
WHO: World Health Organisation

Introduction

Moderate-to-vigorous intensity physical activity (MVPA) is very important to the health and well-being of children as it provides both immediate and long-term health and other benefits (such as academic performance).[1–4] Despite these positive impacts, it is estimated that approximately only 20% of children and adolescents globally meet the WHO recommendation of an average of at least 60 minutes of MVPA per day.[5,6] As a result, children's current and future health is at risk.[6] As there is good evidence that physical activity generally declines by age 6–7 years in the UK and globally,[7] future interventions to promote MVPA should start before adolescence.[8]

There is high potential for school time to help pupils meet the WHO MVPA recommendation.[9] Schools are an important setting for promoting children's daily physical activity (PA) as pupils from all socio-economic and cultural backgrounds spend around half of their days per year at school.[10] Schools can therefore play a vital role in keeping young people active through all activity opportunities,[11] such as morning and lunch breaks, recess, active travel, afterschool activities, play and sports,[12] but most importantly in physical education (PE) lessons.

The United States Centers for Disease Control and Prevention (CDC, USA)[13] recommends that MVPA levels during primary school PE lessons should reach 50% of lesson time. The UK Association for Physical Education (AfPE, UK)[14] recommends that children be actively moving for 50-80% of the available PE learning time. In its health position paper, AfPE also outlines that active learning time is about developing children's physical skills by providing them with the opportunity to practise those skills during lessons in a fun and purposeful learning environment, as PE involves 'learning to move' and 'moving to learn',[14] so PE lessons can enhance MVPA beyond just class time. Nevertheless, most primary school PE lessons globally do not meet recommendations for the MVPA content of class time,[15] so there is a need to find more effective and sustainable good practices to increase children's MVPA levels during school time and in PE lessons.[16]

In Scotland, there is a great public health need for population-wide interventions to increase Scottish children's physical activity as few children reach the recommended minimum of 60 minutes of MVPA per day.[5,17] Scotland faces a crisis arising from unhealthy lifestyles which begin in early childhood: poor diet and low physical activity or exercise create a massive burden of later heart disease and stroke, diabetes, obesity, and cancers.[18] Hence the Scottish Government is keen to improve children's health and wellbeing as guidelines stated in the national "Curriculum for Excellence[19] that *"Learning in health and wellbeing ensures that children and young people develop the knowledge and understanding, skills, capabilities, and attributes which they need for mental, emotional, social and physical wellbeing now and in the future"*.

To find interventions that could increase the MVPA content of school PE, a systematic review was undertaken by the author in 2019.[20] A literature search of global evidence (within the past decade) on effective interventions to increase MVPA during PE classes in children (8 to 11 years) was conducted. The systematic review identified five eligible intervention studies.[21–25]

Specific rationale for the choice of the SHARP intervention for translation to Scotland

One study from our recent systematic review[20] was identified as the most promising for translation to Scotland among the five eligible studies, the 'SHARP Principles' model (SHARP), an intervention developed in one part of England.[21] This intervention, with a few modifications, now forms the basis of the present feasibility study. The SHARP intervention was chosen for future intervention development and evaluation, starting with the proposed feasibility study, as it:

1. had clear evidence of efficacy in increasing MVPA content of PE in children in our target age range. Indeed, there was evidence that the SHARP lessons had a much higher MVPA content than standard (control) PE lessons in the original evaluation studies. SHARP had been tested twice across multiple schools in the West Midlands, England it increased children's MVPA during PE lessons by 30% and 27% respectively.[21,26]

2. had a theoretical basis - the intervention was grounded in a combination of theoretical frameworks namely the Self-Determination Theory (SDT),[27] the Socio-Ecological Model,[28] and key components (e.g., barrier identification, action planning, and providing instruction) from Behaviour Change Taxonomy.[29] In the original development of SHARP, SDT was applied to connect the roles of the Head Teachers, PE subject leader, and the individual teachers. The components of SDT were implemented through a supportive autonomous role (autonomy) along with developing teachers' social networks (relatedness) and knowledge (competency). Implementation of the SHARP Principles in Scotland is underpinned through the original SHARP Principles model. It is intended that when the intervention is translated to Scotland teachers have relatedness through the shared aims of PE within the school and their connection with each other as professional practitioners working towards this shared aim, along with the support of their PE subject leader and school leadership team. Moreover, since SHARP is applied to teachers' existing planning, it ensures that they can retain autonomy, so it is also faithful to SDT.

3. could be applied at little cost, as it could be potentially applied to any PE lessons with no additional equipment or other resources.

4. appeared applicable for the Scottish context, in part due to the close cultural and social contexts between England and Scotland. SHARP involves teaching existing PE lessons but in a more physically active way and does not require curriculum changes or extensive re-learning by teachers.

5. had readily accessible online resources available. The SHARP teaching resource cards and videos were available online for teachers' use.[30] The SHARP Principles can be learned by both generalist class teachers and specialist teachers of primary PE in a workshop with the support of these materials.

Table 1. Key areas of focus to be addressed and method to assess that area.[31]

Areas of focus	The feasibility study asks	Method to assess/evaluate
Acceptability	of the intervention	assessed by qualitative methods
Implementation	of the intervention - can it be implemented as planned/what refinements are needed? What adaptations to the intervention might be needed?	assessed by a combination of quantitative evaluation of the number of SHARP sessions delivered and qualitative work
Integration	of the intervention into the new setting - can teachers integrate it into their routine teaching practice?	assessed by qualitative methods
Limited efficacy testing	is there any preliminary evidence of efficacy?	quantitative evaluation (MVPA content of PE lessons by collecting accelerometers data between intervention vs control classes) - the SHARP lessons had higher MVPA content in two previous evaluations in England. Increased children's MVPA during PE lessons by 30% and 27% respectively.[21,26]

The present study aims to describe how we will test the feasibility of the SHARP intervention in Scotland. We propose this study as the foundation of future research which tests whether the SHARP-Scotland intervention works or not, and how it might be implemented across various parts of Scotland to increase MVPA during PE (two lessons of PE per week are timetabled in Scottish primary schools), and in turn increase overall MVPA. Hence, to assess the issue of 'can the SHARP Scotland intervention work?', the current study is planned to assess some key areas of focus for feasibility studies as proposed by Bowen *et al.*,[31] particularly Acceptability, Implementation, Integration, and Limited Efficacy Testing (Table 1).

Methods

The study sample, recruitment, randomization, and consent

Children from 8-11 years old (Primary 4 to 6) will be involved from two local authority primary schools in the Glasgow area, characterised for socio-economic status using the Scottish Index of Multiple Deprivation (SIMD).[32] All class teachers from 18 classes will be invited to take part and we intend to recruit a total of eight classes/class teachers which will then be randomly allocated to four intervention classes and four control classes (standard curriculum, offered the SHARP intervention training after the eight-week intervention, i.e., a wait-list control) by a member of staff from the Mathematics and Statistics Department in our university who is not connected to the study. A total maximum of around 240 children will be involved in this study (the typical class size in Scottish primary schools is 30 pupils).

We have not yet registered this trial because the local authority will only give agreement in principle until the schools are operating normally post-COVID. We also cannot apply for ethics approval until schools are operating normally post-COVID. When schools will be operating normally is unclear, and the restrictions which might apply to PE classes, or to our research (e.g., access to schools) are unknown at present. Once confirmed, this study will seek ethical approval from the University of Strathclyde's School of Psychological Sciences and Health Ethics Committee. Any amendment to the study protocol will be submitted for ethical approval before implementation. Consent will be obtained from all participating children via parental consent forms. All pupils attending the relevant PE classes will be considered as suitable for inclusion, with no exclusions, though if children have health reasons which might impair their ability to take part in PE this will be noted. Teachers will be required to provide informed written consent. Verbal assent will be sought from children before enrolment in the study, and their parents will be required to provide informed written consent.

Teacher training in the SHARP intervention

The intervention will be delivered by generalist class teachers and the SHARP Principles (more active approach) will be adopted when they are teaching PE lessons. Teachers of intervention classes will be trained in the SHARP approach (via a workshop) before intervention commencement. They will then be asked to apply the principles in their PE lessons over one school term (eight weeks). The workshop will be delivered by the originator of the SHARP (EP) and the PE specialist (CS) involved in translating SHARP Scotland. Existing SHARP resources and training materials are available online[30] and will be used by the teachers involved. Group planning sessions (30 minutes), as required will be used to help teachers deliver the intervention and intended also to motivate teachers to use the SHARP Principles in their planning and teaching. Training content will be flexible and would depend on what is needed to modify the SHARP Principles according to the curriculum and environment of Scotland. To provide additional motivation for teachers to take part, the training will count towards continuous professional development hours.

(A summary of the intervention description (trial process) is outlined in Figure 1).

To apply the SHARP teaching principles in the intervention

The SHARP intervention is based on five teaching principles named 'SHARP Principles' (Stretching whilst moving, High repetition of skills, Accessibility, Reducing sitting and standing, and Promotion of physical activity[21,26]). SHARP Principles are designed specifically to help teachers deliver their existing PE classes but to do so in ways that involve more children in the class moving for much more of the class time, to increase MVPA during the lesson. The authors of the present study consist of the original developers of the SHARP intervention in England, a PE specialist teacher from Scotland, and the researchers responsible for evaluation. We consider that SHARP can be adapted to the Scottish context relatively easily, in part because it does not seek to change what is taught in the class but focuses on how it is taught (in a more active way).

In brief, the SHARP Principles are as follows[30]:

Stretching whilst moving - During the warm-up section of a SHARP PE lesson, activities are to include dynamic movements (such as movements that engage the lower and upper body), and stretches (e.g., side shuffles, jump and twist, high knees, and skipping).

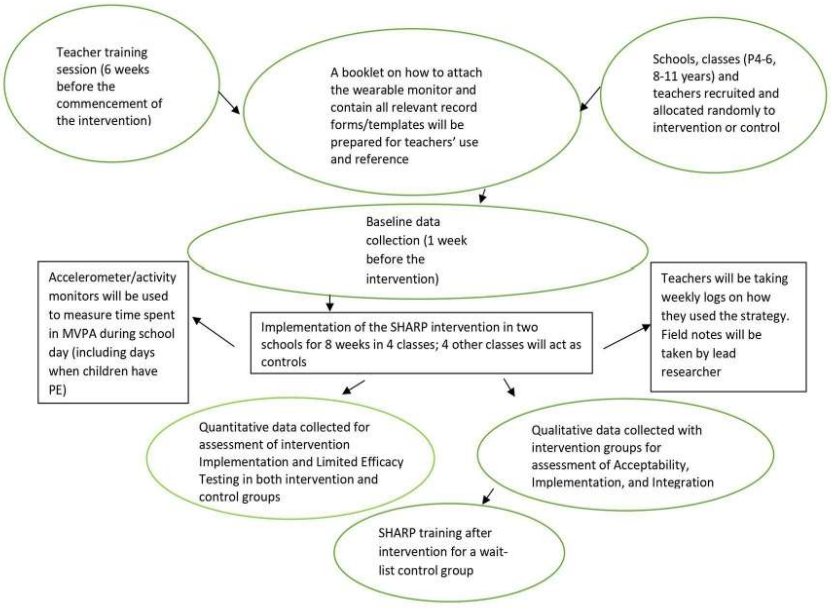


Figure 1. Intervention description.

High repetition of motor skills - SHARP increases active learning time by reducing queueing. SHARP can also increase the amount of existing equipment used in each class or increase the number of learning stations.

Accessibility through differentiation - SHARP focuses on setting tasks appropriate to children's physical, cognitive and social development, which will enable them to engage in more active learning time. Teachers can use the 'STEP framework' (space, task, equipment, and people) for more effective differentiation of activities in class.[21,26]

Reducing sitting and standing - SHARP increases teachers' awareness of the amount of time children are sitting and standing during the lesson with knowledge transfer, teacher feedback, and improved organisation of equipment. In a SHARP lesson, teachers should engage children in activity as soon as possible at the start of a lesson, they should not stop the whole class from moving while instructions are being given, they should encourage children to stay active (e.g., by continuing to practice skills) while receiving instructions, and they should organize equipment to minimize queueing.

Promoting in-class physical activity - This principle is based on teachers' encouragement of greater children's in-class physical activity through positive praise such as 'Great teamwork, keep moving and looking for space'.

Assessment of feasibility

The Bowen *et al.* Framework[31] (Acceptability, Implementation, Integration, Limited Efficacy Testing) will be used to assess the feasibility of the SHARP intervention and evaluation in Scotland (Table 1).

Acceptability

Acceptability assessment is an attempt to answer the question framed by Bowen *et al.* but applied to the present study of 'Can SHARP work in Scotland?'[31] Qualitative methods will be used to assess the willingness of school staff to deliver the programme, (e.g., willingness to be allocated randomly to intervention or control groups, willingness to deliver lessons using the SHARP Principles), and willingness of children to participate. Acceptability of the methods used for measuring the intervention effect in a future evaluation (e.g., whether children find using the accelerometer acceptable) will also be assessed. All qualitative data will be collected via questionnaires and semi-structured focus groups with teachers and pupils on completion of the intervention.

Implementation

Implementation is an assessment of the extent to which the intervention was delivered as planned[31] - can it be implemented as planned/what refinements are needed? The process evaluation will be supported by the Medical Research Council (MRC) guidance on process evaluation of complex interventions.[33] Quantitative methods will be used to assess recruitment and participant attrition rates (class level and individual level), and intervention fidelity. The researcher's observations of the delivery, relevant documentation, and records (such as teachers' logs - teachers will be asked to log each PE lesson delivered and whether they used SHARP Principles and which ones, using a checklist) will enable the researcher to reflect on the appropriate use of and application of behaviour change tools utilised. Qualitative semi-structured focus groups with the class teachers will be used to identify any refinements to the delivery of the SHARP Scotland intervention which might be required from teachers' perspective.

Integration of the SHARP intervention in the Scottish context (SHARP Scotland)

Integration, as defined by Bowen *et al.*[31] and applied to the present study, is an assessment of the extent to which changes to the school were necessary to integrate SHARP PE lessons (e.g., any changes to timetabling, equipment, unintended teacher impacts such as increased workload). This type of assessment, as framed by Bowen *et al.*,[31] is necessary to assess whether the intervention is feasible beyond the counting of the number of sessions delivered. The integration will be assessed by qualitative methods. Semi-structured focus groups with class teachers will be used to identify the changes to the school which was necessary and to identify any unintended consequences if integrating SHARP lessons.

To some extent, the issue of integration of SHARP Principles into the Scottish primary school system has been addressed by co-production work[34] involving the study authors (researchers, original SHARP development team in England, plus primary school PE specialist from Scotland) before the feasibility study. The main outcome of this co-production was a modified version of the original SHARP Principles intervention ('SHARP Scotland'). Table 2 outlines the differences between the original SHARP intervention and the translated version of the SHARP Scotland intervention which will be tested for feasibility.

Limited efficacy testing

Bowen *et al.*[31] recommend limited efficacy testing in feasibility studies. Only preliminary evidence of efficacy will be obtained in the present study, and the extent to which the primary outcome of a future evaluation (MVPA content of PE lessons in both the intervention and control groups using accelerometer) can be measured feasibly will be assessed by quantitative methods. We will measure MVPA during PE lessons and the whole school day in all children with hip-worn Actigraphs. Children will be asked to wear the Actigraph during school time for five days from the beginning to the end of the intervention.

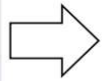
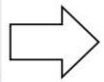
Whole-school day MVPA data will be collected to provide useful contextual information on the amount of MVPA being accumulated during the school day, and because in previous studies we have found that it is more practical to collect accelerometry data during specific periods of the school day (e.g., PE class, recess) if children simply put the Actigraph on at the start of the school day and return it to class teachers at the end of the school day. The feasibility of accelerometry will be assessed as the number of school days with at least 75% of wear time as a percentage of the total number of school days in which children were asked to wear the accelerometers. The teachers in the classes will be shown how to help children put the monitors on/check that they are being worn and worn properly and asked to ensure that the monitors will be put on the consenting participants at the start of the school day and remove just before school finishing. This process of accelerometry data collection also minimizes disruption and delay to PE classes (by avoiding the need to distribute accelerometers during the PE class). Teachers will also be asked to record children's PE classes (PE date, day start time, and finish time) in a class diary.

Analyses of between-group differences in the MVPA content of PE (the percentage of time in PE class spent in MVPA), will be preliminary, as the feasibility study is not powered to test for intervention effects. As this is a feasibility study, one of the main objectives is to collect appropriate data to inform a power calculation for a future Randomised Control Trial (RCT). Therefore, no sample size calculation was undertaken for this feasibility study, but the samples will be sufficient to measure important feasibility parameters, notably accelerometer loss, accelerometer data loss, and our ability to identify and extract accelerometer data from PE classes. The analyses will inform a future full-scale trial if feasibility is high.

Dissemination

Findings of the study will be disseminated via publications in peer-reviewed journals, conference presentations, and lay summary reports/presentations which will be given to parents and primary school teachers who participate in the study.

Table 2. The differences between the original SHARP intervention and the translated version of SHARP Scotland intervention.

Original SHARP Principles Model **Duration – 1 school year** **Population: Primary school children (year 3 and 4 (aged 7 to 9 years)/year 1 to year 6 (aged 5 to 11)**[21,26]			**Adapted "SHARP Scotland" Intervention:** **Duration – 8 weeks (1 school term in Scotland)** **Population: Primary school children (P4 to P6, aged 8 to 11 years)**
Components	**Details**		**Details**
Teacher training	• Support by head teachers at the organisational/policy levels, PE coordinators, and other staff members in the use of the SHARP Principles during PE lessons • Joint planning sessions (30 minutes)		• Four teachers provided with a "3-hour workshop". Aimed to get teachers on board, motivate them with initiate peer group support among trained teachers, and empower them with the knowledge and skills to deliver the SHARP. • Arranged with ongoing support plus online communication to provide instant feedback if required. • Group planning sessions (30 minutes).
Provision of materials and equipment	• Pedagogical guidelines for teachers to consider during the planning and delivery stage of their PE lessons • Provide the SHARP Principles instruction and resources cards		• Pedagogical dialogue on what and how to modify the SHARP Principles Model according to the curriculum and environment of Scotland. • Provide the SHARP Principles instruction and resources cards and an overview video resource & SHARP PE lessons – for example, video resource. • Online communication to provide instant feedback if required.
Teaching content	• A minimum of two different activity areas of the primary PE National Curriculum (e.g., dance, gymnastics, games, athletics, and adventure activities), joint planning • Content aligned with the National Curriculum for England.		• Co-production approach to the translation of SHARP to Scotland (input of PE coordinator and relevant class teachers will be needed via online if necessary) has already taken place. • Minimal modifications made to original SHARP intervention content and training materials as it was felt that SHARP Principles can be applied to existing PE lessons. Teachers will be using their normal PE curriculum but delivering the lesson in a SHARP (more active) way. • Contents align with the Curriculum for Excellence in Scotland as based on existing PE classes.
Nature of intervention	• A quasi-experimental, non-equivalent group design intervention		• A feasibility study
Theoretical constructs of the SHARP Principles model are not affected by curriculum activity type or teaching style.	• Self Determination Theory • Behaviour Change Taxonomy • Social-Ecological Components • (Specifically directed at teachers)		• Self Determination Theory – (Teachers' competence relatedness and autonomy) • Behaviour Change Taxonomy • Social-Ecological Components (Teachers' individual level, interpersonal level, organisational level)
Measurement tools	• SOFIT, (pre-and post-direct observation, training provided to observers) • Semi-structured teachers interview during the post-intervention		• Accelerometer/activity monitor used during PE lessons and whole school day • Quantitative evaluation of SHARP PE lesson delivery • Semi-structured teachers/pupils focus groups
Others			• Pre-school visit/observation. • Talk to school health staff, if appropriate. • City Council meeting.

Data management
Paper-format documents (e.g., field notes) will be kept locked in filing cabinets. All electronic data will be stored in the University of Strathclyde's centralised secure data storage system. Only the immediate research team will have access to raw data and will be kept for five years before being destroyed. Participants' information will also be given codes and will not be referred to by name in published documents. Only the researchers will have access to the codes and their relating participant names. Consent forms will be stored separately from participant data. Teachers' and pupils' questionnaires will be kept by the researchers after completion. After the transcription, data from interviews will be deleted immediately from voice recorders, with pseudonyms used in all reports in place of participants' names. All data collection and storage procedures will be general data protection regulation compliant.

Safety procedures
Every primary school has its health and safety policies, which the SHARP Scotland feasibility study will not breach. In the event of an accident occurring as a direct consequence of participation in the study (no high-risk activities were identified by risk assessment during ethics application) primary school teachers will report this to the research team and appropriate measures will be taken according to existing policies. The researchers will adhere to any Covid-19 safety requirements in place at the time of the study.

Data analysis
A descriptive analysis will summarise the findings of the feasibility and acceptability parameters of interest such as the proportion of children measured at baseline and follow-up to calculate recruitment and attrition rates. Accelerometer data (primary outcome MVPA during PE lessons) will be used to estimate differences in the MVPA content of school PE between intervention and control groups and it is useful for planning future trials. Qualitative interviews/focus groups will be audio-recorded, transcribed verbatim, and thematically analysed. Due to the small sample size, anticipate these analyses will be exploratory and will be used to inform a future trial rather than to draw definitive conclusions regarding the effectiveness of the intervention.

Study status
Teacher training in the intervention is currently scheduled for summer 2022 (at the end of the 2021-2022 school year in Scotland) and the feasibility study itself is intended to begin later in 2022, ideally towards the start of the school year in 2022-2023 (August-October, 2022), but with the precise timing depending on how the COVID-19 pandemic is affecting schools in Scotland at the time.

Discussion
While concerns about insufficient MVPA in childhood have focused on the impact on their physical and mental health, low MVPA also impairs cognitive function and academic attainment in children.[1,35] Only a small proportion of Scottish children are achieving the recommended minimum of 60 minutes of MVPA daily[36,37] and so a simple school-based intervention could provide an effective measure in childhood for increasing MVPA. Therefore, it is hoped that the outcome of this study will be a demonstration that applying the SHARP Principles intervention is feasible in Scottish schools. An intervention that is translated so that it fits the Scottish context well could produce much more active PE lessons and consequently help large numbers of children achieve the MVPA recommendations.

This paper describes the protocol for the SHARP Scotland intervention feasibility study. As noted above, the original SHARP Principles intervention studies[21,26] were successful in improving MVPA significantly in school PE lessons in the Midlands of England. Adapting successful interventions for use in other settings should be more efficient than developing entirely new interventions. Using existing interventions means that intervention evaluation does not need to start at the beginning of the process described by the UK MRC.[33] To translate an existing intervention from one setting to the other, context-specific modifications might need to be made to ensure the intervention can function as intended while still meeting its desired aims. The study outlined in this protocol aims to test whether the SHARP Scotland intervention is both feasible and acceptable in the Scottish primary schools while it follows along with the intervention development and evaluation pathway described by the UK MRC Framework.[33]

Strengths and limitations of this study
There are some strengths to this study. First, it is a translation of a previously successful intervention (SHARP Principles Model) to be used in another setting (SHARP Scotland) and the feasibility testing is a low-cost, culturally relevant school-based intervention with great public health potential.[21,26] Furthermore, both quantitative (accelerometry data; process evaluation logs; recruitment data) and qualitative (interviews/focus groups) approaches are utilised to test feasibility in the present study, so the data are complementary and can be triangulated. Lastly, information on the feasibility of the SHARP intervention and SHARP evaluation in Scotland will be useful to provide insight for a fully powered effectiveness trial in the future.

However, there are also limitations to the study. Firstly, in this study, we are only dealing with one part of the school day, PE lessons. However, PE lessons are an important part of school day MVPA since they can both increase MVPA directly (MVPA during PE time, 2 lessons per week in Scotland), and indirectly (e.g., by enhancing motor competence, physical fitness, and/or physical literacy). The MVPA accumulated in the whole school day is crucial, but it is the result of a complex system made up of many other elements e.g., influences on what children do during recess, lunchtime, and whether they have active breaks at other times. A whole school day MVPA intervention will probably be required to achieve desired population levels of MVPA but is beyond the scope of the present study. This study will be focused on one element of the whole-school complex system, but future studies will have to build on it and address the other parts of the school system. The present study is restricted to the issue of enhancing existing PE lessons through teaching strategies designed to increase physical activity above routine practice.[38] Secondly, as a small-scale pilot and feasibility study, the generalisability of this study may be limited due to its short duration and small sample size. However, the feasibility study is required to develop and evaluate the intervention on a larger scale in the future - it is a foundation for future evaluation research. Thirdly, since the feasibility study may be carried out during the COVID-19 pandemic in 2022, an unstable education environment might cause research delays and modifications may be required to the proposed intervention or feasibility evaluation.

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Appendix IV: Published format of Study 3

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Original research

Moderate-to-vigorous intensity physical activity during school hours in a representative sample of 10–11-year-olds in Scotland☆

Lan Sum Wong [a,*], John J. Reilly [a], Paul McCrorie [b], Deirdre M. Harrington [a]

[a] Physical Activity for Health Group, School of Psychological Sciences and Health, University of Strathclyde, UK
[b] MRC/CSO Social and Public Health Sciences Unit, University of Glasgow, Glasgow, UK

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ABSTRACT

Objectives: Growing concern about children and adolescent physical inactivity has made the promotion of physical activity a public health priority. International recommendations suggest children should accumulate at least 30 min of moderate-to-vigorous physical activity (MVPA) during school hours. This study assessed levels of objectively-measured MVPA in a large nationally representative sample of Scottish children aged 10–11. Risk factors for not meeting the school-hours MVPA recommendation were examined.
Design: Cross-sectional.
Methods: Mean time spent in MVPA during school hours across five weekdays was measured using Actigraph accelerometry (May 2015–May 2016). Binary logistic regression, presented as odds ratio (O.R.) and confidence intervals (C.I.), explored associations between meeting/not meeting the recommendation by sex, socioeconomic status (SES), season, and urban/rural residence in 2022.
Results: Valid data were obtained from 773 children (53.9% girls, 46.1% boys) from 471 schools. Mean daily school-hours MVPA was 29 (SD 11) minutes; 42.7% of children reached the recommendation. The odds of girls (O.R. 0.43; C.I. 0.32, 0.57) meeting the recommendation was significantly lower ($p < 0.001$) compared to boys. Children living in rural areas had higher odds (O.R. 1.49; C.I. 1.04, 2.15) of meeting the recommendation compared with those in urban areas ($p = 0.032$). No significant differences in meeting the recommendation by SES ($p = 0.700$). The overall trend for season was significant ($p < 0.001$), with lower odds of meeting the recommendation in winter compared to summer.
Conclusions: Most Scottish children aged 10–11 did not meet the 30 minute MVPA recommendation. Interventions to increase MVPA during school hours are essential to promote public health.

Practical Implications

Schools could promote optimal MVPA for students as suggested below:

- A careful examination of the school's role in contributing to their student's daily MVPA.
- A whole-school approach to promoting health-enhancing MVPA, via a combination of PE lessons, active breaks, and recess.
- More active PE and recess, active classroom breaks, greater use of outdoor space, and use of covered playgrounds or school halls in cold and wet seasons.
- MVPA opportunities tailored to the preferences of both boys and girls are needed.

1. Introduction

Physical activity is important for children as it improves both short-term and long-term health and wellbeing.[1] Specifically, World Health Organisation (WHO) guidelines state that achieving an average of 60 min per day of moderate-to-vigorous intensity physical activity (MVPA) provides children and adolescents with a wide variety of health benefits.[2] Most children and adolescents globally have low levels of MVPA and do not meet the previous WHO recommendations (i.e., achieving at least 60 min MVPA daily).[3] Children spend a large part of their day at school, and the school setting is a significant contributor to MVPA.[4] MVPA recommendations during school hours from the American Heart Association[5] and the UK Government[6] state that children should achieve at least 30 min of MVPA during school hours.

Abbreviations: WHO:, World Health Organisation; MVPA:, Moderate to vigorous intensity physical activity; SPACES:, Studying physical activity in children's environments across Scotland; SIMD:, Scottish index of multiple deprivation; SES:, Socioeconomic status; PE:, Physical education.

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* Corresponding author.
E-mail address: lan.wong@strath.ac.uk (L.S. Wong).

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A recent systematic review[7] on physical activity (PA) levels during school hours found only three studies[8–10] that analysed the extent of achieving the school-based MVPA recommendation of 30 min using the most valid method of measuring MVPA objectively accelerometry. These studies, which included PA opportunities during different time periods at school, involved small samples[8,9] and only one sample was representative.[10] Van Stralen et al.'s[8] and Hubbard et al.'s[9] study showed that only 7%–8% of European and American elementary school students (aged 7–12) met the recommendation for 30 min of school-hours MVPA, while Grao-Cruces et al.'s study[10] indicated that in Spanish 8-year-old children, 24% of boys and 8% of girls met the recommendation. If low MVPA during school hours is widespread, then school-based strategies to further increase physical activity will need to be implemented.[11]

Development of strategies to increase school-hours MVPA will be informed by understanding risk factors for low MVPA while at school. Only two studies[8,9] have considered the risk factors associated with not meeting the 30 min daily school-hours MVPA recommendation. These two studies found very limited information, for example, it is not clear whether season and urban or rural residency are risk factors for achieving the recommendation. In summary, there is a dearth of evidence from representative samples using objective measures of MVPA, and limited evidence on risk factors for insufficient school-hours MVPA in primary schoolchildren. We, therefore, aimed, in a large nationally representative sample of Scottish children aged 10–11 years, to (a) assess the prevalence of meeting the school-hours MVPA recommendation, and (b) identify risk factors for not achieving the recommendation.

2. Methods

This present study used the data from the "Studying Physical Activity in Children's Environments across Scotland" (SPACES) study (see http://spaces.sphsu.mrc.ac.uk/home) which was carried out during school terms between May 2015–May 2016.[12] SPACES participants were recruited from the Growing up in Scotland (GUS) study, a nationally representative longitudinal cohort study originating in 2005 (https://growingupinscotland.org.uk/). Of a possible 2404 children (aged 10/11 years old) who had participated in the GUS interview conducted between September 2014 to February 2015, 2162 parents consented to be contacted by the SPACES staff. They were sent SPACES study information, registration documents, and consent forms by post. There were 1096 children who took part and both child and parent were required to sign consent forms. Data were received for this present analysis in 2022. Variables such as sex, socioeconomic status (SES), season, and urban or rural residence were obtained as part of the GUS Study, and weightings were included. These variables were also used as the potential risk factors in the present study.

An accelerometer[13,14] (ActiGraph GT3X+) was used to measure school-hours MVPA. Non-wear time periods (60 consecutive minutes of zero acceleration were recorded by the device) were removed from analyses. Accelerometry values ≥2296 per minute (cpm - count per minute) defined children's MVPA as this is commonly used to estimate MVPA, supported in the calibration study of Evenson et al. (2008).[15] We used minimum wear criteria of ≥ three days lasting ≥4 h/during school hours/day (4 h is two-thirds of a 6-hour school day or contains at least 70% of a full school daytime).[16]

School hours are not the same across Scotland, for the present study, school start and end times (range 9.00 am – 3.00 pm/8.45 am – 3.15 pm) were identified by using the primary schools' online handbooks for 2015–2016 school year found on the school's or the local authority website. School hours for each child were then identified and extracted manually from the individual accelerometry data by referring to the times from the schools' handbook. The total time spent in MVPA of children was measured, and their MVPA data were extracted for school hours only.

Other than the sex/gender, potential risk factors also included SES, season, and urban or rural setting. Students' SES was defined using the Scottish Index of Multiple Deprivation (SIMD),[17] a composite area-based measure (not based on the individual child/family) of relative social, economic, environmental, and health circumstances which are used and accepted widely in health inequality research and policy in Scotland. SIMD rank scores were grouped into 5 quintiles where 1 represented the most deprived area and 5 represented the least deprived area.[12]

Season of data collection - a four-level categorical variable (spring, summer, autumn, and winter) was used to classify the season of measurement and indicated the data collection period when each participant wore the activity monitors.[18] Regarding the urban or rural setting, children were classified according to their residency in urban or rural areas, with a standard classification method used in Scotland.[12] Population size between 3000 to ≥125,000 was classified as urban and if <3000 was classified as rural.[12]

For statistical analysis, as SPACES data were collected to be nationally representative, a weighting variable was applied ahead of the analysis. Data were weighted to compensate for potential bias to ensure the sample matched the population, and then to provide a representative sample.[12,19] - to correct the over-representation of children with higher SES in the sample. Continuous variables were presented as means and standard deviations (SD) and categorical variables are presented as numbers and percentages of the overall sample and for boys/girls separately. Binary logistic regression was used to estimate the odds (odds ratio: O.R.) of meeting the 30-minute MVPA recommendation (the dependent variable). All other variables were analysed and included in the logistic models. Models were run separately for each explanatory variable so the associations of each risk factor could be ascertained separately to check if it would be an actual risk factor for not meeting the school hours MVPA recommendation or not. P values for the overall trend and confidence intervals (C.I.) for each category of explanatory variables are presented (Table 3 in the results). Reference categories for each explanatory variable are also identified. Data were analysed with SPSS Statistics (IBM Corp, Chicago, IL; version 26). The level of significance was set at $p < 0.05$.

3. Results

Out of 1096 participants, 774 (417 girls and 357 boys aged 10 to 11 years old) provided the required accelerometry data to be included in the final SPACES study dataset.[12] For the present analysis, one participant had only 1 day of wear time data, so this participant was excluded from the data set (the total number of students was reduced to 773 from 774 included in the original SPACES study of overall MVPA). A total of 97 non-valid days (2.5% of total days measured from 89 participants) were identified and removed. So, there were 3768 valid days of accelerometry data during school days included in the present analysis (mean valid school days 4.9 per child for the 773 children).

Table 1 presents the demographic data and exploratory variable data from 773 children (mean age 11.1 years, 53.9% girl, and 46.1% boy) from 471 schools. There were 306 schools that provided one participant each; 94 schools had 2 participants and 71 schools had ≥3 participants.

The percentage (n) of children who met the 30-minute school-hours MVPA/day recommendation was 42.7% (n = 329/770 bases weighted; Table 2). Mean time spent in MVPA was 29 min (SD 11) for the overall sample; with 26 min (SD 10) accumulated for girls and 32 min (SD 11) for boys. Fig. 1 shows a more concrete picture of the distribution between girls and boys in MVPA in schools. A higher percentage of girls achieved between 10 and 30 min MVPA, while a higher percentage of boys accrued more than 30 min of MVPA during school hours.

Regarding factors associated with meeting/not meeting the 30 min MVPA per school hours recommendation, Tables 2 and 3 present the numbers and percentages of meeting the 30-min goal and the results of the logistic regression for each risk factor, respectively. The odds of girls (O.R. 0.43; C.I. 0.32, 0.57) meeting the recommendation was significantly lower ($p < 0.001$) compared to boys. Despite a higher number of children from the upper quintiles, there were no significant differences

Table 1
Participant characteristics (n(%) unweighted) split by sex and for the overall sample.

	Girls (n = 417)	Boys (n = 356)	All (n = 773)
Sex			
Girls	–		417 (53.9%)
Boys	–	–	356 (46.1%)
SES – using SIMD quintile			
1 (most deprived)	35 (8.4)	29 (8.1)	64 (8.3)
2	55 (13.2)	43 (12.1)	98 (12.7)
3	96 (23.0)	73 (20.5)	169 (21.9)
4	110 (26.4)	97 (27.2)	207 (26.8)
5 (least deprived)	121 (29)	114 (32)	235 (30.4)
Season of data collection[a]			
Winter	89 (21.3)	74 (20.8)	163 (21.1)
Spring	46 (11)	47 (13.2)	93 (12)
Summer	74 (17.7)	61 (17.1)	135 (17.5)
Autumn	207 (49.6)	175 (49.2)	382 (49.4)
Urbanicity			
Urban	313 (75.1)	254 (71.3)	567 (73.4)
Rural	104 (24.9)	102 (28.7)	206 (26.6)
MVPA minutes in school-time[b]	26 (SD 10)	32 (SD 11)	29 (SD 11)

Note: categorical variables are presented as numbers with percentages in parenthesis. The continuous variable of MVPA is presented as mean with standard deviation in parenthesis. SIMD: Scottish Index of Multiple Deprivation; SD: standard deviation.
[a] Winter is from late Dec to mid-March, Spring is from mid-March to mid-June, Summer is from mid-June to late Sept, and Autumn is from late Sept to late Dec.
[b] For MVPA the total sample (weighted) is 770 (415 girls and 355 boys).

in meeting the recommendation by SES as there were no statistically significant differences between quintiles of SIMD when C.I. were compared or the overall ($p = 0.700$) analysis by SIMD quintiles. The overall trend for seasonal influence was significant ($p < 0.001$). Those with spring (O.R. 1.54; C.I. 0.93, 2.56), and summer data collection showed higher odds (O.R. 1.98; C.I. 1.26, 3.11) and autumn data collection showed lower odds (O.R. 0.71; C.I. 0.49, 1.03) of meeting the recommendation compared to the winter reference group. There were significantly ($p = 0.032$) higher odds (O.R. 1.49, C.I. 1.04, 2.15) of children who lived in rural areas meeting the recommendation compared with those living in urban areas.

For the contribution of school hours MVPA to overall daily MVPA, we compared the 29 min of school hours' MVPA with an average of 76 min per weekday (school-hour and non-school-hour) in the previous study in the same sample,[12] and found that around 38% of students' total daily MVPA on weekdays (school days) occurred during school hours.

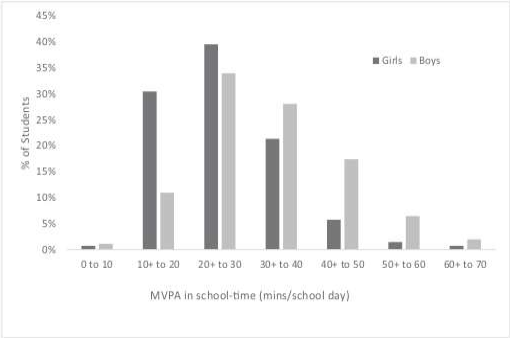

Fig. 1. The percentage of children (with boys and girls separately) accumulating MVPA in school-time per 10-minute increment.

4. Discussion

The main findings showed that only 42.7% of children accumulated ≥30 min/day of MVPA during school hours in this large sample, representative of 10- to 11-year-olds in Scotland. Gender, season, and urban/rural status were all associated with the probability of meeting the recommendation to accumulate at least 30 min MVPA per day during school hours. School hours provided an average of 29 min of MVPA per day in the present study.

While previous nationally representative studies of accelerometer measured school-hours MVPA in primary school-age children have been limited, the present study was consistent with previous findings in Europe[8,10] and the USA[9] that girls were less active and more sedentary during school hours than boys. Rooney et al.[20] found that boys (8–11-year-olds) physical education lessons and recess (break and lunch time) provided important occasions for children to be engaged in PA. Bailey et al.[21] suggested that boys' physical activity may typically be greater during PE. Some similar studies[7,22] suggested that girls are typically less active than boys due to socio-ecological factors at the individual, family, school, and environmental levels. This is possibly due to the persistence of sex/gender stereotypes.[7] Consequently, opportunities

Table 2
Weighed number (n) and percentages (% in parenthesis) meeting the school-based MVPA guidelines for each risk factor.

30 min MVPA/day during school hours	No	Yes	Total bases weighted	Total unweighted
Sex				
Girls	277 (66.7%)	138 (33.3%)	415	417
Boys	164 (46.2%)	191 (53.8%)	355	356
Total	441 (57.3%)	329 (42.7%)	770	773
SES – using SIMD quintile				
1 (most deprived)	96 (58.5%)	68 (41.5%)	164	64
2	77 (56.6%)	59 (43.4%)	136	98
3	80 (55.9%)	63 (44.1%)	143	169
4	88 (53%)	78 (47%)	166	207
5 (least deprived)	99 (61.5%)	62 (38.5%)	161	235
Total	440	330	770	773
Season				
Winter	100 (58.1%)	72 (41.9%)	172	163
Spring	45 (47.9%)	49 (52.1%)	94	93
Summer	58 (40.6%)	85 (59.4%)	143	135
Autumn	237 (65.7%)	124 (34.3%)	361	382
Total	440	330	770	773
Urbanicity				
Urban	367 (59.6%)	249 (40.4%)	616	567
Rural	74 (48.1%)	80 (51.9%)	154	206
Total	441	329	770	773

Note: total weighted number of participants used in the calculation of proportions is represented by total bases weighted. The total number of participants measured is represented by total unweighted.

Table 3
Odds ratios (OR) (95% C.I.) for meeting 30-min recommendation of MVPA during school hours.

	Meeting 30 min MVPA during school hours
Sex	
Boys	1.00 reference
Girls	0.43 (0.32, 0.57)
P value	<0.001
SES – using SIMD quintile	
5 (least deprived)	1.00
4	1.40 (0.89, 2.15)
3	1.24 (0.78, 1.97)
2	1.25 (0.79, 2.00)
1 (most deprived)	1.25 (0.79, 1.96)
P value	0.700
Season of data collection	
Winter	1.00
Spring	1.54 (0.93, 2.56)
Summer	1.98 (1.26, 3.11)
Autumn	0.71 (0.49, 1.03)
P value	<0.001
Urbanicity	
Urban	1.00
Rural	1.49 (1.04, 2.15)
P value	0.032

Note: all models control for school number; bolded category is significant at p = 0.003.

for physical activities offered by schools and communities may typically be more attractive to boys than girls.[22]

We found that SES was not a significant predictor of meeting the school-hours MVPA recommendation, consistent with Hubbard et al.'s study.[9] In Scotland, the school environment and physical activity provision should vary little by SES. Almost all Scottish children and adolescents attend the public school system, and schools follow the same national curriculum[23] with similar levels of funding (in fact additional funding per student for schools in lower SES areas). Consequently, schools may have similar opportunities and capacity to engage all children in MVPA broadly equally during school hours.

The reasons for rural settings being associated with higher school-hours MVPA than urban schools are unclear, but rural schools may have more space for outdoor physical activity than urban schools.[18] The seasonal difference in school-hours MVPA in the present study may be explained by the fact that in Scotland primary schools tend to keep children inside during recess and lunchtimes when it is windy or rains heavily which happens less often during summer. Ridgers et al.[24] and Harrison et al.[25] found that temperature[24] and rainfall[25] are negatively associated with PA.

The present study provides support for the concept that schools need to develop a whole-school approach to promoting health-enhancing MVPA, via a combination of PE lessons, recess,[20] more active classroom breaks,[26] and greater use of outdoor space[27] with covered playgrounds in cold and wet seasons. As suggested by Harrison et al.[25] a focus on encouraging indoor physical activities in wet weather may help children remain active during school hours.[25] While Zahi-Thanem et al.[28] indicated that increased outdoor time increases MVPA and Telford et al.[22] recommended that opportunities for MVPA should be tailored to the preferences of boys and girls.

The MVPA accrued during school hours in the present study, while lower than recommendations, was higher than from other European countries.[8,10] The differences may be partially explained by using different accelerometry cut points to classify physical activity intensities, as well as due to the differences in the educational system and weather conditions. The 2296 count per minute Actigraph cut-off used to define MVPA provides a conservative threshold for estimating time spent in MVPA - if the appropriate cut-point to classify MVPA in children is higher than this, then the prevalence of meeting the 30-minute recommendation will be even lower than observed in the present study.[29]

The present study had some strengths. First, the dataset used was from a large representative sample of children across Scotland - few other international studies of school hours MVPA have been based on large nationally representative samples.[7] Second, MVPA was measured objectively by using accelerometers - accelerometry is a valid method for measuring actual levels (intensity) of physical activity.[13] Third, few previous studies addressed factors influencing MVPA accumulated during school hours.[7]

There were also a few limitations in this study. A total of ninety-seven non-valid days across the entire study were identified because eighty-nine participants provided invalid accelerometer data on some days. However, compared with a total of 3768 valid days of data, the percentage (2.5% of non-valid days) was small and should not make much difference to the estimates of time spent in MVPA in the sample. Second, we were limited to a small number of individual and family-based potential risk factors for not meeting the school-hours MVPA recommendation (sex, SES, season, and urban or rural residence) available in the original SPACES dataset.[12] Other potential risk factors for insufficient MVPA (such as the number and arrangement of break times, and the amount of MVPA provided during school PE lessons) were not collected in SPACES study. Third, the participants were restricted to children aged 10–11, the findings may not be generalisable to younger children or older youths. Fourth, the present study examined school-hours MVPA and not where that came from, for example, recess, PE lessons, or class time.

5. Conclusions

This present study demonstrated that a relatively high proportion (around 57%) of children (regardless of sex, SES, season, or urban/rural setting) did not meet the 30-minute MVPA recommendation during school hours. School is a valuable setting to prevent chronic disease as it creates a unique opportunity to reach children across the population, and during a critical period in establishing health behaviours.[30] A careful examination of the school's role in contributing to their student's daily MVPA is essential. Further studies on how to promote physical activity within school hours and settings with a whole school approach are recommended.

CRediT authorship contribution statement

Lan S Wong: Data management and analysis; Data interpretation; Conceptualization; Writing – original draft; Writing – review & editing. John J. Reilly: Provided scholastic views; Data interpretation; Writing – review & editing. Paul McCrorie: Data management and analysis; Writing – review & editing. Deirdre M. Harrington: Data analysis & interpretation; Writing – review & editing. All authors provided important intellectual content and approved the final version of the manuscript.

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Confirmation of Ethical Compliance

Ethical approval was provided by the College of Social Sciences, University of Glasgow, and all participants and/or their legal guardians consented to be contacted and sent data back to SPHSU for processing to complete the SPACES study. Prior to sharing data, agreements were

established between the authors of the present study and the MRC/CSO Social and Public Health Sciences Unit, University of Glasgow, Scotland.

Declaration of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix V: Published format of Study 4

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Human Kinetics
ORIGINAL RESEARCH

Physical Activity Levels During School Recess in a Nationally Representative Sample of 10- to 11-Year-Olds

Lan Sum Wong,[1] John J. Reilly,[1] Paul McCrorie,[2] and Deirdre M. Harrington[1]
[1]Physical Activity for Health Group, School of Psychological Sciences and Health, University of Strathclyde, Glasgow, United Kingdom;
[2]MRC/CSO Social and Public Health Sciences Unit, University of Glasgow, Glasgow, United Kingdom

Purpose: School recess provides a valuable opportunity for children's daily moderate- to vigorous-intensity physical activity (MVPA). This study aimed to quantify MVPA during school recess in a representative sample of Scottish children and examine whether recess MVPA varied by gender, socioeconomic status, season, urban/rural residency, and recess length. ***Method:*** Five-day accelerometry MVPA data were analyzed from 773 children (53.9% girls, 46.1% boys, 10- to 11-y-olds) from 471 schools. Binary logistic regression explored associations between meeting/not meeting the recommendation to spend 40% of recess time in MVPA and the aforementioned risk factors. Descriptive recess data were also analyzed. ***Results:*** Participants spent an average of 3.2 minutes (SD 2.1) in MVPA during recess. Girls engaged in 2.5 minutes (SD 1.7) of MVPA compared with 4.0 minutes (SD 2.2) for boys. Only 6% of children met the recess MVPA recommendation. The odds of girls (odds ratio 0.09; 95% confidence interval, 0.04–0.25) meeting the recommendation was lower ($P < .001$) compared with boys. No statistically significant differences were observed in meeting the recommendation for the other risk factors. ***Conclusion:*** Levels of MVPA during school recess are very low in Scottish children, and interventions aimed at increasing MVPA during recess are needed.

Keywords: moderate- to vigorous-intensity physical activity, health, accelerometer, primary school children

Childhood physical activity (PA) is associated with positive physical, developmental, and psychological health (12,14) and helps prevent noncommunicable diseases (50), which means a lower risk of cardiovascular disease, hypertension, diabetes, and many cancers later in life. Low PA in children is one of the most important public health issues in the 21st century (23). The World Health Organization has recommended that school-age children engage in moderate to vigorous PA (MVPA) for an average of at least 60 minutes per day (51). However, many children globally do not meet the recommendation (13,50). School is a key environment where children accumulate MVPA (41) on around half of all days (allowing for weekends and school holidays). There are recommendations in the United States (25) and in the United Kingdom (6) that children and adolescents should achieve 30 minutes of MVPA daily during school hours. Weaver et al (48) found that most children (in grades 1–3) were not accumulating 30 minutes per day of MVPA during school hours. Grao-Cruces et al's (11) systematic review showed that less than a quarter of children reached the 30-minute MVPA recommendation during school hours.

Reilly https://orcid.org/0000-0001-6165-5471
McCrorie https://orcid.org/0000-0003-4850-0568
Harrington https://orcid.org/0000-0003-0278-6812
Wong (lan.wong@strath.ac.uk) is corresponding author, https://orcid.org/0000-0001-5083-6381

The PA Guidelines for Americans (7) suggest that, as part of the school strategy to increase MVPA, school-day segments (such as physical education and recess) are opportunities for providing MVPA (7). School recess is an essential school experience that has developmental (27) and behavioral (3) benefits. Recess also serves as a necessary break from the rigors of academic challenges (29). This is particularly important now as Kharel et al's (15) systematic review has shown that since the start of the COVID-19 pandemic, children and adolescents typically spend less time in MVPA and more time on screens (15). It is crucial to examine how active children are during recess and what factors are associated with MVPA at recess so that interventions aimed at improving recess MVPA can be optimized. In 2005, Ridgers and Stratton (35) suggested that children should engage in MVPA for at least 40% of recess time. This benchmark has been accepted by many researchers since (30). Despite this specific MVPA recommendation, few studies have examined children's compliance with MVPA during recess. The Sánchez and Gallego (41) systematic review found only 2 studies (1,22) of children's compliance with the recess MVPA recommendation. Furthermore, the sample sizes of these 2 studies were small (n = 135 and n = 379), and there was a lack of studies using accelerometers in large, nationally representative samples. In addition, a number of factors (such as gender, climate, and recess length) that may affect children's recess MVPA have been reported (32,36,43). To date, no large-scale, nationally representative accelerometry studies have explored the possible influence of these factors on children's activity levels. Therefore, this study aimed to (1) examine how much MVPA is accumulated during recess and the percentage of recess time spent in MVPA and (2) explore the risk factors for low recess MVPA, including gender, socioeconomic status (SES), season, urban/rural residency, and recess length, on recess MVPA in a representative sample of 10- to 11-year-olds in Scotland.

Methods

Participants and Study Design

The present study used data from the SPACES (Studying PA in Children's Environments across Scotland) study (19) conducted during the school year between May 2015 and May 2016. Both children (n = 1096) and their parents were required to sign consent forms before participating. (More details of the SPACES study can be found in Supplementary Material [available online].)

Instruments

Measurements of MVPA During Recess

ActiGraph GT3X+ (Actigraph Inc). In the SPACES study (19), accelerometry data were collected using the ActiGraph GT3X+ (Actigraph Inc) worn on a belt around the waist. Children were asked to wear the device for 8 consecutive days (with a minimum of 10 h on a weekday/school day) during waking hours (19,38).

ActiLife software (version 6, Actigraph Inc). In the present study, accelerometry data were considered valid with a minimum of 4 hours per day over 3 school days (31). To ensure that the sample was broadly representative of the Scottish population, the sample was weighted to compensate for potential bias (5,19). Nonwear time periods (if 60 consecutive min of strings of 0 counts acceleration were recorded by the device) were removed from further analyses. ActiLife software (version 6, Actigraph Inc) was used to download, clean, and analyze data. Once downloaded, data files (.agd) were reintegrated from the original 10-second epoch to a 60-second epoch to establish the pupil's recess time. To define children's MVPA, the commonly used cut points (values ≥2296 counts/min) from Evenson et al (9) were used to define MVPA levels from the accelerometer count data.

Procedures

Definition and Identification (Extraction) of Recess Time

Recess time was defined as the timetabled 15- or 20-minute (typically between 10 and 11 AM) morning break that primary school children have during school days in Scotland. Time spent in MVPA was extracted for this morning recess only from each day of data. Each child's morning recess time was identified by using the primary schools' online handbooks for the 2015–2016 school year and extracted manually from the individual accelerometry data by matching the child to their school's recess time. Accelerometry counts from each day of each pupil were visually checked to verify that the counts increased at the expected start of the recess interval and whether the counts decreased at the expected end of recess for each day. MVPA values are reported as the percentage of the length of recess time (ie, time available) to control for varying durations of school and recess (using mean minutes and percentage per day in the statistical analysis).

Definition of the Explanatory Variables

The widely used Scottish Index of Multiple Deprivation (SIMD) (42), a composite area-based measure (not based on the individual child/family) of relative social, economic, environmental, and health circumstances, was used to define children's SES. SIMD rank scores were grouped into 5 quintiles where 1 represented the most deprived area and 5 represented the least deprived area (19). Season of data collection when each participant wore the accelerometer was a 4-level categorical variable (spring, summer, autumn, and winter) (20). Children's urban or rural residency was defined using their home address combined with a standard classification method used in Scotland that recognizes settlement size (population between 3000 and ≥125,000 was urban and <3000 was rural) (19).

Data Analysis

Continuous variables were presented as means and standard deviations (SD), and categorical variables were presented as numbers and percentages of the overall sample and for boys/girls separately. Binary logistic regression analyses were used to examine the association between the risk factors (independent explanatory variables) and meeting the 40% recess time MVPA (the dependent variable—based on the benchmark suggested by Ridgers and Stratton [35]). Models were run for each explanatory variable (with reference categories identified) separately. We did not produce a combined model with all risk factors included simultaneously because we found that only one of the factors was associated with meeting the recess MVPA guideline in initial analyses. *P* values for the overall trend, odds ratio, and confidence intervals (CIs) for each category of explanatory variables are presented. All models controlled for the number of schools involved. Significance was set at $P < .05$. Data were analyzed with SPSS Statistics (version 26) in July 2022.

Results

Characteristics of Participants

Of 2162 parents who had consented to be contacted for SPACES, 1096 (50.7%) children took part in data collection. Of those, 859 (78.4% of those who participated) children provided data, but only 774 (70.6% of those who participated; 417 girls and 357 boys aged 10–11 y) provided sufficient (defined as at least 4 weekdays and 1 weekend day) data for inclusion in the SPACES data set (19). One participant did not meet the minimum inclusion criterion enabled for the present analysis (3 school days with at least 4 h/d) and was removed from the present study data set. A small number of nonvalid recess periods (132 periods, representing 3.5% of the total recess periods) were removed because only 0 counts could be found during recess time in a valid school day. The final analytical sample comprised 773 children across a mean of 4.8 days of data per participant. Valid data from 3733 recess periods were included in the analyses. Table 1 presents the descriptive characteristics (mean [SD]) of the sample. Overall, 773 children (mean age 11.1 y, 53.9% girls, and 46.1% boys) attending 471 schools participated, with 306 schools having one participant each, 94 schools having 2, and 71 schools having ≥3 participants. Mean daily recess length was 16.1 minutes (SD 2.2).

Prevalence of Meeting 40% of Recess Time in MVPA Recommendation

Only 6% (1% of girls and 11% of boys) of children spent at least 40% of their recess time in MVPA. Table 1 shows that mean MVPA during recess was 3.2 minutes (SD 2.1), equating to 20% of recess time, on average, for the entire sample (mean minutes of recess MVPA [3.2 min] divided by mean recess time [16.1 min] × 100). Girls engaged in 2.5 minutes (SD 1.7) compared with 4.0 minutes (SD 2.2) for boys. This equated to 16% and 25% of recess time in MVPA for girls and boys, respectively.

Table 1 Participant Characteristics (n [%] Unweighted) Split by Gender and for the Overall Sample

	Girls (n = 417)	Boys (n = 356)	All (N = 773)
Gender			
Girls	—	—	417 (53.9%)
Boys	—	—	356 (46.1%)
SES—Using SIMD quintile			
1, most deprived	35 (8.4)	29 (8.1)	64 (8.3)
2	55 (13.2)	43 (12.1)	98 (12.7)
3	96 (23.0)	73 (20.5)	169 (21.9)
4	110 (26.4)	97 (27.2)	207 (26.8)
5, least deprived	121 (29)	114 (32)	235 (30.4)
Season of data collection[a]			
Winter	89 (21.3)	74 (20.8)	163 (21.1)
Spring	46 (11)	47 (13.2)	93 (12)
Summer	74 (17.7)	61 (17.1)	135 (17.5)
Autumn	207 (49.6)	175 (49.2)	382 (49.4)
Urbanicity			
Urban	313 (75.1)	254 (71.3)	567 (73.4)
Rural	104 (24.9)	102 (28.7)	206 (26.6)
MVPA minutes per school recess[b]	2.5 (SD 1.67)	4.0 (SD 2.17)	3.2 (SD 2.05)
Proportion of MVPA during recess, % (recess MVPA/mean recess length in minutes)	15.7% (2.5/16.1 min)	24.8% (4.0/16.1 min)	19.9% (3.2/16.1 min)
Recess time contributed to school hours MVPA,[c] %	8.6% (2.5/29.0 min)	13.8% (4.0/29.0 min)	11% (3.2/29.0 min)

Abbreviations: MVPA, moderate to vigorous physical activity; SIMD, Scottish Index of Multiple Deprivation; SES, socioeconomic status. Note: Categorical variables are presented as numbers with percentages in parenthesis. The continuous variable of MVPA is presented as mean with standard deviation in parenthesis.
[a]Winter is from late December to mid-March, Spring is from mid-March to mid-June, Summer is from mid-June to late September, and Autumn is from late September to late December. [b]For MVPA, the total sample (weighted) is 770 (415 girls and 355 boys). [c]An average of 29 minutes was found during school hours in the previous study (50) in the same sample.

Risk Factors for Not Meeting 40% of Recess Time in MVPA Recommendation

Tables 2 and 3 present the weighted number, percentages/results of the logistic regression, and the odds ratios (95% CI) for meeting the 40% MVPA recommendation during recess. Odds of meeting the recommendation were significantly lower in girls (odds ratio 0.09; 95% CI, 0.04–0.25; $P < .001$) than in boys. SES was not related to meeting the recommendation. There was no statistically significant relationship for the overall SIMD (42) factor ($P = .29$) nor differences between quintiles and the reference category (least deprived) of SIMD with all CIs overlapping 1.0. The overall trend for seasonal influence was also not significant ($P = .25$). No differences in compliance were found between urban or rural residency and when the length of recess time (15 min vs 20 min) was compared (both factors $P = .91$).

Discussion

This study revealed that most children spent very little time (an average of 20% of recess time) in MVPA at morning recess. In Scotland, schools have lunch periods wherein children can/may be active as well. However, lunchtime is an unpredictable combination of time spent queuing for, and eating, lunch and recess time for play, so we only counted the nationally mandated morning recess for practical considerations. None of the risk factors for low recess MVPA (SES, season, urban/rural residency, and recess length), other than gender, influenced the odds of meeting the recommendation.

Our evidence of lower compliance with the recess recommendation in girls than boys was consistent with older accelerometry studies from Bailey et al (1) and Nettlefold et al (22), though we found lower compliance in the present analysis. The former (1) found that 28% of girls and 60% of boys, aged 10–14 years, met the recess MVPA recommendation, and the latter (22) reported that 16% of girls and 34% of boys, aged 8–11 years, were compliant with recess recommendations. Differences in compliance between studies may relate to the time period of measurement, the age range of the samples, or a different length of recess time. Our findings concerning activity levels are similar to those found in the UK-based study by Ridgers and Stratton (35) (4.3% of girls and 14.9% of boys, 5- to 10-y-olds, met the 40% value) and are consistent with other studies (ie, ~20% of recess spent engaged in MVPA) (17,39,44). The reasons for gender differences in recess MVPA may be attributable to the social context (1,41), the structure of the playground environment, and differences in the behaviors that boys and girls typically engage in during recess. Pawlowski et al (25) indicated that girls tend not to be interested in competitive sport-based activities, and they like socializing with friends during recess (25). Saint-Maurice et al (40) reported that boys prefer to engage more in team sports activities, and this may be due to gender stereotype/socialization (10,18). The absence of an association between SES and meeting the recess MVPA recommendation in our results is consistent with Tercedor et al (47). Taylor et al (46) found that school environments provide the opportunity for the influence of SES during school hours to be minimized as all children are exposed to similar environmental context regardless of individual circumstances (46). However, some studies either

Table 2 Weighed Number (n) and Percentages (% in Parenthesis) Meeting the Recess MVPA Recommendation for Each Potential Risk Factor

	No	Yes	Total bases weighted	Total unweighted
Gender				
Girls	410 (98.8%)	5 (1.2%)	415	417
Boys	315 (88.7%)	40 (11.3%)	355	356
Total	725 (94.2%)	45 (5.8%)	770	773
SES—Using SIMD quintile				
1, most deprived	159 (96.4%)	6 (3.6%)	165	64
2	121 (89%)	15 (11%)	136	98
3	136 (95.1%)	7 (4.9%)	143	169
4	155 (93.4%)	11 (6.6%)	166	207
5, least deprived	154 (95.7%)	7 (4.3%)	161	235
Total	725	46	771	773
Season				
Winter	160 (93.6%)	11 (6.4%)	171	163
Spring	86 (91.5%)	8 (8.5%)	94	93
Summer	135 (94.4%)	8 (5.6%)	143	135
Autumn	344 (95%)	18 (5%)	362	382
Total	725	45	770	773
Urbanicity				
Urban	582 (94.5%)	34 (5.5%)	616	567
Rural	143 (92.9%)	11 (7.1%)	154	206
Total	725	45	770	773
Length of recess				
15 min	581 (94.6%)	33 (5.4%)	614	609
20 min	140 (92.1%)	12 (7.9%)	152	161
25 min	1 (100%)	0	1	1
30 min	3 (100%)	0	3	2
Total	725	45	770	773

Abbreviations: MVPA, moderate to vigorous physical activity; SIMD, Scottish Index of Multiple Deprivation; SES, socioeconomic status. Note: Total weighted number of participants used in the calculation of proportions is represented by total bases weighted. The total number of participants measured is represented by total unweighted.

reported that children with higher SES spend more time in MVPA (21) or that children from lower income families in America are least likely to have recess (4). In Scotland, recess is mandatory, and all primary school children receive one 15- or 20-minute morning recess period per day. Moreover, schools have similar capacity (fixed equipment) and funding (in fact additional funding per pupil for schools in lower SES areas) to engage all children in MVPA broadly equally during recess. As no comparable studies currently exist exploring links between urban or rural residency and MVPA during recess, no direct comparisons are possible. As our results showed no significant difference between urban and rural residency influencing the recess MVPA, this might demonstrate the similar school environments across Scotland. Our finding of no seasonal influence on recess MVPA is contrary to some studies that reported that children are more active in spring compared with autumn or winter (40) or in cooler compared with warmer months (34). The seasonal variability between the studies may be due to differences in sample size, the number of recesses included, and geographical locations. There is some evidence that the impact of short-term changes in the weather (eg, rain or temperature during recess) might have more of an impact than seasons (16).

Results from the present study showed no association between the length of the recess and compliance with the recommendation. This result is different from those found by Suga et al (45) and Ridgers et al (37): Their studies reported that a longer duration of recess was associated with increased PA in the playground. Stanley et al indicated that length of recess time was found to positively facilitate interventions in school recess time PA (43). When checking the pupils' individual accelerometer data in the present study, their MVPA typically did not appear until around 5–8 minutes into recess time, suggesting that higher MVPA levels may be more possible in a longer recess length.

Recess is a valuable opportunity for all children to increase their PA (33). Erwin et al (8) argued that the potential of recess for MVPA accumulation is undervalued especially for inactive children (8). Schools should, therefore, carefully consider the time available for breaks and work to ensure that pupils in schools have adequate breaks in the day for them to play and socialize with peers (2). Pfledderer et al (28) suggested altering or adding playground markings and utilizing zonal design along with the markings indicating the types of activities that might be performed in that area to suit the needs of boys and girls. Parrish et al (24) suggested

Table 3 OR (95% CI) for Meeting the 40% Recommendation of MVPA During Recess

	Meeting 40% of recess time in MVPA
Gender	
Boys	1.00 reference
Girls	**0.09 (0.04–0.25)**
P value	<.001
SES—Using SIMD quintile	
5, least deprived	1.00
4	1.55 (0.70–3.44)
3	1.09 (0.44–2.71)
2	2.39 (0.97–5.86)
1, most deprived	2.11 (0.70–6.42)
P value	.294
Season of data collection	
Winter	1.00
Spring	0.75 (0.28–2.04)
Summer	0.93 (0.41–2.10)
Autumn	0.51 (0.25–1.05)
P value	.245
Urbanicity	
Urban	1.00
Rural	1.04 (0.51–2.13)
P value	.91
Length of recess time	
15 min	1.00
20 min	1.29 (0.65–2.58)
P value	.915

Abbreviations: CI, confidence interval; MVPA, moderate to vigorous physical activity; OR, odds ratio; SIMD, Scottish Index of Multiple Deprivation; SES, socioeconomic status. Note: All models control for school number; bolded category is significant at $P = .003$.

that longer term plans, which incorporate changes to interventions over time, may assist in maintaining children's interest and, so, promote sustained increases in PA during recess. Schools need to create strategies that are not only gender equal (18) and feasible but that also cater specifically for different pupils' needs.

Our study had a number of strengths, notably the large representative sample with accelerometry measures of MVPA. Few other international studies have been based on large, nationally representative samples with accelerometry measures of MVPA, which are considered more valid and reliable tools to assess MVPA than self- or proxy reports (32). Few studies have examined the proportion of children meeting the benchmark of 40% recess time in MVPA (35).

There were some limitations in this analysis. Despite the very large sample size relative to the previous studies, the low MVPA may have limited our ability to assess potential risk factors for not meeting the recommendation. Second, as this is a secondary data analysis, accelerometer data were extracted to fit this study's purpose. Actual recess time was not measured, and whether the recess periods reported aligned with movement/activity could not be verified. To analyze the data, we reintegrated from the original 10-second epoch to a 60-second epoch, and if MVPA is being accumulated in very short and sporadic bursts, the epoch of 60 seconds is likely to reduce the apparent time spent in MVPA. Third, the potential risk factors for not meeting the recess MVPA recommendation were limited to those factors available in the original SPACES data set (19); other potentially important factors, such as teachers or peer influence and the context of the playground, were not available. It would be difficult to control for school in the analysis due to the small number of children (only 1–2 children) recruited from each school, which aimed to minimize school-level effects and achieve a nationally representative sample. Fourth, the focus of the present study was purely on the morning recess period because this is a time of the school day when free play is prioritized over waiting and eating lunch. Hence, MVPA during lunchtime was not examined and could be considered in future research. Finally, the results of this study were restricted to children aged 10–11 years old and are not necessarily generalizable to younger children or older youths.

Conclusions

Recess can make a worthwhile contribution to school children's daily MVPA. However, levels of MVPA during school recess are low in Scottish children aged 10–11 years old. Despite small gender differences in reaching MVPA recess goals, recess-based interventions are recommended for both boys and girls for the benefit of public health.

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Appendix VI: Agreement Form for Access to SPACES Data

Agreement Form for Access to Data

The Key External Researcher (designated PI) and each member of the proposed team who will have access to data should sign a separate copy of this agreement and return it to the proposed MRC/CSO Social and Public Health Sciences (SPHSU) lead on the project. The Head of Department of the Key External Researcher, and the SPHSU lead on the project should sign the same copy as the Key External Researcher.

AGREEMENT FORM

The data in the SPACES Study are highly confidential and have been given by respondents on the understanding they will be treated with the utmost confidentiality and respect. All users must ensure that respondents' confidentiality and the reputation of the study are safeguarded at all times.

Failure to uphold this agreement may result in all further access to MRC/CSO SPHSU, University of Glasgow data by you and your team being denied.

Title of Project ..... Contribution of in-school moderate-to-vigorous-intensity physical activity (MVPA) to overall MVPA in Scottish children

External Researcher (Print Name) .....Professor John Reilly.....

SPHSU lead on project (Print Name).....Dr Paul McCrorie.....

Declaration

I have read the Guidance on Completing the Generic Application Form, which forms part of the Generic Application Form for Access to Data, and agree to the conditions therein.	x
I have also read and agree to abide by the requirements of the MRC's Using Information about People in Health Research and by the MRC's Good Research Practice: Principles and Guidelines.	x
I will not share the data with any third party other than those who have also signed this agreement. Nor will I attempt to match the dataset covered by this agreement with any other SPACES data I currently hold. I will make no attempt to identify any individual within the study.	x
I will not submit any papers for publication or presentation or have any media contact about results from SPACES data without the prior consent of the SPHSU Director or their delegate and the final manuscript will be submitted for SPHSU internal peer review before being submitted for publication.	x

Agreement Form for Access to Data

At the end date of the project I will destroy all copies of the data I hold and will securely return any outputs of value such as derived variables and related documentation. | x |

Data Protection – to be read by ALL signatories

The external researchers and the SPHSU agree that the data will be stripped of direct personal identifiers and will therefore be pseudonymised before the external researcher is given access to it for the purposes of their research project. However, the external researcher and the SPHSU both further acknowledge and agree that circumstances may arise in which it may be or become possible to identify one or more living individuals from the data contained within the data set in which case such data shall be or become personal data for the purposes of data protection laws ("Personal Data"). If any such circumstance should arise, either the party first becoming so aware shall notify the other party as soon as is reasonably practicable and the parties shall discuss how to proceed or the external researcher may reject such data until it is pseudonymised such that it is not possible to identify one or more living individuals."

Signature(s)

External Researcher

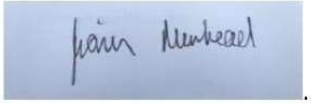
PRINT NAME.....John J Reilly.....

SIGN NAME.....  date.....4th December 2020.....

PRINT NAME.....Lan Sum Wong.....

SIGN NAME....  .....4th December 2020.....

PRINT NAME.....Fiona Muirhead .....

SIGN NAME.....  .....4th December 2020.....

Agreement Form for Access to Data

PRINT NAME……Emma Powell ……

SIGN NAME……  4th December 2020……

SPHSU Lead

PRINT NAME……Paul McCrorie……

SIGN NAME……  ……date……22/01/21……

Agreement Form for Access to Data

Sponsorship of research

I confirm that this institution is willing to act as joint sponsor of this research project with MRC SPHSU and will ensure the confidentiality, protection and appropriate ethical use and management of SPACES data at all times.

Head of Department

PRINT NAME.....Dr Allan Hewitt.....

SIGN NAME..... .....date...21 01 2021.

Project Number 2020_MKH_02

Date agreed by Data Access Committee 27th January 2021

Chair..Mary-Kate Hannah date 28th January 2021

Collaboration approved

SPHSU Director...Laurence Moore... date 3rd February 2021

Appendix VII: Additional Methodology Used in Studies 3 and 4

1. Background Data on Studies 3 and 4

Some critical problems identified to allow analysis to progress:

1) How to identify a typical "school day" for a normal Scottish primary school, (i.e., how long does a typical school day last, what time school starts and what time it ends?)
2) The SPACES data came from a range of schools from all over Scotland. No school identifiers (only a seed school number was provided). No school hours, lesson timetables, or recess (including lunch) times were recorded in the original dataset.
3) The Covid restrictions (during 2020 – 2022) meant that many non-essential services of Government departments/administration throughout Scotland were reduced significantly so obtaining accurate school data information was difficult.

Therefore, it was important to identify primary school hours and recess times across Scotland, as accurately as possible, prior to carrying out the actual detailed analysis of pupils' MVPA levels during school hours and recess. Studies 3 and 4 are based on a detailed factual analysis of the SPACES dataset.

Objectives of the Methods: Identify school hours and recess time.

1) Identifying school hours and recess time school by school from individual school handbooks
2) Adding this information as new variables to the SPACES dataset to allow analysis to be done.

Objective:

- to establish the school starting and finishing times
- to identify the possible timeslot for the morning recess, so as to accurately measure the time interval during which the relevant MVPA data should be collected. Hence it was

important first to establish what a typical Scottish school day was in terms of daily length of time and duration over a week (Monday to Friday).

2. School **Handbook** Research

All Scottish primary schools have a handbook available online. This provides information about school hours (starting and finishing times), including recess intervals and lunch times. This was considered the best way to establish normal school hours for individual schools.

Therefore, the researcher started a search using publicly accessible internet information drawn directly from the primary schools' own handbooks for the year, 2015-2016. Firstly, the researcher assessed complete lists of primary schools from all parts of Scotland via the Internet. Then from this list of primary schools, 440 primary schools were chosen at random. From the handbooks (2015-2016 school year) of these primary schools, only relevant data on school hours plus recess times or special activities was extracted.

It was noted that there are two main types of primary schools in Scotland, asymmetric/ Edinburgh-type (the E-type) and non-asymmetric Glasgow-type (the G-type). The E-type schools have longer school hours from Monday to Thursday (starting around 8:45 a.m. to 3:25 p.m.) and finishing at lunchtime on Fridays. The G-type schools keep the same starting and closing times from Monday to Friday which predominantly start around 9.00 a.m. and finish at 3.00 p.m.

However, another key fact was discovered from these 440 schools. With the G-type schools, there were nearly twenty school-time and recess combinations, while with the E-type there were more than 30 such combinations. For this reason, the researcher thought it best to change the method of analysing the SPACE data, to a slower but more detailed individual analysis. Most MVPA research carried out in a school setting has a large number of pupils, but school hours and recess time are the same. This allows for a blanket approach for collecting data at the relevant school time. However, in this particular thesis, there were 470+ individual

schools (from the SPACE dataset) which could only be resolved by a time-consuming detailed analysis of individual records. 440 school handbooks were examined, and this represents a sampling of 22% (440/2040) of all Scottish primary schools taken across the whole of Scotland. Details are shown in (Appendix D). Once each individual pupil's school hours and recess times could be established, individual pupil's daily MVPA during these timeslots could be identified for analysis for use in Study 3 and Study 4.

3. Table 1: Number of Glasgow Types and Edinburgh Types of Schools Based on the Handbook Search

	No. of G- types schools	No. of E- types schools	TOTAL
Handbook Schools	329 (75%)	111 (25%)	440

4. Extracting data from the SPACES Dataset

5. Number **of** Schools

As identified from the seed school numbers provided in the original dataset, participants came from 471 schools (identified by a unique sorting code or identifier plus an extra six schools without this numbers). Out of these schools, 306 schools had only one pupil while another ninety-four schools had two pupils and a further 71 schools had three or more pupils.

6. Establishing
School Hours MVPA for Each Pupil by Analysis ActiGraph Data

Once the 'normal' school day times had been established, the researcher then looked primarily at individual data files (.agd) and reintegrated the file from the original 10-second epoch to a 60-second to establish the pupil's school hours MVPA patterns from Monday to Friday by checking the following aspects. First, the school times for each pupil and the school type of either the Edinburgh-type (Friday afternoon off) or Glasgow-type (all day-every day same hours). Examining the activity levels and times taken from 08.30 am to 9.15 am for each day could establish a rough starting time. The second was to establish the finishing times and verify this by looking across each day in turn. Third, to check Friday afternoons and see whether the

activity was consistent with other days or a clear cut-off from lunchtime and this mostly applied to those schools identified as Edinburgh-type or those few schools which had school times outside the normal ranges. This process was carried out for all 774 pupils over five weekdays, resulting in over 3,870 (774 pupils x 5 days) daily records being examined initially. At the same time, the pupils were grouped into the classifications of Edinburgh-type and Glasgow- type schools based on their associated school hours group (records checked). Based on 5 days'data which were extracted from each pupil's (.agd), it was recognised that the number of Glasgow-type schools was three times more than the Edinburgh-types. Details are shown in Table 2.

7. Table 2: **Number** of Glasgow Types and Edinburgh Types of Schools Based on the Data Analysing from Each Pupil's Records for Five Weekdays.

	No. of Glasgow-types schools	No. of Edinburgh – types of schools	Sub-total	TOTAL
From analysing SPACE dataset	365 (78%)	105 (23%)	471 (with 6 schools unknown)	477

8. Extracting Pupils' School Hours MVPA Records

After identifying the precise starting and finishing time of a school day for each pupil, their activity levels during that timeslot for 5 days were downloaded. To be able to include in the analysis, pupils should have at least three school days (with at least 4 hours/day, equivalent to two-thirds of a school day) records. One pupil did not meet these criteria, so this pupil's data was removed from the analysis. 773 pupils, with a total of 3,865 (773 pupils x 5 days) daily MVPA records were included in the analysis for Study 3.

Among these 3865 daily records, however, certain records of individual pupils exhibited only 0 (zero) MVPA count records throughout that school day and therefore were classified as a non-valid day. The reasons were unknown. It may be the pupil did not wear the device for that day, or he/she was absent from school because of illness/ school holiday, etc. In the end,

these 0-count records or non-valid days data were removed from the analysis. A total of ninety-seven non-valid records/data were removed, resulting in 3768 (total of 3865 daily records minus 97 non-valid data) daily records being included in the final analysis for pupils' school hours MVPA.

9. Extracting **Pupils'** Recess Periods MVPA Records

Based on the handbook, it was shown that almost all the primary schools in Scotland have 15–20-minute mandatory recesses (typically taken between 10 - 11 am) in the morning. After identifying the recess timeslot as between 10 to 11 am in the morning, each pupil's activity levels during that one hour were individually checked. The same criteria used in Study 3 were adopted in Study 4, (i.e., for the records to be included in the analysis, pupils should have at least three school days - with at least 4 hours/day, equivalent to two-thirds of a school day). Over a total of 3865 daily recess records, 132 recess periods were found to be invalid. As a result, atotal of 3733 (3865 total recess records minus 132 invalid records) recess MVPA records wereincluded in the analysis. It must be noted that during recess, a 0 (zero)-count in MVPA may not be invalid, as a sedentary or light level of MVPA would still be considered valid data.

10. Analysing Pupils' School Hours and Recess Periods MVPA Levels

Overall, a total of 3768 pupils' school hours MVPA records (please refer to file two for details) and 3733 pupils' recess MVPA records (please refer to file 3 for details) were analysed individually and with SPSS Statistics (IBM Corp, Chicago, IL; v.26).

This entire process was time-consuming, but it allowed the author to answer the two research questions raised in study three and study 4, using a reliable identification of school hours and recess time rather than a rough estimate. Each individual record was checked separately rather than using a blanket time search. This was possible given that data from the original school handbooks indicated variations in school hours and recess times and therefore it was more rigorous though more time-consuming to examine each of the valid records separately. These

two studies have been published. It is hoped that the publications will contribute towards more effective interventions in helping primary school children achieve the 30-min MVPA school hours as well as the 40% recess time MVPA goals in Scotland. Moreover, the school hours and recess time variables will be handed over to the MRC (Medical Research Council)/CSO (Chief Scientist Office) Social and Public Health Sciences Unit, at the University of Glasgow and added to the SPACES dataset so that more researchers can initiate new researchers in this area. (A question raised on other comparisons that can be drawn from the 440 school handbooks data compared to the 471 from the SPACE indicated a rough similarity with a 78% to 22% split in G-Type to E-type compared to 75% to 25%. (These discrepancies can be explained bythe higher number of pupils coming from the same school.)

Appendix VIII: A List of School Hours and Recess Time (References Made from 440 School Handbooks Across 24 Districts and Councils inScotland)

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
	Edinburgh 14 (88*)			
1	School 1	08.50-15.15 except Friday 12.25	10.30-10.45	12.45-13.30
2	School 2	08.55-15.20 except Friday 12.30	10.35-10.50	12.30-13.15
3	School 3	08.55-15.20 except Friday 12.30	10.35-10.50	12.30-13.10
4	School 4	08.45-15.05 except Friday 12.20	10.30-10.45	12.30-13.10
5	School 5	08.50-15.15 except Friday 12.25	10.30-10.45	12.15-13.00
6	School 6	08.50-15.20 except Friday 12.30	10.40-11.00	12.50-13.35
7	School 7	08.50-15.15	10.30-10.45	12.30-13.15
8	School 8	08.50-15.15 except Friday 12.25	10.30-10.45	12.15-13.00
9	School 9	08.55-15.20 except Friday 12.20	10.50-11.05	12.30-13.30
10	School 10	08.45-15.05 except Friday 12.20	10.30-10.45	12.00-13.10
11	School 11	08.50-15.00 except Friday 12.25	10.30-10.45	12.35-13.05
12	School 12	08.45-15.15 except Friday 12.30	10.30-10.45	12.30-13.15
13	School 13	08.30-15.30 except Friday 12.00	10.45-11.00	12-25-13.10
14	School 14	08.55-15.20 except Friday 12.30	10.30-10.45	12.45-13.30
15	School 15	08.50-15.15 except Friday 12.25	10.30-10.45	12.45-13.30
16	School 16	08.50-15.20 except Friday 12.05	10.30-10.45	12.15-13.00
17	School 17	08.50-15.15	10.45-11.00	12.30-13.15
18	School 18	08.45-15.15 except Friday 12.00	10.30-10.45	12.30-13.30
19	School 19	08.50-15.10 except Friday 12.25	10.30-10.45	12.00-?

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
	Glasgow (42/200)			
1.	School 1	09.00-15.00	10.30-10.45	12-15-12.45
2.	School 2	09.00-15.00	10.30-10.45	12-15-12.45
3.	School 3	08.55-15.15	10.25-10.40	12.10-13.15
4.	School 4	09.00-15.00	10.30-10.45	12.15-13.00
5.	School 5	09.00-15.00	10.30-10.45	12-15-13.00
6.	School 6	09.00-15.00	11.00-11.15	12.15-13.00
7.	School 7	09.00-15.00	10.30-10.45	12.15-13.00
8.	School 8	08.50-15.10	10.30-10.50	12.30-13.30
9.	School 9	09.00-15.00	10.30-10.45	12-15-12.45
10.	School 10	09.00-15.00	10.30-10.45	12-15-13.00
11.	School 11	09.00-15.00	11.00-11.15	12-15-13.15
12.	School 12	09.30-15.00	?	12.30--13.15
13.	School 13	09.00-15.05	10.45-11.00	12.15-13.05
14.	School 14	09.00-15.00	11.00-11.15	12-15-13.15
15.	School 15	09.00-15.05	10.30-10.45	12.30-13.20
16.	School 16	09.00-15.00	10.30-10.45	12-15-13.00
17.	School 17	09.00-15.00	10.30-10.45	12-15-13.00
18.	School 18	09.00-15.00	10.30-10.45	12.15-13.00
19.	School 19	09.00-15.00	10.30-10.45	???-13.15
20.	School 20	09.00-15.00	10.30-10.45	12.15-13.00
21.	School 21	09.00-15.00	10.30-10.45	12.15-13.00
22.	School 22	09.00-15.00	10.30-10.45	12.15-13.00
23.	School 23	09.00-15.00	10.30-10.45	12.15-13.00
24.	School 24	09.00-15.00	10.30-10.45	12.15-13.00

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
25.	School 25	09.00-15.00	10.30-10.45	12.15-13.00
26.	School 26	09.00-15.00	10.30-10.45	12.15-13.00
27.	School 27	09.00-15.00	10.30-10.45	12.15-13.00
28.	School 28	09.00-15.00	10.30-10.45	12.15-13.00
29.	School 29	09.00-15.00	11.00-11.15	12.30-13.15
30.	School 30	09.00-15.00	10.45-11.00	12.30-13.15
31.	School 31	09.00-15.00	10.45-11.00	12.30-13.15
32.	School 32	09.00-15.00	10.30-10.45	12.15-13.00
33.	School 33	09.00-15.00	10.30-10.45	12.15-13.00
34.	School 34	09.00-15.00	10.30-10.45	12.15-13.00
35.	School 35	08.55-14.55	10.45-10.55	12.05-12.55
36.	School 36	09.00-15.00	10.30-10.45	12.15-13.00
37.	School 37	09.00-15.05	10.40.10.55	12.35-13.25
38.	School 38	09.00-15.00	10.30-10.45	12.30-13.15
39.	School 39	09.00-15.00	10.30-10.45	12.30-13.15
40.	School 40	09.00-15.00	10.30-10.45	12.30-13.15
41.	School 41	09.00-15.00	10.30-10.45	12.30-13.15
42.	School 42	09.00-15.00	10.30-10.45	12.30-13.15
	Stirling 9 (40)			
1.	School 1	09.00-15.00	10.45-11.00	12.45-13.30
2.	School 2	09.00-15.15	10.45-11.00	12.30-13.30
3.	School 3	09.00-15.00	10.30-10.45	12-15-13.00
4.	School 4	09.00-15.00	10.30-10.45	12-30-13.15
5.	School 5	09.00-15.00	10.30-10.45	12-15-13.00
6.	School 6	09.00-15.15	10.30-10.45	12.15-13.15

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
7.	School 7	09.00-15.00	10.45-11.00	12.15-13.00
8.	School 8	09.15-15.15	10.45-11.00	12.15-13.00
9	School 9	09.00-15.15	10.30-10.45	12.00-13.00
	Aberdeen 10 (49)			
1.	School 1	08.45-15.00	10.15-10.30	12.00-13.00
2.	School 2	09.00-15.15	10.30-10.50	12.20-13.15
3.	School 3	09.00-15.15	10.30-10.45	12-15-13.15
4.	School 4	09.00-15.20	10.30-10.45	12-15-13.20
5.	School 5	09.00-15.00	10.30-10.45	12-15-13.00
6.	School 6	09.15-15.15	10.25-10.40	12.15-13.30
7.	School 7	08.40-15.00	10.40-11.00	12.30-13.30
8.	School 8	09.00-15.00	10.30-10.45	12.15-13.00
9.	School 9	08.55-15.15	10.40-11.00	12.30-13.30
10.	School 10	09.15-15.00	10.30-10.45	12-05-12.55
	Dundee 15 (33)			
1.	School 1	09.00-15.15	10.30-10.45	12.15-13.15
2.	School 2	09.00-15.15	?	12.15-13.15
3.	School 3	09.00-15.30	10.40-11.00	12.30-13.30
4.	School 4	09.00-15.00	10.40-10.55	12.35-13.20
5.	School 5	09.00-15.15	?	?
6.	School 6	09.00-15.15	10.30-10.45	12-15-13.15
7.	School 7	09.00-15.15	10.30-10.45	12.15-13.15
8.	School 8	09.00-15.15	?	12.15-13.15
9.	School 9	09.00-15.15	?	12.15-13.15
	Perth and Kinross 15 (68)			

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
1.	School 1	09.00-15.15	10.30-10.45	12.15-13.15
2.	School 2	09.00-15.00	?	12.15-13.00
3.	School 3	09.00-15.30	10.30-10.45	12.15-13.15
4.	School 4	09.00-15.15	?	12.35-13.35
5.	School 5	08.45-15.09	?	11.57-12.36
6.	School 6	09.00-15.15	10.40-10.55	12.35-13.35
7.	School 7	09.00-15.10	10.40-11.00	12.20-13.10
8.	School 8	09.00-15.00	10.30-10.45	12-15-13.00
9.	School 9	09.00-15.15	?	12.30-13.30
10.	School 10	09.00-15.15	10.30-10.45	12.15-13.15
11.	School 11	09.00-15.00	?	12.15-13.00
12.	School 12	09.00-15.15	?	12.30-13.30
13.	School 13	09.00-15.00	10.30-10.45	12-15-13.00
14.	School 14	09.00-15.20	10.30-10.50	12.20-13.20
15.	School 15	09.00-15.25	10.40-10.55	12.35-1335
	Inverness 14 (60)			
1.	School 1	09.10-15.10	10.40-10.55	12.35-13.20
2.	School 2	08.50-15.00 except Fri 14.00	?	12.30-13.15
3.	School 3	09.00-15.00	11.00-11.15	12.45-13.30
4.	School 4	09.00-15.00	11.05-11.20	13.00-13.45
5.	School 5	09.00-15.00	10.35-10.50	12.45-13.30
6.	School 6	09.00-15.30 except Fri 12.15	?	12.45-13.30
7.	School 7	08.50-15.00	?	12.25-13.20
8.	School 8	08.50-15.00	10.30-10.50	12.30-13.20
9.	School 9	09.00.15.00	10.30-10.45	12.30-13.15

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
10.	School 10	09.00-15.15	10.40-11.00	12.30-13.25
11.	School 11	08.50-15.10 Except Fri 12.05	10.30-10.50	12.30-13.15
12.	School 12	09.00-15.00	?	12.30-13.10
13.	School 13	09.00-15.15	10.45-11.00	12.30-13.30
14.	School 14	09.00-15.30 Except Fri 12.15	10.30-10.50	12.15-13.00
	Motherwell 13 (56)			
1.	School 1	09.00-15.00	10.40-10.55	12.35-13.20
2.	School 2	09.00-15.00	10.40-10.55	12.35-13.20
3.	School 3	09.00-15.00	10.30-10.45	12.30-13.15
4.	School 4	09.00-15.00	10.30-10.45	12.30-13.15
5.	School 5	09.00-15.00	10.30-10.45	12.20-13.05
6.	School 6	09.00-15.00	10.30-10.45	12.15-13.00
7.	School 7	08.55-15.00	10.50-11.05	12.35-13.25
8.	School 8	09.00-15.00	10.35-10.55	12.35-13.20
9.	School 9	08.55-15.00	10.20-10.35	12.10-13.00
10.	School 10	08.50-14.50	10.20-10.35	11.45-12.30
11.	School 11	09.00-15.00	?	12.45-13.30
12.	School 12	09.00-15.00	10.30-10.45	12.15-13.00
13.	School 13	09.00-15.00	10.45-11.00	12.30-13.15
	Dumfries and Galloway 20 (98)			
1.	School 1	09.00-15.15	10.45-11.00	12.15-13.15
2.	School 2	09.00-15.00	10.45-11.00	12.30-13.15
3.	School 3	09.00-15.15	10.30-10.50	12.15-13.15
4.	School 4	09.00-15.00	10.45-11.00	12.30-13.15
5.	School 5	09.00-15.00	10.35-10.55	12.30-13.15

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
6.	School 6	09.00-15.00	10.45-11.00	12.30-13.15
7.	School 7	09.00-15.00	10.30-10.45	12.30-13.15
8.	School 8	09.00-15.00	10.40-11.00	12.30-13.10
9.	School 9	09.00-15.00	10.30-10.45	12.30-13.15
10.	School 10	09.00-15.00	10.45-11.00	12.15-13.00
11.	School 11	09.00-15.00	10.40-11.00	12.40-13.20
12.	School 12	09.00-15.00	10.15-10.30	12.15-13.00
13.	School 13	09.00-15.00	10.30-10.50	12.30-13.15
14.	School 14	09.00-15.00	10.40-11.00	12.30-13.10
15.	School 15	09.00-15.00	10.40-11.00	12.30-13.10
16.	School 16	09.00-15.00	10.30-10.45	12.15-13.00
17.	School 17	09.00-15.05	10.30-10.50	12.15-13.00
18.	School 18	09.15-15.15	10.45-11.00	12.25-13.10
19.	School 19	09.10-15.10	10.45-11.00	12.25-13.10
20.	School 20	09.00-15.00	10.30-10.45	12.15-13.00
	Kilmanock 13 (56)			
1.	School 1	09.00-15.00	10.45-11.00	12.20-13.05
2.	School 2	09.00-15.00	10.30-10.45	12.30-13.15
3.	School 3	09.00-15.00	10.30-10.45	12.15-13.00
4.	School 4	09.00-15.05	10.45-11.00	12.30-13.20
5.	School 5	09.00-15.15	10.40-10.55	12.35-13.35
6.	School 6	08.55-15.00	10.35-10.50	12.30-13.20
7.	School 7	09.00-15.00	10.40-10.55	12.35-13.20
8.	School 8	09.00-15.15	10.30-10.50	12.20-13.15
9.	School 9	09.00-15.15	10.45-11.00	12.30-13.15

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
10.	School 10	09.00-15.00	10.30-10.45	12.30-13.15
11.	School 11	09.00-15.00	10.30-10.45	12.30-13.15
12.	School 12	09.00-15.00	10.30-10.45	12.30-13.15
13.	School 13	09.00-15.15	10.45-11.00	12.30-13.30
	Highland Council 42 (201)			
1.	School 1	09.00-15.00	10.40-11.00	12-30-13.10
2.	School 2	09.00-15.15	10.30-10.50	12.30-13.25
3.	School 3	09.15-15.15	?	12.45-13.30
4.	School 4	08.50-15.15 except Fri 12.45	10.30-10.45	12.25-13.15
5.	School 5	08.50-15.10 except Fri 12.25	10.45-11.00	12.30-13.10
6.	School 6	09.00-15.00	10.30-10.45	12.30-13.15
7.	School 7	09.00-15.00	?	12.30-13.15
8.	School 8	08.50-15.15 except Fri 13.00	?	12.30-13.15
9.	School 9	09.15-15.15	10.45-11.00	12.30-13.15
10.	School 10	09.00-15.00	10.45-11.00	12.10-12.55
11.	School 11	09.00-15.00	10.45-11.00	12.45-13.30
12.	School 12	09.30-15.30	?	12.45-13.30
13.	School 13	08.45-15.30 except Fri 12.15	10.45-11.00	12.30-13.15
14.	School 14	08.45-15.15 except Fri. 12.30	10.30-10.50	12.15-13.00
15.	School 15	09.00-15.30 except Fri 12.15	10.30-10.45	12.15-13.00
16.	School 16	09.00-15.00	?	12.00-13.10
17.	School 17	09.15-15.15	10.45-11.00	12.45-13.30
18.	School 18	09.00-15.30	10.30-11.00	12.15-13.00
19.	School 19	09.00-15.15	10.45-11.00	12.30-13.30
20.	School 20	09.00-15.00	10.30-10.45	12.45-13.30

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
21.	School 21	09.00-15.30	10.45-11.00	12.30-13.15
22.	School 22	09.00-15.00	?	12.30-13.30
23.	School 23	09.00-15.15	10.45-11.00	12.30-13.30
24.	School 24	09.00-15.00	10.45-11.05	12.40-13.20
25.	School 25	09.15-15.16	10.40-11.00	12.35-13.30
26.	School 26	08.50-15.15 except Fri 12.46	?	?
27.	School 27	08.50-15.05	10.45-11.00	12.30-13.15
28.	School 28	09.00-15.00	10.45-11.05	12.30-13.10
29.	School 29	09.15-15.15	10.45-11.00	12.30-13.30
30.	School 30	09.05-15.00	10.50-11.05	12.50-13.30
31.	School 31	09.00-15.00	10.45-11.00	12.15-13.00
32.	School 32	08.50-15.20 except Fri 13.15	10.30-10.50	12.30-13.15
33.	School 33	09.06-15.30 except Fri 12.45	11.00-11.15	12.45-13.30
34.	School 34	09.00-15.00	10.30-10.45	12.30-13.15
35.	School 35	09.00-15.00	10.45-11.00	12.30-13.15
36.	School 36	09.00-15.00	10.45-11.00	12.30-13.15
37.	School 37	09.00-15.30	10.40-11.15	12.30-13.30
38.	School 38	09.00-15.30 except Fri 12.15	10.30-10.45	12.30-13.15
39.	School 39	09.00-15.00	10.45-11.00	12.30-13.15
40.	School 40	09.00-15.15	10.45-11.05	12.30-13.25
41.	School 41	09.00-15.00	10.35-10.50	12.30-13.15
42.	School 42	08.55-15.35 except Fri 13.05	10.25-10.45	12.15-13.05
	Scottish Borders 14 (59)			
1.	School 1	08.45-15.15 except Fri 12.15	10.30-10.45	12.15-13.00
2.	School 2	08.50-15.20 except Fri 12.20	?	?

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
3.	School 3	08.35-15.00 except Fri 12.25	10.45-11.35	12.10-12.50
4.	School 4	08.45-15.15 except Fri 12.15	10.30-10.45	12.10-13.00
5.	School 5	08.45-15.20 except Fri 12.15	10.30-10.45	12.10-13.00
6.	School 6	08.50-15.15	10.30-10.45	12.00-13.10
7.	School 7	08.35-15.05 except Fri 12.20	10.00-10.15	12.15-13.00
8.	School 8	08.45-15.15 except Fri 12.30	10.30-10.45	12.15-13.00
9.	School 9	08.45-15.15 except Fri 12.50	10.15-10.30	12.30-13.15
10.	School 10	08.40-15.15 except Fri 12.30	10.10-10.30	12.15-13.00
11.	School 11	08.45-15.30 two breaks am & pm	10.15-10.30	12.00-12.45
12.	School 12	08.45-15.15	10.30-10.45	12.15-13.00
13.	School 13	08.40-15.10 except Fri 12.20	10.30-10.45	12.15-13.00
14.	School 14	08.40-15.15 except Fri 12.25	?	12.00-12.50
	South Lanarkshire 27 (125)			
1.	School 1	09.00-15.00	10.30-10.45	12.00-12.45
2.	School 2	08.55-15.00	10.30-10.45	12.10-13.00
3.	School 3	09.00-15.00	10.30-10.45	12.35-13.20
4.	School 4	08.55-15.00	10.40-10.55	12.25-13.15
5.	School 5	09.00-15.00	10.40-10.55	12.30-13.15
6.	School 6	09.00-15.00	?	12.15-13.00
7.	School 7	09.00-15.00	10.30-10.45	12.15-13.00
8.	School 8	09.00-15.00	10.45-11.00	12.30-13.15
9.	School 9	09.00-15.00	?	12.15-13.00
10.	School 10	09.00-15.00	?	12.35.13.20
11.	School 11	09.00-15.00	10.30-10.45	12.15-13.00
12.	School 12	09.00-15.00	10.30-10.45	12.15-13.00

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
13.	School 13	09.00-15.00	10.30-10.45	12.15-13.00
14.	School 14	09.00-15.00	10.45-11.00	12.30-13.15
15.	School 15	09.00-15.00	?	12.30-13.15
16.	School 16	09.00-15.00	10.40-10.55	12.35-13.20
17.	School 17	09.00-15.00	10.30-10.45	12.15-13.00
18.	School 18	09.00-15.00	10.30-10.45	12.15-13.00
19.	School 19	09.00-15.00	?	12.15-13.00
20.	School 20	09.00-15.00	10.45-11.00	12.30-13.15
21.	School 21	09.00-15.00	10.40-10.55	12.35-13.20
22.	School 22	08.55-15.00	10.40-10.55	12.25-13.15
23.	School 23	09.00-15.00	10.30-10.45	12.15-13.00
24.	School 24	09.00-15.00	10.30-10.45	12.15-13.00
25.	School 25	09.00-15.00	10.40-10.55	12.35-13.20
26.	School 26	09.00-15.00	10.45-11.00	12.45-13.30
27.	School 27	09.00-15.00	10.30-10.45	12.30-13.15
	North Lanarkshire 31 (120)			
1.	School 1	09.00-15.00	10.45-11.00	12.15-13.00
2.	School 2	09.00-15.00	10.30-10.45	12.15-13.00
3.	School 3	09.00-15.00	10.30-10.45	12.45-13.30
4.	School 4	09.00-15.00	10.30-10.45	12.15-13.00
5.	School 5	09.00-15.00	10.30-10.45	12.15-13.00
6.	School 6	09.00-15.00	10.15-10.30	12.15-13.00
7.	School 7	09.00-15.00	10.30-10.45	12.15-13.00
8.	School 8	09.00-15.00	10.30-10.45	12.15-13.00
9.	School 9	08.55-15.00	10.40-10.55	12.00-13.00

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
10.	School 10	09.00-15.00	10.30-10.45	12.15-13.00
11.	School 11	09.00-15.00	10.30-10.45	12.15-13.00
12.	School 12	09.00-15.00	10.30-10.45	12.15-13.00
13.	School 13	08.55-15.00	10.35-10.50	12.30-13.20
14.	School 14	09.00-15.00	10.35-10.50	12.30-13.45
15.	School 15	08.50-14.50	10.20-10.35	11.45-12.20
16.	School 16	08.55-15.00	10.20-10.35	12.10-13.00
17.	School 17	09.00-15.15	10.30-10.45	12.15-13.15
18.	School 18	08.55-15.00	10.45-11.00	12.30-13.15
19.	School 19	09.00-15.00	10.40-10.55	12.35-13.20
20.	School 20	09.00-15.00	10.30-10.45	12.15-13.00
21.	School 21	09.15-15.15	10.45-11.00	12.30-13.15
22.	School 22	08.55-15.00	10.35-10.50	12.30-13.20
23.	School 23	09.00-15.00	10.40-10.55	12.35-13.20
24.	School 24	09.00-15.00	10.30-10.45	12.15-13.00
25.	School 25	08.45-14.45	?	12.25-12.55
26.	School 26	09.00-15.00	?	12.15-13.00
27.	School 27	09.00-15.00	10.40-10.55	12.15-13.00
28.	School 28	08.55-15.00	10.40-10.55	12.30-13.20
29.	School 29	09.00-15.00	10.30-10.45	12.15-13.00
30.	School 30	08.50-14.50	10.30-10.45	12.00-12.45
31.	School 31	09.00-15.00	10.30-10.45	12.15-13.00
	East, West & Mid-Lothian 35 (146)			
1.	School 1	08.54-15.25 except Fri 12.35	10.40-11.00	12.30-13.14
2.	School 2	08.45-15.10 except Fri 12.20	10.30-10.45	12.15-13.00

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
3.	School 3	08.55-15.25 except Fri 12.10	10.30-10.45	12.15-13.00
4.	School 4	08.45-15.05 except Fri 12.30	10.30-10.45	12.00-12.45
5.	School 5	08.50-15.15 except Fri 12.00	10.30-10.45	12.45-13.30
6.	School 6	09.00-15.20 exp Fri 12.30	10.45-11.05	12.30-13.15
7.	School 7	08.50-15.15 except Fri 12.25	10.30-10.45	12.25-13.10
8.	School 8	08.50-15.15 except Fri 12.25	10.30-10.45	12.30-13.15
9.	School 9	08.50-15.15 except Fri 12.25	?	12.30-13.15
10.	School 10	08.55-15.15 except Fri 12.30	10.30-10.45	12.20-13.00
11.	School 11	08.45-15.10 except Fri 12.20	10.30-10.45	12.15-13.00
12.	School 12	09.00-15.20 except Fri 12.15	10.50-11.05	12.30-13.05
13.	School 13	08.50-15.15 except Fri 12.25	10.30-10.45	12.20-13.05
14.	School 14	08.50-15.15 except Fri 12.30	10.40-10.56	12.35-13.20
15.	School 15	08.50-15.30 except Fri 12.25	10.30-10.45	12.35-13.25
16.	School 16	08.50-15.15 except Fri 12.30	10.30-10.45	12.30-13.15
17.	School 17	08.45-15.10 except Fri 12.20	10.30-10.45	12.25-13.10
18.	School 18	08.55-15.20 except Fri 12.30	10.40-10.55	12.30-13.15
19.	School 19	08.50-15.15 except Fri 12.30	10.30-10.45	12.30-13.15
20.	School 20	08.55-15.30 except Fri 12.35	10.40-11.00	12.30-13.20
21.	School 21	08.50-15.15 except Fri 12.25	?	?
22.	School 22	08.50-15.15 except Fri 12.20	?	?
23.	School 23	08.50-15.15 except Fri 12.25	10.30-10.45	12.15-13.00
24.	School 24	08.50-15.15 except Fri 12.25	10.30-10.45	12.35-13.20
25.	School 25	08.45-15.00 except Fri 12.00	?	?
26.	School 26	08.50-15.15 except Fri 12.25	?	?
27.	School 27	08.45-15.15 except Fri 12.00	10.15-10.30	12.30-13.00

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
28.	School 28	08.50-15.20 except Fri 12.35	10.35-10.50	12.35-13.05
29.	School 29	09.00-15.30 except Fri 12.30	10.30-10.45	12.40-13.25
30.	School 30	08.50-15.15 except Fri 12.25	?	12.15-13.00
31.	School 31	08.50-15.15 except Fri 12.25	?	?
32.	School 32	08.50-15.15 except Fri 12.25	10.30-10.45	12.20-13.05
33.	School 33	08.50-15.25 except Fri 12.10	10.30-10.45	12.00-13.25
34.	School 34	08.45-15.05 except Fri 12.35	?	?
35.	School 35	08.45-15.15 except Fri 12.00	10.15-10.30	12.30-13.15
	Clackmmanshire 4 (18)			
1.	School 1	09.00-15.00	11.00-11.15	12.15-13.00
2.	School 2	09.00-15.00	?	12.15-13.00
3.	School 3	09.15-15.15	10.45-11.00	12.30-13.15
4.	School 4	09.00-15.00	?	12.15-13.00
	Renfrewshire & East Renfrewshire 17 (74)			
1.	School 1	09.00-15.00	10.30-10.45	12.15-13.00
2.	School 2	09.00-15.15	10.40-10.55	12.35-13.35
3.	School 3	09.00-15.00	10.40-10.55	12.35-13.20
4.	School	09.00-15.00	10.40-10.55	12.35-13.20
5.	School 5	09.00-15.00	10.40-10.55	12.35-13.20
6.	School 6	08.55-15.00	10.35-10.50	12.30-13.20
7.	School 7	09.00-15.00	10.30-10.45	12.15-13.00
8.	School 8	09.00-15.00	10.30-10.45	12.15-13.00
9.	School 9	09.00-15.00	10.30-10.45	12.15-13.00
10.	School 10	09.00-15.00	10.30-10.45	12.15-13.00
11.	School 11	09.00-15.00 but can enter at 08.45	10.40-10.55	12.35-13.20

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
12.	School 12	09.00-15.00	10.30-10.45	12.15-13.00
13.	School 13	09.00-15.15 but can enter at 08.50	10.40-10.55	12.35-13.35
14.	School 14	08.55-15.10	10.40-10.55	12.35-13.30
15.	School 15	09.00-15.15 early entry 08.55	10.40-10.55	12.35-13.35
16.	School 16	09.00-15.15	10.30-10.45	12.15-13.00
17.	School 17	09.00-15.00	10.30-10.45	12.15-13.00
	East Ayrshire 9 (40)			
1.	School 1	09.00-15.00 early entry 08.50	10.45-11.00	12.30-13.15
2.	School 2	09.00-15.00	10.45-11.00	12.30-13.15
3.	School 3	09.00-15.00 but early entry 08.40	10.40-10.55	12.35-13.20
4.	School 4	08.50-14.50	?	?
5.	School 5	09.00-15.00	10.45-11.00	12.15-13.00
6.	School 6	09.00-15.00	10.40-10.55	12.35-13.25
7.	School 7	09.00-15.00	11.00-11.15	12.45-13.30
8.	School 8	09.00-15.00 (8.30 in & late out 15.30)	10.35-10.50	12.30-13.15
9.	School 9	09.00-15.00	10.35-10.50	12.30-13.15
	Argyll & Bute 17 (81)			
1.	School 1	09.00-15.00	10.30-10.45	12.15-13.00
2.	School 2	09.00-15.15	10.45-11.00	12.30-13.30
3.	School 3	09.00-15.00	10.30-10.45	12.15-13.00
4.	School 4	09.15-15.15	10.45-11.00	12.15-13.00
5.	School 5	09.00-15.30 with am and pm breaks	10.30-10.45	12.00-13.00
6.	School 6	09.00-15.00	10.30-10.45	12.15-13.00
7.	School 7	09.00-15.00	10.30-10.45	12.30-13.15
8.	School 8	09.00-15.00	10.30-10.45	12.00-12.45

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
9.	School 9	09.00-15.05	10.20-10.35	12.15-13.00
10.	School 10	09.00-15.00	10.30-10.45	12.15-13.00
11.	School 11	09.00-15.15	10.30-10.45	12.15-13.15
12.	School 12	09.00-15.00	10.30-10.45	12.15-13.00
13.	School 13	09.00-15.20 with am and pm breaks	11.00-11.20	12.20-13.20
14.	School 14	09.00-15.00	10.30-10.45	12.15-13.00
15.	School 15	09.00-15.00	10.30-10.45	12.15-13.00
16.	School 16	09.00-15.30 with am and pm breaks	10.30-10.45	12.00-13.00
17.	School 17	9.30-15.30	10.45-11.00	12.30-13.15
	Fife (27/134)			
1.	School 1	0900-15.00	10.40-11.00	12.40-13.20
2.	School 2	09.00-15.00	10.40-10.55	12.35-13.20
3.	School 3	09.00-15.00	10.40-10.55	12.30-13.15
4.	School 4	09.00-15.00	10.40-10.55	12.25-13.20
5.	School 5	09.00-15.00 except Fri 08.30-15.30	10.40-10.50	12.25-13.20
6.	School 6	09.00-15.05	10.40-10.55	12.35-13.25
7.	School 7	09.00-15.00	10.40-10.55	12.35-13.20
8.	School 8	09.00-15.05	10.40-10.55	12.35-13.20
9.	School 9	09.00-15.00	10.30-10.45	12.35-13.25
10.	School 10	09.00-15.00	11.11-11.15	12.30-13.15
11.	School 11	09.00-15.05	10.40-10.55	12.35-13.20
12.	School 12	09.00-15.00	10.30-10.45	12.30-13.20
13.	School 13	09.00-15.00	10.40-11.00	12.40-13.20
14.	School 14	09.00-15.00	?	12.40-13.30
15.	School 15	09.00-15.05	10.40-10.55	12.35-13.25

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
16.	School 16	09.00-15.00	10.40-10.55	12.35-13.20
17.	School 17	09.00-15.05	10.40-10.55	12.35-13.25
18.	School 18	09.00-15.05	10.40-11.00	12.40-13.25
19.	School 19	09.00-15.00	10.35-10.55	12.35-13.20
20.	School 20	09.00-15.00	10.40-10.55	12.35-13.20
21.	School 21	09.00-15.05	10.40-11.00	12.40-13.40
22.	School 22	09.00-15.10	10.30-10.50	12.40-13.30
23.	School 23	08.55-15.00	10.35-10.50	12.30-13.20
24.	School 24	09.00-15.05	10.40-10.55	12.40-13.30
25.	School 25	09.00-15.00	10.40-10.55	12.35-13.20
26.	School 26	09.00-15.05	10.40-10.55	12.35-13.25
27.	School 27	09.00-15.05	10.40-10.55	12.35-13.25
	Angus Council 11 (51)			
1.	School 1	09.10-15.20 but pre-school at 09.00	10.45-11.00	12.30-13.30
2.	School 2	09.00-15.20 (nursery 08.45-15.30)	10.30-10.50	12.30-13.30
3.	School 3	09.00-15.20	10.30-10.50	12.30-13.30
4.	School 4	09.00-15.20	10.30-10.50	12.30-13.30
5.	School 5	09.00-15.20	10.35-10.50	12.30-13.30
6.	School 6	09.00-15.20 (early Walk-in 08.50-09.05)	10.30-10.50	12.30-13.30
7.	School 7	09.00-15.20	10.30-10.50	12.30-13.30
8.	School 8	09.00-15.20 (early walk in from 08.50)	10.40-11.00	12.30-13.30
9.	School 9	09.00-15.20 (nursery 08.00-18.00)	10.30-10.50	12.30-13.30
10.	School 10	09.00-15.20	10.40-11.00	12.30-13.30
11.	School 11	09.00-15.20 (nursery 08.00-16.30)	10.20-10.40	12.30-13.30

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
	East & West Dunbartonshire 14 (63)			
1.	School 1	09.00-15.00	10.30-10.45	12.15-13.00
2.	School 2	09.00-15.00	10.30-10.45	12.15-13.00
3.	School 3	09.05-15.05 (early entry 08.45)	10.55-11.10	12.45-13.30
4.	School 4	09.00-15.00	10.30-10.45	12.15-13.00
5.	School 5	08.50-14.50	10.15-10.30	12.00-12.45
6.	School 6	09.00-15.00	?	12.15-13.00
7.	School 7	09.00-15.00	10.30-10.45	12.15-13.00
8.	School 8	09.00-15.00	10.30-10.45	12.15-13.00
9.	School 9	09.00-15.00	10.30-10.45	12.00-12.45
10.	School 10	09.00-15.00 (can enter at 08.55)	10.30-10.45	12.15-13.00
11.	School 11	09.00-15.00	10.30-10.45	12.30-13.15
12.	School 12	09.00-15.00	10.40-10.55	12.30-13.15
13.	School 13	09.00-15.00	10.30-10.45	12.15-13.00
14.	School 14	09.00-15.00	10.30-10.45	12.15-13.00
	Peeblesshire 13 (59)			
1.	School 1	08.45-15.15 except Fri 12.20	10.30-10.45	12.20-???
2.	School 2	08.50-15.15 except Fri 12.25	10.30-10.45	12.15-13.00
3.	School 3	08.50-15.15 except Fri 12.25	10.30-10.45	12.25-13.10
4.	School 4	08.50-15.15 except Fri 12.25	10.30-10.45	12.30-13.15
5.	School 5	08.30-15.00 except Fri 12.05	10.30-10.45	12.00-12.45
6.	School 6	08.50-15.15 except Fri 12.25	?	12.40-13.25
7.	School 7	08.30-15.15 except Fri 12.50	10.25-10.40	12.20-13.15
8.	School 8	08.45-15.15 except Fri 12.15	10.15-10.45	12.15-13.00
9.	School 9	08.50-15.25 except Fri 12.25	10.35-10.50	12.20-13.15

	Number of schools searched (Total no. of schools in the city)	School Time	Morning Recess Time	Lunch Time
10.	School 10	08.55-15.20 except Fri 12.30	?	12.35-13.20
11.	School 11	08.30-15.00 except Fri 12.15	10.15-10.30	12.15-13.00
12.	School 12	08.40-15.10 except Fri 12.20	10.20-10.35	13.15-13.00
13.	School 13	08.50-15.25 except Fri 12.40	10.35-10.50	12.20-13.10
	Berwickshire (Border Council) 15 (60)			
1.	School 1	08.40-15.15 except Fri 12.30	?	12.10-13.00
2.	School 2	08.45-15.30 except Fri 12.30	10.15-10.30	12.15-13.15
3.	School 3	08.35-15.10 except Fri 12.25	10.15-10.30	12.25-13.15
4.	School 4	08.40-15.10 except Fri 12.30	10.30.10.45	12.15-13.00
5.	School 5	08.50-15.15 except Fri 12.3	10.30.10.45	12.30-13.10
6.	School 6	08.4-15.15 except Fri 12.45	10.30.10.45	12.15-13.00
7.	School 7	08.45-15.15 except Fri 12.15	10.30.10.45	12.15-13.00
8.	School 8	08.30-15.05 except Fri 12.40	10.15-10.35	12.20-13.10
9.	School 9	08.30-15.05 except Fri 12.15	?	12.10-13.00
10.	School 10	08.35-15.05 except Fri 12.20	10.35-10.50	12.05-12.50
11.	School 11	08.45-15.15 except Fri 12.15	10.30-10.45	12.15-13.00
12.	School 12	08.45-15.15 except Fri 12.30	10.30-10.45	12.15-13.00
13.	School 13	08.40-15.10 except Fri 12.20	10.30-10.45	12.15-13.00
14.	School 14	08.45-15.15 except Fri 12.20	10.30-10.45	12.15-13.00
15.	School 15	09.05-15.30 except Fri 12.50	10.30-10.45	12.30-13.10

Legend

a. The bracket figure behind each Area/Region indicates the total number of PS listed there.
b. From the National Statistics Office of the Scottish Government, the total number of primary schools in 2014 was 2028, and by 2020 had dropped to 2005.

c. This sample is drawn from the primary schools (PS) listed per council, Edinburgh, Glasgow, Aberdeen, Inverness, Stirling, Perth Dundee, Dumfries and Galloway, Kilmarnock, Highland Council, and Scottish Borders only.
d. Keywords search Pattern - "School name" - "2015" - "Handbook."
e. If "2015" is not located, then use the first available closest-to-date handbook.
f. A “? “Denotes where the relevant information on interval or lunchtime is missing or not given.
g. Ten percent+ of primary schools were chosen randomly but with a view to geographical spread so looking at postcode.
h. Primary schools were chosen from the various large conurbations, cities, towns, and councils across Scotland, including the Highland council and Scottish borders.
i. PS does not include special schools or independent PS.
j. Many schools in areas around Edinburgh and beyond finish early on Fridays so, have longer school times from Monday to Thursday.

Notes

1. Data from the research indicated only 38% of schools and parents asked to participate agreed to join. So, 774 pupils and roughly 470 schools but which could not be identified.
2. This research amounted to roughly less than a quarter of all primary schools in Scotland.
3. Data referring to schools, location, school day or timetables cannot be easily extracted without further due process, privacy issues, and time.
4. The key research questions require all MVPA to be carried out during the actual school day only.
5. Establishing an accurate school (schools in the western part of Scotland use an asymmetric – longer school times Monday-Thursday and short Fridays) is critical.
6. Time consists of intervals, lunch, and breaks.
7. 774 pupils were recorded, and most did 5 days or 6 days (excluding weekends) – this amounts to 83% of the total sample (other pupils did longer)
8. The current tables show a randomly generated sample of slightly more than 22% of all Scottish primary schools where the school day data has been extracted. (More since some school days data was missing so the sample increased to ensure at least a 22% sample)
9. As Asymmetric schools form a larger percentage of the random sample then a separate way needs to be found to analyse the data. For example, P1-4 have lunch from 12.00-12.30 but P5-P7 have it from 12.30 to 13.10 so the lunch period lasts from 12.00-13.10.