THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF EDGE HILL UNIVERSITY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

AN INVESTIGATION INTO MUSCULAR FITNESS ACTIVITY IN UK SECONDARY SCHOOLS

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Abstract

This thesis aimed to: (1) establish the efficacy of school-based muscular fitness (MF) interventions and the varying forms in which MF activity can be delivered, (2) to explore perceptions of MF activity amongst adolescent boys, (3) investigate physical education (PE) teachers' knowledge and understanding of MF activity delivery to better understand MF activity implementation fidelity in the school environment and (4) design and assess the feasibility and acceptability of a suitable intervention to enable delivery of MF activity in schools. Study 1 was a systematic review and meta-analysis to investigate the efficacy of school-based physical activity (PA) interventions for improving MF outcomes in adolescent boys. Study 1 found that school-based interventions (n=11) which aimed to increase MF outcomes in adolescent boys demonstrated small-to-moderate effects (*g*=0.32, CI 0.17,0.48, *p* < 0.00). Traditional (*g*=0.43, 95%CI 0.09,0.78, *p*=0.01) and plyometric (*g*=0.39, 95% CI 0.09,0.68, *p*=0.01 methods of resistance training appeared to be the most effective form of MF delivery in adolescent boys. Study 1 concluded that more quality research is required to assess the impact of MF delivered in the school environment to inform future MF intervention design.

Study 2 used a combination of qualitative techniques to explore adolescent boys' (n=32) understanding, perceptions, and experiences of PA and the role MF plays within boys' physically active lifestyles. Study 2 revealed there was a perceived lack of opportunity to participate in MF activities, particularly in school, and knowledge of how to conduct MF activities was limited. The contribution of PE was highlighted as being key to facilitating exposure to MF activities.

Study 3 was the first survey investigating UK secondary school PE teachers' (n=194) perceived knowledge and understanding of MF activity, and teacher CPD requirements for its delivery in PE. Relative to less experienced teachers, those with at least 5 years' service were 2.2 times more likely to have completed MF activity CPD (OR=2.16; ß=0.77; 95% CI: 1.25-3.74; P <0.01), and 1.8 times more likely to use assessments of MF to inform PE programme decision making (OR=1.83; ß=0.60; 95% CI: 1.18-2.82; P <0.01). Teachers delivering PE from across the UK believed their knowledge of school-based MF activity needed development, and this lack of knowledge reflected a limited understanding of programme design and concepts of MF activity. Study 3 also revealed that preconceived biases surrounding the safety and efficacy of MF activity exist among UK PE teachers. Overall, study 3 demonstrated that CPD to improve teachers' knowledge and understanding

of MF activity is warranted to overcome the perceived barriers to MF activity delivery and ensure implementation fidelity.

Study 4 involved the co-production of an online CPD platform with secondary school PE teachers. A quasi-experimental pre-post control group design for the CPD was adopted for study 4. Study 4 found that co-production of an online CPD programme can improve knowledge (CPD score vs control score; U =37, z = -5.96, P <0.01) and affect teaching practice. PE teachers that completed the CPD reported the online platform was beneficial for overcoming the limitations of face-to-face CPD such as time and financial constraints and suggested the content covered was beneficial and appropriate to their teaching. It was acknowledged that future work is required to establish links between teachers' learning following CPD, the translation into PE practice and student MF outcomes. Overall, this thesis has demonstrated that MF activity is an effective complementary activity to traditional team sports and aerobic moderate to vigorous PA (MVPA) among adolescents in schools. Indeed, the qualitative data provided by the adolescent boys in this thesis suggested that MF activity is an aspect of PA they would like to engage further with. The findings further support the need to expose adolescents to MF as a mode of PA they are likely to engage in after formal education and ensure they are adequately prepared to engage in MF activity throughout the life course. As demonstrated in this thesis, there may be a lack of knowledge among PE teachers to provide opportunities to engage in MF activity during secondary school PE. However, the lack of knowledge can be overcome through co-produced online CPD that accounts for the pedagogical needs and requirements of the PE teacher.

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Publications and communications

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Conference communications

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Review and Meta-Analysis. British Heart Foundation funded Motor Competence in Childhood: the forgotten pathway to improved cardiovascular health, Coventry University, Oral presentation, UK, June 2019.

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Cox, A., Noonan, R. & Fairclough, S. J. Physical Education Teachers' Perceived Benefits, Challenges and Experiences of Delivering Muscular Fitness Activities During Physical Education: PE Teacher EmPOWERment Survey. International society of Behavioural Nutrition and Physical Activity. Children and families special interest group. Xchange 2021.

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List of Abbreviations	Definition
1RM	1 repetition maximum
β	Beta coefficient
B	Boy
BMI	Body mass index (kg/m²)
CI	Confidence interval
CPD	Continued professional development
CRF	Cardiorespiratory fitness
CVD	Cardiovascular disease
EE	Energy expenditure
EDD	Exercise deficit disorder
F	Female
G	Girl
Kg	Kilogram
LLPA	Life-long physical activity
M	Male
MBSE	Muscle and bone strengthening exercise
METs	Metabolic equivalent of tasks

MF	Muscular fitness
MVPA	Moderate-to-vigorous intensity physical activity
n	Sample size
PA	Physical activity
PAQ-C	Physical Activity Questionnaire for Children
PE	Physical education
PIT	Paediatric inactivity triad
PL	Physical literacy
RE	Resistance exercise
REE	Resting energy expenditure
RPE	Rate of perceived exertion
RT	Resistance training
RTSC	Resistance training skills competency
SD	Standard deviation
SDT	Self-determination theory
SE	Standard error
SES	Socioeconomic status
ST	Strength training
T2DM	Type 2 diabetes
UK	United Kingdom
VPA	Vigorous intensity physical activity
W	Watts
WDST	Write, draw, show and tell
WHO	World Health Organization
YPAPM	Youth Physical Activity Promotion Model

CHAPTER 1

Introduction

1 Introduction

1.1 The research problem

Physical activity (PA) guidelines for the UK and other developed countries recommend that children and young people engage in at least 60 minutes moderate-to-vigorous PA (MVPA) per day averaged across the week, and engage in various types and intensities of PA to develop movement skills, bone strength, and muscular fitness (MF) (Bull et al., 2020; Davies et al., 2019). Despite the growing body of evidence supporting the health benefits of MF activity (García-Hermoso et al., 2019), this second element of the PA recommendations is often an overlooked element in messaging and promotion efforts. Throughout the last 50 years, there has been a decline in MF across most developed countries, including the UK (Dooley et al., 2020; Kaster et al., 2020; Sandercock & Cohen, 2018). Furthermore, recent data suggest that most European adolescents do not accrue the recommended dose of PA to develop MF (Bennie, Faulkner, et al., 2021). This presents a potentially missed opportunity to develop MF to facilitate participation in an important and popular form of life-long PA amongst adults (Sport England, 2019), and therefore its promotion is warranted during childhood and adolescence.

Schools are suitable settings to promote MF activity and develop MF (Cohen et al., 2015; Cox et al., 2020; Faigenbaum & McFarland, 2016; Lloyd et al., 2014; Pichardo et al., 2019; Ten Hoor et al., 2016) because they have the facilities and the physical education (PE) curricula to embed health promotion programmes into, irrespective of students' socio-economic backgrounds (CDC, 2012; Love et al., 2019). However, reflecting the primary PA recommendation, to date school-based PA interventions have predominantly attempted to increase aerobic-based PA rather than MF activity. Many of these aerobic-based PA interventions have had limited success, which may reflect them not reaching the target populations as intended (Love et al., 2019; G. A. Ten Hoor et al., 2018).

Despite the role schools and PE have in offering a diverse curriculum that supports life-long PA, there is still a disproportionate global focus on traditional team sports (Hulteen et al.,

2016; Kennedy, Smith, Hansen, et al., 2018). Team sports though, are not representative of adolescents' physical activities during the transition to adulthood and throughout adulthood, with adults favouring activities such as cycling, running and gym-based activities (Hulteen et al., 2016; Sport England, 2019). Moreover, some evidence suggests a disconnect between the physical activities adolescents want to participate in and the physical activities offered in the PE curriculum (Corder et al., 2013; Cox et al., 2021). Where MF activity is included in the PE curriculum there is evidence of its effectiveness. Such success has been reported in Australian adolescents considered 'at risk' of obesity based on PA and screen time behaviours (Lubans et al., 2016). Following a 20 week school-based intervention Lubans and colleagues (Lubans et al., 2016) reported sustained positive changes in resistance training skill competency, motivation for school sport, and reduced screen-time. Additionally, MF activity delivered twice a week for one year during timetabled PE classes resulted in improvements in body composition amongst adolescent boys and girls in Dutch secondary schools (Ten Hoor et al., 2018). However, the efficacy, feasibility, and acceptability of delivering MF activity in UK secondary schools is yet to be investigated.

The central aim of this thesis was to explore and understand how MF activity can be implemented in secondary school PE. The delivery of MF in the school environment has been historically greeted with caution and negative preconceptions. This controversy arose between 1979 and 1987, when the reports published by the NEISS (National Electronic Injury Surveillance System) in the United States yielded some data on injuries in children and adolescents who practised strength training. These publications resulted in MF not being included as a reccomended mode of activity for children and young people (Dooley et al., 2020; Stricker, Faigenbaum, & McCambridge, 2020). Despite evidence since disproving these claims, PE teachers still avoid delivering MF activity during PE (Dos Santos et al., 2021). The avoidance of MF activity may be counter intuitive to the activities adolescent boys have specifically suggested they want to take part in due to the perceived masculine nature of MF (Lubans et al., 2016; Lubans & Cliff, 2011). Therefore, this thesis aimed to: (1) establish the efficacy of school-based muscular fitness (MF) interventions in adolescent boys and the varying forms in which MF activity can be delivered, (2) to explore perceptions of MF activity amongst adolescent boys to better understand the ability and acceptability of participating in MF activity, (3) investigate physical education (PE) teachers' knowledge and understanding of MF activity delivery to better understand MF activity implementation fidelity in the school environment and (4) design and assess the feasibility and acceptability of a suitable intervention to enable delivery of MF activity in schools.

1.2 Conceptual framework

The overall aim of this thesis was to explore and understand how MF activity can be implemented in secondary schools. Previous PA research investigating school-based interventions to increase MVPA have not impacted PA levels across the full day, irrespective of gender or socioeconomic status (Love et al., 2019; van Sluijs et al., 2021). Understanding how MF interventions can be delivered in the school environment is a fundamental concern for health-related research and practice.

To fully understand the complexities of MF activity behaviour the Youth Physical Activity Promotion Model (YPAPM) (Welk, 1999) was utilised to address the broad range of factors that may impact MF activity. The YPAPM is a conceptual framework used to investigate factors that may predispose, reinforce, and enable adolescent PA (Welk, 1999); Figure 1.1). Welk (1999) understood that to effectively promote PA in adolescents a broader focus that explored the predisposing (i.e., questions of “Am I able?”, “Is it worth it?”), enabling (access, environment) and reinforcing factors (family, peer, and teacher influence) was required. This thesis has taken the model and aligned the framework to investigate for the MF aspect of PA. The YPAPM allows for sociocultural dynamics to be taken into consideration whilst recognising the policies and the environment that support opportunity and convenience to MF. Furthermore, Welk et al (1999) acknowledged the importance of peer and parental influence to reinforce PA, which may impact MF and life-long PA (LLPA) participation.

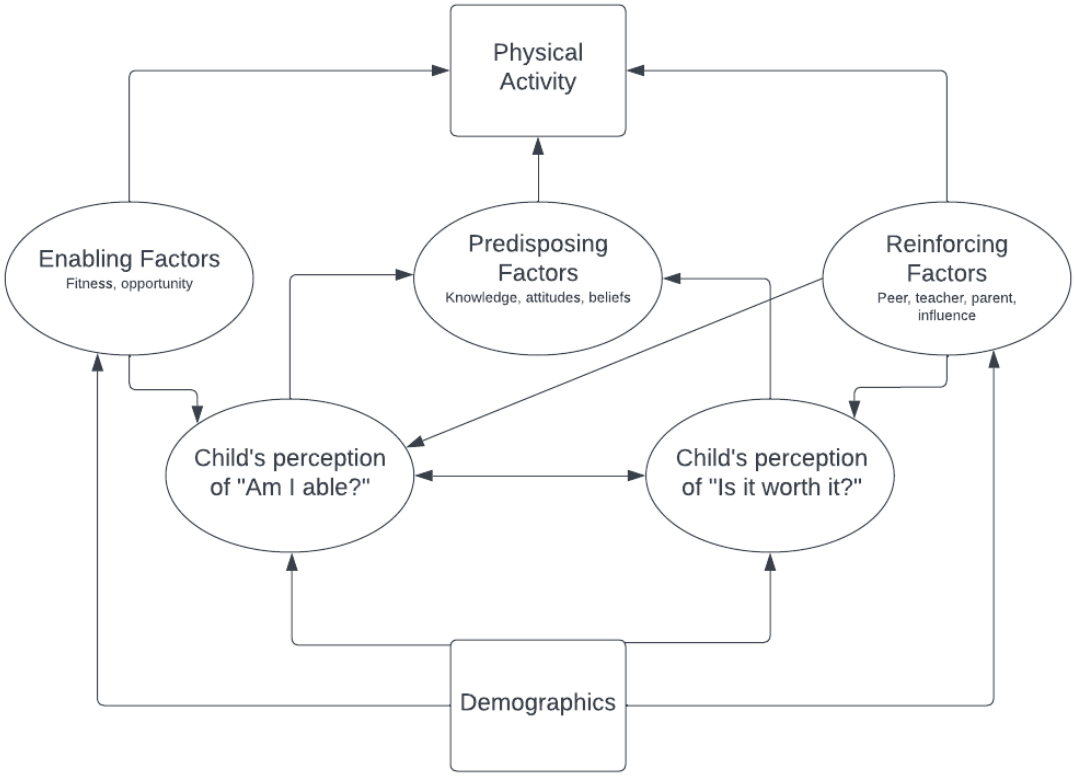

Figure 1.1 - A conceptual diagram of the youth physical activity promotion model (Welk, 1999)

This model supports the notion that to elicit a change to the proposed population with regards to their health-related behaviour and PA status, all factors that impact their behaviour outcomes need to be catered for simultaneously (Belton et al., 2014). Schools are considered an ideal setting to promote lifetime PA (Fairclough et al., 2002; Green, 2002; Hulteen et al., 2015), with PE practitioners key to cultivating positive expressions of PA that can track across into adulthood and should consider all aspects that may act as barriers to involvement and participation. The use of the complex intervention cycle and the YPAPM will ensure thorough investigation into the implementation of school-based MF, accounting for the intended target population whilst ensuring a systematic process. This approach should afford a greater understanding of the MF intervention design relevant to the target population and in context specific settings.

1.3 Organisation of the thesis

This thesis is presented in an order to help inform the direction of the PhD work based on the findings of work conducted. Chapter 1 introduces the research problem. Chapter 2 builds on the Introduction and provides a comprehensive review of the literature. Key topics

discussed during the literature review are adolescent PA, school-based PA, developing MF, the health benefits of MF, school-based MF, PE teachers' ability to deliver MF activity, and continued professional development (CPD) for PE teachers. Chapter 3 (Study 1) is a systematic review and meta-analysis that examines the efficacy of school-based MF interventions in adolescent boys. This chapter has been published as:

Cox, Ashley, Stuart J. Fairclough, Maria Christina Kosteli, and Robert J. Noonan. 'Efficacy of School-Based Interventions for Improving Muscular Fitness Outcomes in Adolescent Boys: A Systematic Review and Meta-Analysis'. *Sports Medicine* 50, no. 3 (15 March 2020): 543–60. https://doi.org/10.1007/s40279-019-01215-5.

Chapter 4 (Study 2) presents a qualitative study that used a novel combination of qualitative techniques to explore adolescent boys' understanding, perceptions, and experiences of MF activity. This study used a dual-method (write, draw, show and tell; WDST) which represents an evolution of the write and draw and focus group method and has not previously been used with adolescents. This chapter has been published as:

Cox, Ashley, Stuart J. Fairclough, and Robert J. Noonan. '"It's Just Not Something We Do at School". Adolescent Boys' Understanding, Perceptions and Experiences of Muscular Fitness Activity'. *International Journal of Environmental Research and Public Health* 18, no. 9 (5 May 2021): 4923. https://doi.org/10.3390/ijerph18094923.

An investigation into PE teachers' perceived expertise and professional development requirements in the delivery of MF activity was conducted in Chapter 5 (Study 3). Based on the findings of Chapters 2-5, an online MF CPD programme was developed with PE teachers to increase MF the level of foundational knowledge required to deliver MF in schools in Chapter 6 (Study 4). Studies 3 and 4 have been submitted for publication and are currently undergoing peer-review. Chapter 7 synthesises the results from each of the 4 studies and discusses the key findings. Finally, Chapter 8 provides recommendations for future research, practice, and CPD development before reflecting on the PhD journey and providing a conclusion.

1.4 Thesis study map

A thesis study map appears at the beginning of each chapter to highlight the key objectives and findings of the studies, and to clarify where each study fits in the overall thesis.

Study	Aim	Outcome
Study 1. Efficacy of School-Based Interventions for Improving Muscular Fitness Outcomes in Adolescent Boys: A Systematic Review and Meta-analysis	To investigate the efficacy of school-based interventions on MF outcomes in adolescent boys	
Study 2. "It's Just Not Something We Do at School". Adolescent Boys' Understanding, Perceptions, and Experiences of Muscular Fitness Activity		
Study 3. PE Teachers' Perceived Expertise and Professional Development Requirements in the Delivery of Muscular Fitness Activity: PE Teacher EmPOWERment Survey		
Study 4. The Feasibility and Acceptability of an Online CPD Programme to Enhance PE Teachers' Knowledge of Muscular Fitness Activity.		

1.5 Thesis contribution and role of the supervisor

Under the primary supervision of Professor Stuart Fairclough (Edge Hill University) and Dr Robert Noonan (University of Bolton), the work comprising this thesis was conducted by the PhD candidate. The four research studies were led by the candidate, from the conception to delivery and conduct, involving: engaging with stakeholders, completing the necessary research ethics processes, data collection, database management and data analysis. The candidate is the first author of both published papers contained in Chapters 3 and 4 and both papers currently under review in Chapters 5 and 6.

In Study 1, Professor Stuart Fairclough, Dr Robert Noonan and Dr Maria-Christina Kosteli all participated in the study design, protocol, and registration of the study. Throughout Study 1 the candidate and Dr Robert Noonan were responsible for selecting articles for inclusion and conducted the risk of bias assessment. The candidate and Dr Robert Noonan were responsible for data extraction during Study 1. The candidate, Professor Stuart Fairclough, Dr Robert Noonan and Dr Maria-Christina Kosteli contributed to the data analysis. The candidate drafted the manuscript and all authors provided critical input and final approval.

Studies 2-4 were conceived and designed by the candidate, Professor Stuart Fairclough, and Dr Robert Noonan. The candidate, Professor Stuart Fairclough, and Dr Robert Noonan performed the data acquisition and analysed the data. Finally, the candidate drafted the manuscript and Professor Stuart Fairclough and Dr Robert Noonan provided critical input and final approval.

1.6 Positionality in relation to muscular fitness

To provide context to how my own ontological and epistemological assumptions may affect the research outcomes and results presented in this thesis, (Darwin Holmes, 2020; Rowe, 2014) I will provide a brief 'autobiography' to explicitly acknowledge my own conscious and unconscious bias (Scheurich, 2014).

I am a 'white' working class male. During my childhood I was in-and-out of the care system as a child exposed to neglect. I was introduced to weightlifting at the age of 11 whilst in the care of an emergency care family. During my stay with this emergency care family, I attended a private school whereby I had to choose an extracurricular activity to engage with as part of my PE. I was deemed not fit for contact sports given my care status and was provided the options of dance, trampolining or weightlifting. My love of weightlifting increased as I lacked the continuity of social circles that allowed for regular team sport participation. This provided the basis for my interest in MF which increased as I aged. Formal education was limited during my adolescence, and I joined the military at the age of 15 and 9 months. My affinity to strength training to enhance MF was further developed as it laid the foundations for my successful attempts at passing some of the most arduous military courses in the world. Whilst serving in the military I was afforded the opportunity to compete at national and international weightlifting and powerlifting competitions and secure multiple podium finishes.

In my final years of military service, I was central to redesigning the injury rehabilitation process for individuals attending the pre-parachute selection course. The redesign was underpinned by knowledge acquired during my undergraduate degrees in Strength and Conditioning, Exercise Science and Exercise Rehabilitation. I proposed to the medical team that some candidates were not strong enough to undertake the arduous selection course and MF should be monitored during the selection and rehabilitation process. I subsequently developed an assessment protocol that was based around the ability of an individual to dynamically control strength, assessing the ability to squat 1.5 times bodyweight or squat 5 repetitions in 5 seconds at 60% of bodyweight (Davies et al., 2015). During the development process I discussed my ideas with Dr Jag Sharma, a member of the medical team investigating medial tibial stress fracture prevalence in young males. I hypothesised that the young males attempting the selection course required structured exposure to MF activity to improve their chances of success and minimise injury. Much of this hypothesis was underpinned by my academic knowledge and personal experiences with MF activity from a young age which I perceived to have supported me in passing various military selection

courses. It was during this period in time where I postulated that young adolescent boys, required exposure to MF to support healthy development and engagement in PA across the life course.

I left the military to further develop my hypothesis and contacted Dr Steve Atkins, a lecturer during my Strength and Conditioning undergraduate degree. Dr Atkins proposed that I contact Professor Fairclough given his expertise in young people's PA and health. Following some initial meetings with Professor Fairclough and Dr Noonan, I was afforded the opportunity to self-fund a PhD related to my area of interest. In June of 2017 I was accepted onto a part-time PhD at Edge Hill university whereby my knowledge surrounding MF activity delivered in schools was challenged during my PhD process. I embarked onto a PhD with an element of ignorance regarding how widely implemented MF is in the curriculum. As a result of my ignorance, it was initially my intent to develop an intervention that would deliver MF activity in schools, which I believed would be straightforward. However, during the development process and literature review, it was evident that MF activity was not given much attention in schools. The lack of attention given to MF as part of PA guidelines at school and at government policy levels resulted in a change of research direction early within the PhD. The result in change of direction allowed me to investigate and gain appreciation for the barriers and facilitators regarding MF activity in schools. The subsequent interactions with PE teachers and adolescents during my PhD informed the research direction. This process allowed me to recognise some of my preconceived bias and ensured the PhD developed in a manner that was organic and aligned with the findings of my research during my PhD. Whilst this autobiography was written retrospectively, it provides the reader with insight into how my past experiences informed the development of this PhD. Furthermore, this autobiography demonstrates how my own ontological and epistemological assumptions were challenged and subsequently altered by virtue of the PhD and research process.

Chapter 2
Literature review

Literature Review

The literature review chapter will provide an overview of the current literature regarding adolescent MF and its associations with physiological and psychological health. Furthermore, it will provide an overview of measures of MF and trends in MF. For the purposes of this thesis resistance exercise (RE), strength training (ST), resistance training (RT) and muscle and bone strengthening exercise (MBSE) will be covered under the term MF activity and will refer to an individual working against a wide range of resistive loads to enhance overall health and muscular fitness (Dos Santos et al., 2021). Additionally, PA will be defined as "people moving, acting and performing within culturally specific spaces and contexts, and influenced by a unique array of interests, emotions, ideas, instructions and relationships." (Piggin, 2020). This broader definition of PA allows for a more holistic approach to ensure a deeper appreciation of the complexities surrounding PA participation, specifically in an educational setting. The term adolescents will be used to define 10-24 year-olds and aligns with the most recent definition to account for adolescent growth and social role transitions (Sawyer & Azzopardi, 2018).

The process of evaluating the current literature will help inform research direction. Additionally, evidence surrounding the challenges and opportunities of social and school environments to conducting MF activity will be discussed to set the context for this thesis. Furthermore, a balanced insight into MF activity and the current PE theoretical framework and its legitimacy into practice is an area that will form the basis of both this literature review and remain prominent throughout this thesis to reflect the practicality and longevity of this research.

2.1 Physical activity guidelines

The current UK PA guidelines for youth aged 5-18 recommend MVPA for an average of at least 60 minutes per day across the week (Davies et al., 2019). Additionally, there should be a variety of types and intensities of PA to develop movement skills, MF, and bone strength with an additional focus to reduce sedentary time (Davies et al., 2019). When investigating the literature surrounding temporal trends in PA amongst youth, there are substantial inconsistencies across and within PA observation initiatives, resulting in varying estimates of the PA situation among children and adolescents at the global, regional, and national levels (Aubert et al., 2021). Despite the reported

discrepancies, it is generally accepted that PA levels amongst youth require improvement (WHO, 2020). It is reported in the Health Behaviour in School-aged Children study (HBSC) that across Europe and North America, less than 50% of youth were meeting the recommended levels of MVPA (Moor et al., 2020). Although HBSC data are self-reported, it suggested that levels of PA decline in young people as they transition from childhood to adolescence. Additionally, device-based measures of PA levels in youth reported elsewhere also suggested that many adolescents fail to meet the recommended levels of PA conducive to improved health outcomes (Cooper et al., 2015). Concerns regarding not meeting the minimum PA recommendations have prompted the medical literature to recognise reduced MVPA levels amongst youth as a condition termed exercise deficit disorder (EDD) (Faigenbaum et al., 2014). This term has been proposed to increase the clinical awareness and seriousness of not meeting PA guidelines as opposed to merely labelling individuals as 'inactive' (Faigenbaum et al., 2014). EDD describes the condition of not meeting MVPA recommendations that are consistent with positive health outcomes (Faigenbaum et al., 2020; Zwolski et al., 2017). Youth deemed to be living with EDD may lack the foundational MF, aerobic fitness, and motor skills to safely participate in sport and recreational PA and are predisposed to increased injury rates (Faigenbaum et al., 2020; Zwolski et al., 2017). In the diagnosis of EDD, poor movement competence and confidence, low levels of MVPA and poor MF are recognised as having a synergistic relationship between one another and require equal attention in overcoming EDD (Faigenbaum et al., 2014).

In an attempt to better understand youth PA, the reported global variations and the factors that may contribute to PA levels, the Active Healthy Kids Global Alliance was established (Aubert et al., 2018). The Active Healthy Kids Global Alliance produced Global Report Cards, which have been implemented across 49 countries as a global matrix with grades being awarded for different components of PA (with an A grade being the highest and F being the lowest) (Aubert et al., 2018). This included reporting on 10 common indicators: overall PA, organised sport and PA, active play, active transportation, sedentary behaviours, physical fitness, family and peers, school, community and environment, and government. Recently, European data from the Global Matrix Report Card were examined in isolation (Coppinger et al., 2020). This paper concluded that it would be useful to develop and share common tools, methods, and instruments to collect data in a uniform way across countries, where possible. However, individual modes of PA are not broken down in this report and there is a lack of clarity on how countries perform on individual PA modes such as MF, aerobic MVPA and

flexibility. Further investigation into individual modes of PA may help inform the direction of future Intervention design.

2.2 Physical activity intensity

Physical activity can be classified according to its intensity (expressed in terms of energy expenditure) as light, moderate, and vigorous (Caspersen et al., 1985; Owens et al., 2016). Data investigating the impact of PA across the life span suggests that participation in higher intensities of PA confer greater health and performance benefits later in life (Landi et al, 2018). Landi et al. (2018) suggest that lower intensity aerobic exercise such as walking, may not be as beneficial when compared with higher intensity exercises such as running and high repetition strength training and/or a combination of different exercises (aerobic and strength training). as higher intensity MVPA for enhancing physical health and performance. However, information regarding PA intensities and the associated energy costs in children and adolescents lack the investigation that has taken place in adult populations. In an attempt to address gaps in understanding Youth PA and the associated energy costs a compendium of energy expenditures for youth was developed in 2008 (Ridley Compendium) (Ridley et al., 2008). Following a literature search and pooled data of energy expenditure measurements in youth, the energy costs of 196 activities were compiled in 16 activity categories to form a Youth Compendium of Physical Activities (Butte et al., 2018). In contrast, the current compendium for adults consists of 821 activities, compared to 196 in the youth compendium (Ainsworth et al, 2011; Butte et al, 2018). PA intensity is categorised by metabolic equivalent (METS). The definition of a MET can be defined as oxygen uptake in ml/kg/min with one MET equal to the oxygen cost of sitting quietly, equivalent to 3.5 ml/kg/min (Ainsworth et al, 2011). In adults, light intensity PA equates to 1.6-2.9 METS, moderate intensity PA is 3-5.9 METS and ≥6 METS vigorous intensity PA (Ainsworth et al, 2011; Tudor-Locke et al, 2009). Furthermore, sedentary behaviour in adults can be defined as an energy expenditure of ≤1.5 METS during a waking day (Pate et al, 2008). However, Ainsworth et al (1993) suggest that adult MET values are not applicable to children and adolescents. Research suggests that this is due to relatively higher resting energy expenditure throughout growth and maturation, with adolescents displaying significantly higher MET values than the conventional 1 MET value used in adults at rest (Melzer et al., 2016). Ridley et al (2008) developed the first compendium of youth energy expenditure to account for these differences in youth energy expenditure. However, such work is in its infancy, with recent calls to action to fill the gaps in the knowledge in order to provide an invaluable tool for public health, policy development and intervention design to improve health and wellness in this population group (Herrmann & Pfeiffer, 2016).

Future research investigating energy expenditure in adolescent boys should ensure adjusted MET values are applied were possible. For example, Table 2.1 provides an overview of MET value adjustments based on average resting energy expenditure for adolescent boys (Harrel et al., 2005). Using the data provided in Table 2.1 will avoid misclassification of adult 1 MET values and provide indicative MET values for adolescent boys (Saint-Maurice et al, 2016).

Table 2.1. Resting energy expenditure (REE) and activity MET thresholds for adolescent males using adult MET values. Adapted from Saint-Maurice et al (2016).

BOYS	REE	SEDENTARY	MVPA
13 YEARS	1.4	2.2	4.3
14 YEARS	1.3	2.0	4.0
15 YEARS	1.2	1.9	3.7
16 YEARS	1.2	1.7	3.5

To date, typical intensities for MF activity lacks sufficient investigation and context regarding energy expenditure estimations based upon MF expression, unlike many aerobic expressions of MVPA (Lazzer et al., 2015; Lazzer et al., 2003). Understanding the energy expenditure of MF activity is an important consideration for MF activity prescription and monitoring weight management. MF activities included in the youth compendium are somewhat limited in their breadth of movements and are limited to push ups, curl ups, bench press, and leg press. However, the difficulties in estimating energy expenditure in youth are also present in adult literature and an area of ongoing investigation (Lytle et al., 2019). This suggests that MF activity warrants further investigation amongst youth to fully understand the energy expenditure costs in conducting a variety of activities covered under the UK and international PA guidelines.

Although limited data exists for energy expenditure calculations in MF activity, there are proposed heart rate and rate of perceived exertion reference points to assist in estimating activity intensity (Raghuveer et al., 2020). However, these reference points are generic and are largely focused on aerobic activity. For example, an adolescent working at 77-95% of their heart rate maximum, or at an RPE of 14-17 is deemed to be working at a vigorous intensity (Ainsworth et al., 2000; Norton et al., 2010; Welk et al., 2011; Williams, 2017). Whilst these estimates are useful, they still lack a degree of specificity to MF activity as reflected in the youth compendium of physical activities (Butte et al., 2018).

Whilst a review of the literature suggests a lack of energy expenditure predictions for MF activity in youth, there remains a healthy and growing amount of literature surrounding MF outcomes. Therefore, until the evidence base in energy expenditure during MF activity is developed, the focus should remain on the outcomes of strength, power, and muscular endurance.

2.3 Adolescent physical activity and health

Adolescent youth aged 10-24 years (Sawyer & Azzopardi, 2018) constitute 24% of the world's population (*World Population Dashboard*, 2019). The benefits of engaging in regular PA for adolescent populations is well established (Janssen & LeBlanc., 2010; Heitzler et al, 2010; Sisson et al., 2009). Research suggests the prevalence of insufficient PA levels amongst adolescents is ~80%, leading to increases in obesity and its associated detriments on health both during and post adolescence (van Sluijs et al., 2021). Whilst it is acknowledged that PA levels are low across all young age groups, adolescence is reported to be statistically correlated with increased declines in PA from age 10 through to 24 (Cooper et al., 2015; Loyen et al., 2017; Steene-Johannessen et al., 2020; Wolff-Hughes et al., 2014). The reported declines in adolescent PA may in part explain the rising obesity levels also reported in this age group (Abarca-GÃ et al., 2017). Given the declining PA levels and rising obesity levels amongst adolescents, adolescent obesity is deemed a public health priority that requires urgent attention to improve health and well-being (Alberga et al., 2011; Azzopardi et al., 2019; van Sluijs et al., 2021). Global age-standardised prevalence of obesity in the 5–19 years range has increased from 0.7% in 1975 to 5.6% in 2016 in girls, and from 0.9% in 1975 to 7.8% in 2016 in boys (Abarca-GÃ et al., 2017). Furthermore, across 40 years, there was a 10-fold increase in the number of girls with obesity (from 5 million in 1975 to 50 million in 2016), and a 12-fold increase in the number of boys with obesity (from 6 million in 1975 to 74 million in 2016) (Abarca-GÃ et al., 2017). PA is a significant contributing factor in the prevention of excessive body mass leading to obesity (Wyszyńska et al., 2020)

In addition to the benefits of regular PA on body composition, regular PA can improve cardiorespiratory fitness (CRF) in youth. CRF refers to the ability of the respiratory systems to supply oxygen to skeletal muscle for energy production (Caspersen et al., 1985). In youth, CRF is a predictor of several health indicators, including cardiometabolic health (Lang et al., 2018; Ortega et al., 2008), premature cardiovascular disease (CVD) (Högström et al., 2014), academic achievement (Santana et al., 2017), and mental health (Lubans et al., 2016; Ortega et al., 2008). It is suggested that international declines in MVPA amongst

youth may explain the downward temporal trend if CRF, raising concerns surrounding the current and future health status of youth (Tomkinson et al., 2019). Whilst the positive impact increasing PA has on CRF is clear, there are further benefits on cardiometabolic markers of health. Declining cardiometabolic health typically follows a sequence beginning with insulin resistance, progressing to metabolic syndrome, pre-diabetes, and finally to CVD and type 2 diabetes (T2DM) (Guo et al., 2014; Sriram et al., 2021). Interestingly, improvements in cardiometabolic health amongst adolescent have been reported following modest improvements in MVPA that align more with the adult guideline recommendations of engaging in 150 minutes of MVPA per week (Sriram et al., 2021). These findings suggest there may be a case for lowering recommended levels of MVPA for adolescents to make them more attainable and less intimidating whilst also supporting the transition to following adult guidelines (Sriram et al., 2021). However, it should be noted, that whilst there has been significant research conducted in traditional aerobic MVPA, MF activity can produce equally favourable health outcomes. For example, strong evidence associated with improving MF and improved bone health, self-esteem and metabolic risk factors has previously been reported (Smith et al., 2014). Low MF contributes to the development of non-communicable disease risk in adolescents, leading to poor health in adulthood including cardiovascular disease, osteoporosis, and type 2 diabetes (Ortega et al., 2008; Smith et al., 2014). Improving MF is associated with a range of health markers including CRF (Alberga et al., 2016; Chung-Wah Yu et al., 2016), metabolic function (Bea et al., 2017; Meinhardt et al., 2013; Smith et al., 2014), bone health (Torres-Costoso et al., 2020) and mental health (García-Hermoso et al., 2019) in youth. However, it is acknowledged that much work is needed to provide longitudinal data and provide context on the type of MF activity that confers specific health outcomes (Smith et al., 2014).

2.3.1 Adolescent physical activity and gender

Objectively measured PA has declined by 7% year on year from the age of 5 until age 18 in boys (Cooper et al., 2015). Furthermore, the pre-pandemic Active Lives Survey for Sport England 2018 reported that 25% of boys aged 9-11 years achieve PA guideline recommendations, whereas only 16% of adolescent boys aged 13-15 years achieved the guideline recommendation of 60 minutes or more of MVPA per day (Sport England, 2018). Additionally, device-based assessment of PA suggests that boys' MVPA levels decrease steeply when transitioning into adolescence and requires further investigation (Corder et al., 2015). Given that boys PA levels are decreasing quicker when compared to girls during adolescence (Corder et al., 2015) and further reports of greater increases in overweight and obesity prevalence among boys when compared to girls (Abarca-GÃ et al., 2017), boys

require a specific focus in PA research. Much of the existing research and policy to promote PA is directed towards adolescent girls, suggesting that boys are at low risk of not meeting the suggested PA levels indicative of good health (Cooper et al., 2015). Furthermore, boys are reported to be at greater risk than girls of becoming overweight or obese, compromising short- and long-term health (De Pelotas et al., 2012; Kansra et al., 2021).

As the literature surrounding MF activity advances, practitioners and researchers alike should remain cognisant of the potential gender bias cultivated from preconceived ideologies of masculine identities associated with MF activity (Lagestad et al., 2021). Universal characteristics of hegemonic masculinities in PE are related to strength and speed, these are often influenced by social factors and are not necessarily the representative of participants views and experiences (Lagestad et al., 2021). Furthermore, the glorification of masculinity in PE may have a negative influence on participation as a result of gendered pressures that may exacerbate insecurities and negatively affect participation across both sexes (Metcalfe, 2018). Whilst there is merit in conducting research with specific sexes to account for physiological differences, the translation of knowledge into practice should avoid gendered habitus based on historical views of gender that may be detrimental to PA and PE participation across both sexes.

2.3.2 Adolescent physical activity and socioeconomic status

Socioeconomic status (SES) measured using adolescent-based (pocket money and academic performance) and family-based (housing tenure, parents education, family affluence) indicators are closely related to health behaviours (Moor et al., 2019). Previous research has found family affluence is positively associated with PA (Borraccino et al., 2009; H. M. E. Foster et al., 2018). However, adolescence cultivates a degree of financial independence from parents (Falese et al., 2021; H. M. E. Foster et al., 2018; Moor et al., 2019). Therefore, it is important that research investigating adolescent PA and health behaviours understands barriers and facilitators to PA from the perspective of adolescents themselves. To date, little research has investigated how adolescent SES specifically impacts PA, often relying on family SES alone as a proxy measure (Bosque-Prous et al., 2017; Falese et al., 2021). Despite the lack of investigation into adolescent SES and PA, it is acknowledged that greater declines in PA have been evidenced among deprived adolescents when using family SES as a proxy measure (Borraccino et al, 2009). Furthermore, unfit adolescents are more likely to be deprived, with qualitative data suggesting cost and access to facilities are barriers to PA (Charlton et al, 2014). Future

research should consider SES and interventions that support deprived population groups that may be at increased risk of not meeting PA recommendations indictive of good health. It has been suggested that schools may provide a safe and accessible environment that allows for PA participation independent of socioeconomic status (Love et al., 2019; Mura et al., 2015; van Sluijs et al., 2021).

Exposure to MF and gym-based PA may only be possible in the school setting for those adolescents from disadvantaged backgrounds due to increasing charges to use public and commercial sports facilities (Ramchandani et al, 2018). The lack of access to public sports and recreation facilities have been found to promote health inequalities (Higgs et al, 2015; Parnell et al, 2015), yet few studies have addressed how adolescents from disadvantaged communities may benefit from MF activity interventions in the schools. Schools may provide an opportunity to reach the majority of adolescents irrespective of background characteristics and socioeconomic status (Love et al, 2018). Engaging adolescents in PA at school may support a life-long willingness to continue engaging in PA following formal education. Therefore, school-based delivery of MF will remain the focus of this literature review.

2.4 Defining muscular fitness

Despite the growing body of literature supporting the health benefits of MF, it is often an overlooked element of the PA guidelines, with much of the focus towards averaging at least 60 minutes of daily aerobic-based moderate to vigorous intensity PA over the week (Bennie et al., 2020; Eliakim et al., 2019). Throughout the last 50 years there has been a downward trend in MF among youth across most developed countries including the UK (Dooley et al., 2020).

MF is a multi-dimensional construct comprising the integrated function of muscle strength, muscle endurance, and muscle power (Pate & Daniels, 2013). Muscular strength is typically defined as the ability of a muscle group to develop maximal contractile force against a resistance and can be expressed in either absolute terms (e.g., 1 RM) or in relative terms by expressing performance relative to body weight. Muscular endurance is the ability of a muscle group to exert sub-maximal force for extended periods. Muscular power incorporates speed and strength and captures work per unit of time (Corbin et al., 2017; Pate & Daniels, 2013; Welk et al., 2022). Development of all MF attributes is dependent on the type of MF activity and the loading parameters prescribed (Suchomel et al., 2018). Strength, endurance, and power can be

enhanced through traditional aerobic MVPA. However, considered loading (intensity) and specific repetition ranges (volume) develop attributes of MF more specifically and are considerations for MF activity design (Corbin et al., 2017; Pate & Daniels, 2013; Welk et al., 2022). Whilst it is acknowledged that specificity of MF activity is required to elicit the desired outcome (i.e., higher volume and lower intensity for muscular strength development), the existing literature often erroneously categorises all MF activity as "strength" (Gamble, 2006). This oversight in the current literature may lead to ineffective MF intervention design and requires further investigation.

2.4.1 Muscular fitness and aerobic physical activity

As discussed earlier (section 2.1) the role of MF in enhancing MVPA levels is recognised as a synergistic relationship and regarded as crucial to overcoming EDD (Faigenbaum et al., 2014). In recognition of the interrelated components that drive physical inactivity in youth, the paediatric inactivity triad (PIT) was proposed (Figure 2.1) (Faigenbaum et al., 2018).

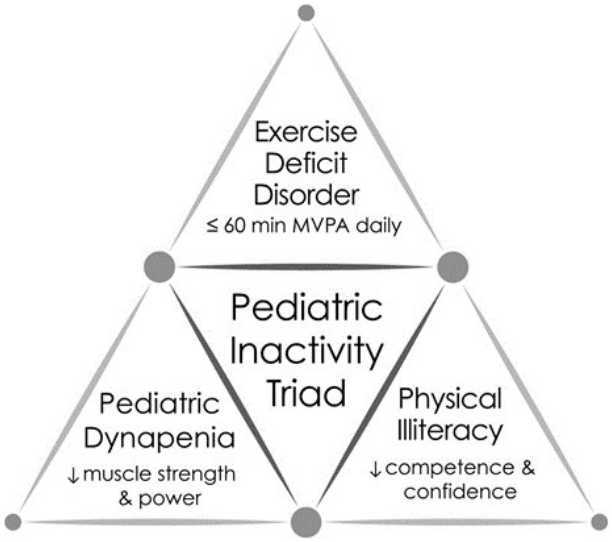

Figure 2.1 Paediatric Inactivity Triad

The PIT acknowledges three separate but inter-related components that contribute to physical inactivity: 1) exercise deficit disorder (EDD), 2) paediatric dynapenia, and 3) physical illiteracy (Faigenbaum et al., 2018). The PIT proposes that these three elements interact and ultimately, should be viewed collectively to better effect change in PA levels among youth (Faigenbaum et al., 2018). It should be noted that all components of the PIT are interrelated and modifiable through exposure to a variety of PA, which aligns with the current UK PA guideline recommendations (Davies et al., 2019). Despite current

UK and international guidelines implicitly acknowledging the inter-related components that effect change in overall PA, there remains an overarching focus on aerobic MVPA (Eliakim et al., 2019).

Whilst the proposed PIT framework attempts to help understand and address the pandemic of physical inactivity in modern-day youth, it is yet to be validated and some elements lack empirical evidence. In particular, the term “Paediatric Dynapenia” lacks supporting evidence for its conception, context and cut-off points for a subsequent diagnosis. Indeed, it is acknowledged that MF is declining amongst some young people (D. Cohen et al., 2011; Dooley et al., 2020b; Kaster et al., 2020; Sandercock & Cohen, 2019). However, the term dynapenia is typically defined as age-associated muscle strength that is not a result of neurologic or muscular disease (B. C. Clark & Manini, 2012). Whilst the PIT attempts to address the interplay of decreased MVPA, poor MF and a lack of physical literacy, more work is required to align with appropriate and contemporary terminology to fully support its use.

Despite the links between MF and habitual PA, there is a paucity of interventions. One study which did investigate links between MF development and habitual PA was conducted with 102 participants (42 girls and 60 boys) in Switzerland (Meinhardt et al., 2013). The participants conducted 2 strength-based sessions per week for 19 weeks. The study concluded that strength training significantly increased daily habitual PA behaviour in boys. The less active children showed the greatest increase in spontaneous PA. However, girls showed a similar increase in strength measured through leg and arm strength, but not in spontaneous PA (Meinhardt et al., 2013). The maximum strength of the lower body in this study was determined on a seated leg press (TECA, ROM prestige, Ortona, Italy) and for the upper body on a Cybex smith press (Cybex; Owatonna, MN) by 1 repetition maximum testing. Whilst the study did indeed investigate the strength element of MF, it fails to recognise muscular power and endurance and may have missed other adaptations that contribute towards MF. When reviewing the exercise prescription, there is a possibility that elements of muscular endurance may have increased due to the nature of high repetition ranges (15 repetitions), yet this was not acknowledged in this study. A further study investigating the link between PA and MF conducted with 46 adolescent boys from an ice hockey team in Switzerland reported increases in PA after a 12 week MF activity intervention (Eiholzer et al., 2010). The boys who participated in the twice weekly programme had significant increases in PA levels when compared to the control group.

Overall, these findings demonstrate the interrelated aspects of MF and device-based PA measures. However, the literature suggests that adolescent boys may be more receptive to MF activity interventions if the aim is to increase device-based measures of PA and further supports the need to investigate the role MF has to play in adolescent boys' PA (Lubans et al., 2016; Lubans & Cliff, 2011).

2.4.2 Assessing muscular fitness

The assessment of MF is a complex and multifaceted area of investigation where specificity of measurement is as important as the prescription of MF activity itself (De Ste Croix, 2012; Welk et al., 2022). Given that MF assessments are specific to the muscle group, type of muscle action, muscle contraction, contraction velocity, equipment, joint and muscle range of motion (Dooley et al., 2020), this literature review will cover three of the most common measures for power, strength, and endurance that are appropriate to be used in a school environment. The efficacy of MF activity is underpinned by appropriate testing and assessment to progress individuals safely (A. Cox et al., 2020). Therefore, developing an understanding of testing and assessments of MF may lead to increases in the quantity and quality of MF activity and provide a non-invasive objective assessment of the impact of school-based MF interventions in particular (Keating et al., 2020; Yager et al., 2021). However, in schools, tests and assessments in PE have been highly contested (Cohen et al., 2015; Yager et al., 2021). Youth sport experiences similar problems whereby the expertise of coaches to conduct measurements of MF and their ability to interpret them is key to the usefulness, application and necessity of MF assessment (Welk et al., 2022).

Many challenges surrounding assessments of MF are centred around the complexities of youth growth and maturation (Lloyd, Oliver, et al., 2014). These challenges are further exacerbated when working with adolescents as the timing of puberty can differ by up to five years between individuals of the same sex (Lloyd, Oliver, et al., 2014; Welk et al., 2022). However, during adolescence an opportunity exists for neural and architectural adaptations in the development of MF due to increases in anabolic and hormonal concentrations centred around peak height velocity (PHV) (Moran et al., 2017, 2018). Available literature suggests that boys demonstrate improved MF activity ability as they age, across a range of MF outcomes indicative of increased type 2 muscle fibre recruitment capability, aligning with PHV and peak strength velocity (Moran et al., 2017; Radnor et al., 2020). Furthermore, current literature also suggests that whilst there are physiological advantages to conducting MF activity with adolescent boys, this population may also be a suitable target group for MF activity in response to the perceived masculine nature that adolescent boys ascribe to MF

activity (Lubans et al., 2016; Lubans & Cliff, 2011). Despite the proposed advantages to conducting MF activity with adolescent boys, there remains a dearth of literature investigating the efficacy of MF interventions and investigation into the thoughts and perceptions of adolescent boys regarding MF activity.

To date, much of the research surrounding MF and MF assessments has focussed on bodyweight movements, counting the increase in repetitions as a marker of progression and improvement in MF. However, performing bodyweight assessments in adolescents may only provide an assessment of relative strength and overlook other areas of MF such as absolute strength and power (Ten Hoor, Plasqui, et al., 2016). Furthermore, the assessment of relative strength alone does not provide an opportunity for overweight or obese adolescents to demonstrate their superior levels of absolute strength when compared against their normal weight counterparts (Tomlinson et al., 2016). It is understood that overweight and obese adolescents may display higher levels of absolute strength and power over their leaner counterparts which should be assessed through power output which accounts for body mass (Hoor et al, 2016). Such opportunities can be derived from assessing power and include the vertical jump, specifically, the counter movement jump (Gomez-Bruton et al., 2019). However, the vertical jump is often reported as the value in height and fails to report the power generated by the individual to conduct the movement (Gomez-Bruton et al., 2019). Adolescents who are overweight or obese, may evoke a higher power output for a similar vertical jump height when compared to leaner adolescents (Hoor et al, 2016; Nuzzo et al, 2009). Therefore, lower-limb power output in addition to the achieved vertical jump height may provide a better understanding of the relationship between body mass, absolute and relative strength in adolescents. Other common measures of MF include hand grip strength and variations of a sit-up test to measure strength and muscular endurance respectively, both of which can be conducted in a field-based setting such as schools.

2.4.2.1 Assessing lower limb power in adolescents

Lower limb power is typically measured using the counter movement jump, relying on the height of the jump as a proxy measure of power (Gomez-Bruton et al., 2019; Welk et al., 2022). From a standing position, with the feet slightly apart and the hands placed on the hips, the adolescent would perform a counter movement with the legs before jumping. To estimate peak muscle power more accurately a simple calculation that has been validated with adolescents can be applied (Gomez-Bruton et al., 2019). Power can be calculated from taking the vertical jump height and body mass of the individual, placing the raw scores into

the following format: Power (W) = 54.2 x VJH (cm) + 34.4 x body mass (kg) – 1,520.4. This will allow the practitioner to account for body mass and get an accurate representation of lower limb power output. However, it should be acknowledged that the researcher or practitioner should be aware of how to conduct and interpret the protocol which requires a level of training and understanding.

2.4.2.2 Assessing abdominal endurance in adolescents

Common measures of abdominal muscular endurance are reported in the literature and consist of three main protocols (Moya-Ramón et al., 2018). The three commonly used tests of abdominal endurance are: a) “timed” protocols, which consist of performing the maximum number of abdominal flexions as possible (e.g., curl-ups, cross-curl-ups, or sit-ups) in a given time (30–120s) (Brotons-Gil et al., 2013; Knudson & Johnston, 1995, 1998; Sidney & Jetté, 1990); b) “cadence” protocols, consisting in the maintenance of a certain cadence while executing trunk flexion or extension motions for as long as possible (Moreland et al., 1997); and c) “isometric” protocols, consisting of maintaining a prone, supine, or lateral posture against gravity until exhaustion (Evans et al., 2007; Ito et al., 1996; McGill et al., 1999). Although measures of trunk strength are simple to conduct in a field-based setting, researchers and practitioners may be discouraged by the lengthy familiarisation process required for accurate reproducibility and standardisation (Brotons-Gil et al., 2013). Indeed, many of the international test batteries used to assess health related fitness include normative data stratified by age and gender to assist in interpretation (‘FitnessGram Administration Manual’, 2017; Knaggs, 2002).

2.4.2.3 Assessing hand grip strength in adolescents

Hand grip strength testing using a dynamometer is deemed to be an inexpensive and effective measure of overall strength that is recommended for school-based assessments (Dooley et al., 2020; Ruiz et al., 2011). The assessment consists of adjusting the grip-span to suit the hand size of the participant. The participant is then asked to squeeze the dynamometer continuously as hard as possible for 3s with the elbow in full extension down by the side of the body (España-Romero et al., 2010; Roberts et al., 2011). This method of assessing hand grip strength is deemed the most reliable protocol to assess hand grip strength in adolescents (España-Romero et al., 2010). Whilst it is acknowledged that hand grip strength is influenced by age, sex, hand size, grip span, posture, position of the elbow, forearm and wrist orientation, the arm by the side method provides the most appropriate protocol to account for such differences and accounts for differences in brand of dynamometer (España-Romero et al., 2010; Roberts et al., 2011).

Whilst the three methods of assessing MF covered are deemed relatively simple and suitable for the school environment, it is not understood the degree to which PE teachers use such protocols. Furthermore, there is no exiting literature investigating how and indeed if, teachers use such measures to monitor students and inform MF activity programme design. This is an area that requires further investigation to support PE teachers in the delivery of school-based MF interventions and ensure implementation fidelity.

2.4.3 Developing muscular fitness

Adolescence is a key period for developing muscular fitness activity competency. Effective promotion of muscular strength, endurance and power, enabling adolescents to perform bodily movements more efficiently and effectively will ensure MF is developed (Stricker, Faigenbaum, & McCambridge, 2020). With the growing body of evidence surrounding the benefits of MF there are concerns regarding the misuse of the term “strength training” and “resistance training”, with much of the current literature in youth overlooking the principals of specificity and the subsequent adaptation in MF (i.e., strength and power) (Cox et al., 2020; Moran et al., 2017; Gamble, 2006). The development of MF is dependent on the type, frequency, intensity (load) and volume (amount) of MF activity conducted (Suchomel et al., 2018). Traditionally prescription of MF activity is aligned to a “repetition continuum”, which recommends a volume and intensity scale to elicit a specific adaptation (Coffey, 1946; Haff, 2016). The general concept of the “repetition continuum” is higher volume and low intensity MF activity will induce endurance adaptations, with low volume and high intensity more aligned to power adaptations. However, this continuum has been recently challenged (Schoenfeld et al., 2021) and much of the work conducted to date involves young men and is not generalisable to adolescents.

Regarding MF delivery in youth guidance for MF activity prescription is provided in the form of an international position statement (Lloyd, Faigenbaum, et al., 2014), which was adapted from the original UK Strength and Conditioning (UKSCA) position stand. Since the inception of the international position stand, there have been very few changes. The international position stand brings together leaders in the fields of paediatric exercise science, paediatric medicine, physical education, strength and conditioning and sports medicine to provide guidance around an area of PA that has been overlooked (Lloyd, Faigenbaum, et al., 2014). More recently, this position stand has been adapted by the American Academy of Paediatrics to provide further guidance on the appropriate prescription of MF activity in youth (Stricker, Faigenbaum, McCambridge, et al., 2020). The following training variables

are provided for consideration when developing MF in youth and consider the major position stands that provide MF activity guidance:

2.4.3.1 Exercise selection

Similar to existing literature surrounding adult MF exercise selection (Suchomel et al., 2016, 2018, 2019), there is an emphasis on the principles of suitability and familiarity of equipment and movements carried out. It is suggested that when youth are competent in moving their bodies (i.e., lunging, squatting, press-ups and pulling movements) and can respond to coaching cues, traditional forms of MF activity (i.e., weightlifting, free weights and plyometrics) can be introduced (Lloyd, Faigenbaum, et al., 2014). To develop competency in movement and to support the development of youth with minimal MF activity experience (termed a low training age), it is suggested that motor skill competency is assessed and developed prior to conducting more complex MF activity movements such as weightlifting (i.e., snatch and clean and jerk) (Lloyd, Faigenbaum, et al., 2014). For youth with previous MF activity experience (high training age), it is suggested to select exercises that possess dynamic qualities and can be enhanced through multi-joint exercises that are velocity specific and typically come in the form of weightlifting and plyometric type movements (Faigenbaum et al., 2007; Lloyd et al., 2012). It is acknowledged that whilst exercise selection is necessary to elicit specific adaptations (Faigenbaum & McFarland, 2016), supervision of exercises can result in improved movement quality and improvements in MF (Coutts et al., 2004; Klusemann et al., 2012; Smart & Gill, 2013). Furthermore, the supervision of MF activity in a controlled environment may ensure the safety of movements conducted and increase the efficacy of MF activity (Peitz et al., 2018).

2.4.3.2 Training volume and intensity

Successful MF outcomes are dependent on the manipulation of volume (total number repetitions) and intensity (the weight being moved) (Lloyd, Faigenbaum, et al., 2014). The dose-response relationship between MF activity intensity and improvements in motor performance, such as running, jumping, and throwing, in adolescents has been reported in previous literature (Behringer et al., 2011). Furthermore, the relationship between intensity and volume prescription is inverse whereby increased load (intensity) requires lower volume (number of repetitions) and both variables must be considered together to avoid injury (Behm, Faigenbaum, Falk, & Klentrou, 2008; Carpinelli, 2012; Faigenbaum et al., 2016; Grgic et al., 2018). To prescribe volume and intensity PE teachers and youth sport coaches need to assess 1 repetition maximum (1RM) and assign a load based on a percentage (Faigenbaum et al., 2013; Myers et al., 2017; Radnor et al., 2018). However, whilst maximal

strength assessments in youth are deemed safe and appropriate (Faigenbaum et al., 2003, 2012) some PE teachers may be put off conducting such assessments due to their perceived complexity and lack of MF activity knowledge (Welk et al., 2022). However, simple field-based measures of MF such as those described in section 2.4.2 can provide an assessment to inform MF activity prescription by monitoring MF progression. Previous literature suggests that vertical jump and hand grip strength are correlated to 1RM strength values in youth (Castro-Piñero et al., 2010; Milliken et al., 2008). This approach, whilst not as accurate as 1RM, may serve as an appropriate measure of MF to inform prescription and monitor progression in school and recreational settings.

2.4.3.3 Progression of volume and intensity

The starting volume and intensity for youth is dependent on training age and technical competency (Welk et al., 2022). However, it is generally accepted that all youth start at a low intensity and volume irrespective of training age until the PE teacher or coach can verify their technical competency to progress (Faigenbaum et al., 2013; Myers et al., 2017; Radnor et al., 2018). Low volume (1-2 sets of 1-3 repetitions) and low intensity (under 60% of 1RM) is recommended to start multi-joint movements such as squatting (Lloyd, Faigenbaum, et al., 2014). Once movement competence is achieved, the individual can be progressed to 2 to 4 sets of 6 to 12 repetitions with a low to moderate training intensity (under 80% 1 RM). Advanced youth can finally progress to lower volume and higher intensity provided that the individual is competent in the movement being conducted. It is generally accepted that intensity increases of 5-10% are reasonable, provided that the individual can comfortably carry out 15 repetitions at the previous weight. Once the intensity has been increased, the volume is dropped back down and gradually progressed until meeting 15 competent repetitions and once again increasing intensity.

To assist PE teachers and youth sport coaches in the development of youth MF activity prescription, the resistance training skills competency (RTSC) framework (Figure 2.3) and an associated checklist has been developed (Faigenbaum & McFarland, 2016). The RTSC framework provides recommendations based on each participant's resistance training skill competency and muscular strength. Additionally, the supporting checklist can be used to assess exercise performance and communicate the specific actions and behaviours that are required for this exercise. Whilst it is evident the tools to assist PE teachers and youth sport coaches exist in the literature, it is not fully understood if and how these tools are applied and the extent of the ability and knowledge of the same practitioners to prescribe MF activity safely and effectively. Further research is required to provide insight into current

knowledge levels of PE teachers to highlight areas of development in the delivery of MF activity.

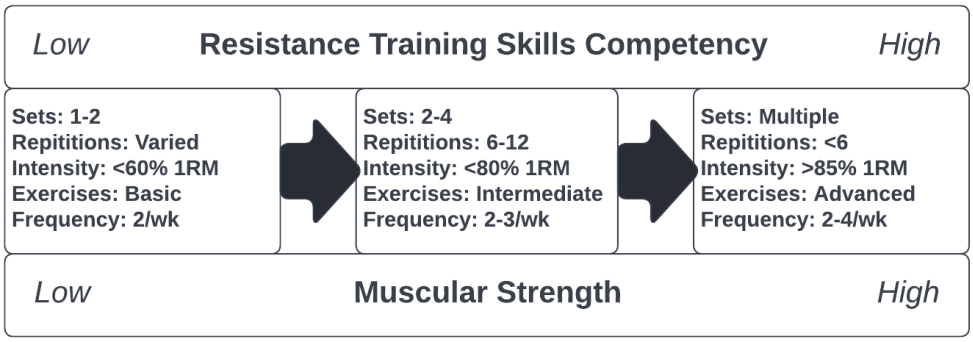

Figure 2.3 Resistance training skills competency framework

2.4.4 Adolescent muscular fitness benefits and risks

In recent years, the importance of MF activity for the healthy development of youth has received increased attention, leading to rapid evidence reviews conducted by Public Health England (Chalkley, 2021). The importance of understanding specific MF outcomes and the association with indicators health is of paramount importance for informing future programme design and delivery. For example, it has been reported that strength (the ability to produce force against an external resistance) may reduce levels of disability and cardiovascular disease in later life if appropriately developed during adolescence (Henriksson et al., 2018). Additionally, power (the ability to accomplish muscular work per unit time) is regarded as fundamental in combatting physical declines associated with sarcopenia and maintaining mobility and performance for everyday life in older adults (Fielding et al., 2011; Quinlan et al., 2018). However, as we age muscular power declines at a faster rate than muscular strength, directly impacting health and quality of life and further supporting the need to investigate specify of MF outcomes and their association with indicators of health (Alcazar et al., 2018; Cadore & Izquierdo, 2018).

Throughout adolescence it is recognised that the development of MF is not homogenous, with muscle morphology, androgen levels, growth, and maturation all contributing to the development of strength and power throughout the development process (Lloyd, Faigenbaum, et al., 2014; Myers et al., 2017). The associations between strength and power and indicators of health are yet to be fully investigated in adolescents in the presence

of the inherent MF development heterogeneity associated with the growth and maturation process. The associated health care costs and accompanying pathologies support the need to address the downward trend in MF currently reported amongst UK adolescents (Cohen et al., 2011; Sandercock & Cohen, 2018). Improvements in MF have been associated with improvements in cardiorespiratory fitness (Alberga et al., 2016; Chung-Wah Yu et al., 2016), metabolic function and efficiency (i.e., glucose transport capacity and lipid oxidation) (Bea et al., 2017; Meinhardt et al., 2013; Smith et al., 2014) and bone health (Torres-Costoso et al., 2020) in youth. Given the strong association between MF and health, it would be prudent to provide further context on what aspects of MF are aligned with established indicators of health in order to inform appropriate use of field-testing protocols and programme design. However, whilst understanding the association between specific measures of MF and health is indeed a priority, it should be noted that MF intervention evidence is still lacking. Future research should ensure specific measures of MF are reported and a move away from erroneous categorisation of strength training is required (Steele et al., 2017).

Recently, MF activity has been associated with long term health benefits when exposure to a training stimulus occurs during adolescence as part of organised PA (García-Hermoso et al, 2019). Some of the health benefits include reductions in fat mass, increased bone density and improvements in psychological health (Fedewa et al, 2011; Whitelaw et al, 2010, Collins et al, 2016). Much of the existing PA literature focusses on traditional aerobic MVPA (such as ambulatory activities such as walking, running, playground games, invasion game sports, etc) which is associated with health benefits such as decreased adiposity, reductions in metabolic syndrome and type 2 diabetes later in life (Mintjens et al, 2018; Ruiz et al, 2009; Poitras et al, 2016). Although evidence acknowledges MF interventions for enhancing health and PA, recent research expresses a need to further investigate the role of resistance-based exercise and its application to adolescent populations (Kennady et al, 2017; Smith et al, 2016).

Although the health benefits of MF are well supported within the literature, concerns regarding the safety and efficacy of MF activity still exist in schools (Cohen et al., 2011). These concerns may prevent MF activity from being conducted in schools and further exacerbate declines in MF witnessed in English school children (Cohen et al., 2011). For example, Cohen et al (2011) reported declines in MF by up to 27% when assessing muscular endurance at the hip flexor and trunk muscles in English school children during the 30 second sit up test. Furthermore, handgrip strength and bent arm hang also displayed

a loss of 6.3% and 25.9% respectively over a 10-year period. Recent research supports the reported declines in muscular fitness and suggests English school children are not exposed to PA that supports the development of MF (Sandercock & Cohen, 2019). Therefore, further research is warranted to explore the efficacy and effectiveness of MF interventions in adolescent school children.

2.4.4.1 Psychosocial health and muscular fitness activity

Psychosocial health has been shown to be positively impacted when engaging in structured PA (Biddle et al, 2011; Morgan et al, 2012). Improved self-efficacy, reductions in anxiety and depression and improvements in self-esteem and PA enjoyment are all indicative of PA (Kennedy et al, 2017; Fedewa & Ahn, 2011; Whitelaw et al, 2010). In adolescents specifically, PA is associated with increased academic performance, increased self-efficacy and lower depression and behavioural issues in adolescents (Spruit et al, 2016). Furthermore, improving MF is associated with positive psychological health in adolescent populations, including improved confidence and self-efficacy and reduced anxiety (Collins et al., 2019; Faigenbaum & Myer, 2010; Padilla-Moledo et al., 2012). Although some research shows positive responses in psychological health following MF interventions, data is still limited and warrants further investigation (Hoor et al, 2016). In the available literature positive changes in adolescent psychological health have been reported following MF interventions and include increased confidence and self-efficacy (Scranz et al, 2013; Velez et al, 2010).

It is suggested that adolescent boys may be more inclined to engage in MF activity due to the perceived masculinity of these movements (Lubans et al, 2016). Long term compliance of PA must focus on what individuals *like to do* and less on what they *have to do* leading to intrinsically motivated participation in PA (Fishbein et al, 2010; Vansteenkiste et al, 2007). Given the reported inclination to participate in MF activity from adolescent boys, it would be prudent to explore this relationship further to understand if it could act as an entry to engaging adolescent boys in other forms of PA. Formal PE may be an individual's only exposure to PA (Sutherland et al, 2014) and therefore, must seek to elicit a positive psychological response if PA is to become habitual (Xiang et al, 2017). Studies have shown that if students are positively engaged in PA by enhancing enjoyment, engagement and performance through PE, PA increases (Bryan et al, 2007; Sun et al, 2010). Furthermore, insufficient PA remains a contributing factor to obesity and its associated health problems (Swinburn et al 2011; Kremers et al, 2005). Therefore, it is important to develop PA interventions that will enhance the self-perceptions of adolescents already disengaged,

overweight and with poor experiences in relation to PA. Many obese and disengaged individuals avoid PA as most current activities are aerobic in nature, thus excluding those individuals who possess a higher fat mass (Faigenbaum, 2007; McManus, 2012). There is a growing body of literature that indicates youth with a higher fat mass are also subject to a higher fat free mass, in turn placing them in a favourable position compared to their leaner peers with regards to MF activity by virtue of absolute strength (Colella et al, 2009; Riddiford-Harland et al, 2006). By combining the physiological adaptations of MF such as increased limb control and kinaesthetic awareness, with improved self-perceptions in competency, this may encourage individuals who perceive themselves proficient in MF to actively pursue different types of MVPA (Bea et al, 2017; Schranz et al, 2014; Serdula et al, 1993). Whilst it is postulated that MF activity may be an attractive form of PA to overweight and obese adolescents in addition to adolescent boys in general, the role of self-determination theory in MF activity is overlooked in adolescents (Ten Hoor, Plasqui, et al., 2016). It has been suggested that MF activity may provide an opportunity for a form of PA that is aligned to what adolescent boys *want to do* whilst also providing an inclusive form of PA that accommodates overweight and obese adolescents (Hoor et al., 2016; Ten Hoor et al., 2017; Ten Hoor et al., 2018; Ten Hoor, Plasqui, et al., 2016). Collectively, the greater involvement, intent and ability to conduct MF activity competently alongside peers may allow for elements of self-determination theory (SDT) to be satisfied.

Self-determination theory (SDT; Deci & Ryan, 1985) is a framework commonly utilised to examine the relationship between motivation and PA (Owen et al., 2014). The need to cater for what individuals *like to do* is further supported by the notion that the development of positive self-perceptions, leading to increased enjoyment may contribute to increases in habitual life-long physical activity (LLPA) (Weiss & Ebbeck, 1996). SDT is made up of 3 components; competence, relatedness and autonomy, by satisfying all of these basic psychological needs an individual can secure optimal psychological health and functioning (Deci & Ryan, 2000). Competence is how one feels towards the task when reflecting upon the level of mastery. A sense of mastery may be present in adolescents with a higher fat mass when taking part in MF due to their higher fat free mass allowing them to outperform their leaner peers (Babic et al., 2014). Furthermore, potential improvements in kinaesthetic awareness, limb control and MF may increase competence in PA and catalyse future PA participation in overweight, obese and previously sedentary adolescents (Bea et al., 2017).

The second element of SDT is that of autonomy, this is the level of perceived control for the individual. RE involving load being added as the adolescent increases in actual

competence, can expect to see loads of up to 5-10% added once the individual can comfortably perform 15 repetitions of a given movement whilst maintaining correct form (Faigenbaum et al, 2016; Dahab & McCambridge, 2009). This method of adding load to progress the intensity of the MF allows for greater perceived autonomy, whilst ensuring loads are not increased dramatically allowing for safe progressions. The perceived control that the adolescent has over their load increases allows for an approach that places a degree of autonomy on the individual. This method of increasing load may be conducive to supporting autonomy with regards to exercise progression, allowing individuals to regulate the PA outcome themselves may enhance the intrinsic appeal (Edmunds et al., 2006; Koestner et al., 2002). By allowing for an amount of autonomy within the curriculum and ultimately the expression of PA, it supports the participant in the decision-making process, allowing them to make the choices they want.

The final element of SDT is relatedness, MF activity may allow the participant to feel part of the process alongside their peers, which may increase PA participation (Cuevas et al., 2016). Relatedness refers to the feeling of closeness and belonging to a social group. MF activity may catalyse positive feedback from peers when considering that previously disengaged and overweight youth may outperform some of their leaner peers, allowing them to feel part of the social group (Faigenbaum, 2011). This connection and feeling of acceptance from peers, whether it be through increases in motor control or by virtue of a higher fat free mass may support the promotion of PA in adolescents (Babic et al., 2014). However, whilst it is hypothesised that overweight adolescents may benefit from being provided the opportunity to outperform their leaner peers, PE and PA participation should remain balanced. The balance of providing opportunities for all adolescents, irrespective of body type, can be achieved by providing a varied curriculum and moving away from the current overemphasis on team sports and aerobic MVPA (Ten Hoor et al., 2017). Furthermore, whilst such social comparisons are not to be encouraged in schools and PE, they are an unavoidable aspect of school life (O'Keefe et al., 2013). Indeed, given the lack of focus currently on MF in schools, there may be a chance for adolescents to develop MF together and build competence in an activity whereby previous exposure has been limited (Ten Hoor et al., 2018). Given the incompleteness of the current evidence base surrounding MF activity and psychological correlates and determinants it would be beneficial to contextualise them using a socioecological model. Socioecological models provide a framework to understand the various personal, social and environmental factors that facilitate and restrict adolescent physical activity (Abdelghaffar et al., 2019; Sallis et al., 2006; Welk, 1999). These factors are represented in the Youth Physical Activity Promotion

Model (YPAPM) (Welk, 1999). The YPAPM socio-ecological approach provides a framework that goes beyond investigating individual factors associated with physical activity, allowing for the social and built environment to be considered and inform future intervention design. Applying the YPAPM to future investigation into MF activity improve understanding on factors that may predispose, reinforce, or enable participation in MF activity. To date, no research has explored adolescent boys' understanding, perceptions, and experiences of MF activity. Therefore, further work in this area is warranted to help inform future intervention design.

2.4.4.2 Muscular fitness and motor skill

It is understood that motor skill is a correlate of PA, with youth possessing high levels of motor skill engaging in more PA than their less able counterparts (Robinson et al, 2015; Stodden et al, 2008; Wrotniak et al, 2006). Failing to develop adequate motor skill during adolescence may result in poor fundamental movement skills and a lack confidence and motivation to engage in PA (De Meester et al, 2018). Motor skill developed through MF activity may help support further participation in various forms of PA and engage adolescents in on-going PA (Smith et al, 2015). The development of MF provides both functional (changes in motor unit coordination) and structural (muscle hypertrophy) changes that impact motor skill (Behringer et al., 2011) and develop motor skill and fundamental movement skills such as jumping, throwing and balancing (Lubans et al., 2010). Such adaptations have resulted in improvement in jumping, running and throwing following structured MF activity (Behringer et al., 2011). It is suggested that if MF activity is not conducted during adolescence there is a potential for motor skill competence and ultimately PA to decrease further over time (Craig et al, 2012; Hands, 2008). To allow adolescents to participate in all expressions of PA, there is a need to develop motor skill and movement confidence in the first instance, allowing for the development of prerequisite skills that are indicative to participating in varying forms of PA later in life (Faigenbaum et al, 2013). Involving adolescents in MF activity may help suppress the inverse relationship between motor skill performance and the prevalence of overweight and obesity through reductions in PA (Lopes et al, 2011; Hardy et al, 2013).

2.5 Life-long physical activity

LLPA is defined as activities that carry over from childhood into adulthood, require minimal equipment, and are generally reserved for one or two people (Ross et al, 1985). Schools play a key role in catalysing successful LLPA outcomes (Kennady et al, 2017) and

promoting the types of gym-based activities adolescents are likely to encounter post formal education (Sport England, 2019). Allen et al (2016) found that PE stakeholders in America agreed that traditional resistance-based MF activity ranked within their top three priorities when considering what LLPA content to deliver within the curriculum. Likewise, gym-based activities rank highly in adult life (Sport England, 2019) and the presence of MF activities remains in both adolescent and adult PA guidelines, supporting the need to explore the role of MF activity within the PE curriculum and schools.

Although schools are achieving a B+ in the recent report card on youth PA, questions remain as to the efficacy of PE in the promotion of LLPA (Standage et al., 2018). The current UK curriculum is underpinned by traditional competitive team sports with little bearing on the LLPA that students will likely take part in upon leaving formal education (Green, 2014). Although team sports are enjoyed by many, competitive team sports may fail to engage the least active and skilled youth (Green, 2014). Team sports, although integral to PE, generally lack significant carry over into adult life and the opportunity to take part in organised sports drops off significantly post formal education (Kjonniksen, 2008). Moreover, team sports appear to be on the decline when exploring habitual PA outside of the school environment, resulting in a D+ grade in organised sport participation on the recent PA report card (Standage et al., 2018). Moreover, in the recent Active Lives Survey, only 50% of adolescents between the ages of 11 and 16 participated in team sports (*Sport England,* 2021). Interestingly, the same report also documents a 7.1% increase in gym-based or fitness type activity, a recognised form of LLPA, with 29% of adolescents now participating in gym-based activity. Fairclough et al (2002) raised concerns over the contribution of PE to the promotion of LLPA in North West secondary schools. Fairclough et al (2002) went on to suggest that PE should develop LLPA as part of the curriculum in order to increase exposure of activities that adolescents may face in adult life. Furthermore, Hills et al (2015) highlighted the potential schools have to develop the necessary skills and knowledge to sustain an active life beyond formal education.

Whitehead (2013) defines physical literacy as “the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life”. Thus, by addressing the potential positive impact schools have on developing LLPA, there is opportunity to develop physically literate pupils, enhancing lifelong engagement in PA. Activities such as yoga, cycling and MF activity have been highlighted by adolescents as an expression of PA that they would like to explore, yet

the curriculum lacks diversity in PA, favouring aerobic based MVPA and team sports (Corder et al, 2013).

MF activity fulfils the criteria associated with LLPA, yet few studies have assessed longitudinal outcomes regarding the impact of MF activity in formal PE and their tracking into adult life (Smith et al, 2017). However, the work of Kjonniksen et al (2008) displayed positive associations between youth exposure to PA when provided with choice of activity in a formal setting and their positive tracking into adulthood, supporting the notion that varying modalities of PA should be utilised in order to elicit an impact on LLPA. By exploring varied forms of PA that adolescents may encounter after formal PE, a curriculum that promotes individual success and ultimately enjoyment may provide adolescents with the skills and confidence to participate in other forms of PA later in life (Babic et al, 2014; Lubans et al, 2010). Maintaining sustained positive results in PA promotion has been reported to present a challenge in adolescents (Lai et al, 2014). A lack of qualitative and formative investigation may have resulted in a lack of understanding of what PA adolescent boys want to engage in. Future research should develop qualitative and formative protocols that allow for an understanding of what PA adolescent boys may engage in long term. This may lead to a greater contextual understanding and ultimately intervention success.

2.5.1 Physical literacy

Physical literacy (PL) can be defined as the ability, confidence, and desire to be physically active for life and is considered the foundation of LLPA and health (Cornish et al., 2020; Whitehead, 2001). PL is comprised of much more than PA alone and considered by some to be more of a process to continue LLPA that is influenced both positively and negatively by life experiences and interactions with the physical world (Edwards et al., 2017). PL should impart knowledge and understanding (cognitive), motivation and confidence (affective) and physical competence (physical) to ensure LLPA (Carl et al., 2022). It is frequently reported in the literature that PL is consistent with the intended outcomes of PE (Edwards et al., 2017; Hylton, 2013; Roetert & MacDonald, 2015). PE is unique in that it has the potential to reach a range of adolescents and provide education through learning to move and moving to learn, satisfying the cognitive and affective elements of PL (Marsden & Weston, 2007). It has recently been suggested that strength and conditioning activities including those that align with MF outcomes should be included in PE to develop PL (Pullen et al., 2020). However, the role MF development has to play in PL is not well established in the literature. Given the role MF has in LLPA, future work exploring the understanding, perceptions, and experiences of MF activity amongst adolescents may provide the basis

for future research. Furthermore, such investigation may help establish initial context to the affective, cognitive, and perceived physical aspects of PL and identify areas for future research.

2.6 School based muscular fitness

Schools have the facilities and the PE curricula to promote and support health promotion including fitness programmes independent of a pupils' sociodemographic profile (CDC, 2012; Love et al., 2019). As such, schools are suitable settings to promote and support MF activity (Cohen et al., 2015; Cox et al., 2020; Faigenbaum & McFarland, 2016; Lloyd, Faigenbaum, et al., 2014; Pichardo et al., 2019; Ten Hoor et al., 2016). In England, the National Curriculum for Physical Education (NCPE) (DfE, 2014) outlines four aims for the subject as follows: (1) develop competence to excel in a broad range of physical activities; and ensure students (2) are physically active for sustained periods of time; (3) engage in competitive sports and activities; and (4) lead healthy active lives. Current recommendations from the UK Government highlight the development of strength as a mandated element of PE for children and young people aged 7-16 (Foster & Roberts, 2022). The development of strength resides within the healthy active lives aspect of the PE curriculum and contributes towards improving MF. Despite the broad aims of PE, with aims 2 and 4 specifically focused on PA and health the curriculum is typically dominated by traditional team sports (Green, 2002, 2014). This may be due to a lack of specific guidance on how to appropriately develop healthy lives, which would include the development of MF (Chalkley, 2021). Indeed, if carried out correctly, MF can contribute and support all of the NCPE aims and form part of a health-related PE pedagogy (Andermo et al., 2020; Green, 2014; Lubans, Smith, Peralta, et al., 2016). Future research should investigate the integration of MF into the curriculum, with specific guidance on the methods and approaches that can be taken whilst ensuring that all curriculum aims are met.

Despite schools being recognised as suitable settings, much of the research is conducted with high school athletes and often outside of the UK (Pichardo et al., 2019). However, schools do provide a unique setting that allows for periodised models of exposure to MF activity at regular points throughout the academic year which support the development of MF (Faigenbaum & Meadors, 2017). One of the unique benefits of schools is that term time MF activity delivered during PE can be appropriately periodised and can extend beyond the recommended minimum 23 weeks of consistent exposure suggested to MF in youth (Lesinski et al., 2016). The use of term-time structure has been theoretically applied in a

high school in New Zealand (Pichardo et al., 2019). The 35 to 40 weeks structure of a term, was deemed sufficient to stimulate meaningful adaptations for strength, power, speed, and aerobic capacity in both children and adolescents (Pichardo et al., 2019). Furthermore, it is acknowledged that doing MF twice a week is enough to increase muscle MF (Dos Santos et al., 2022; Myers et al., 2017). Therefore, a curriculum that includes 2 periods a week, on alternate days, would adequately develop MF in adolescents (Dos Santos et al., 2022; Myers et al., 2017). However, the success of MF activity delivery is still dependent upon the skill and knowledge levels of the individual delivering the activity to manipulate training variables to elicit a desired adaptation (McGladrey et al., 2014). It is suggested that if MF activity is to be implemented in schools, the delivering staff must be suitably qualified (Dos Santos et al., 2022; Faigenbaum & McFarland, 2016; McGladrey et al., 2014).

2.6.1 Teachers delivery of muscular fitness

Unfortunately, it has been reported that some PE teachers avoid implementing MF activity as part of health-based PE and PA promotion due to perceived barriers, including a lack of facilities, teacher confidence and time (Kennedy et al., 2021; Nathan et al., 2018; Naylor et al., 2015). Such perceived barriers can be overcome through continued professional development (CPD) and support to improve foundational knowledge (Cox et al., 2020). Knowledge of MF activity has been assessed among PE teachers in America and suggested that current competence levels to deliver MF activity in a school setting require improvement (McGladrey et al., 2014). Although the literature surrounding MF activity delivery in schools is limited, evidence of successful interventions to improve knowledge of MF activity delivery has emerged from Australia (Kennedy et al., 2019; Kennedy, Smith, Hansen, et al., 2018). Kennedy and colleagues conducted one-day in-person workshops with teachers from 16 secondary schools to equip them with the necessary theoretical and practical knowledge to deliver MF activity. Whilst the research in Australia is promising, other countries, such as the UK, lack research into the provision of PE teacher CPD, specifically in MF. Additionally, future research needs to consider the long-term feasibility of in-person training given the extensive resources required, financial pressures and time constraints PE teachers have reported being a barrier to accessing CPD (Sato et al., 2017).

Despite levels of MF declining amongst some UK school-aged youth (Dooley et al., 2020; Kaster et al., 2020; Sandercock & Cohen, 2018), there is little investigation into how to support PE teachers in the delivery of this health-enhancing activity (Cale et al., 2016). Current CPD opportunities focus on team sports, games, and dance (Armour & Makopoulou, 2012). To support PE teachers in delivering MF activity as part of health-

based PE, foundational knowledge and ongoing professional development opportunities are required to ensure safe and developmentally appropriate practice (McGladrey et al., 2014). Within CPD provision, MF is aligned to the development of health-based pedagogy (Ennis, 2016). Currently, PE teachers and CPD providers are unsure about developing health-based PE content, making it challenging to develop CPD for health pedagogies such as MF activity (Armour & Makopoulou, 2012; Pühse et al., 2011).

Research into PE teacher CPD is relatively new (Ennis, 2016) and there is still a lack of clarity on what constitutes PE CPD, how it is accessed and what subjects should be covered (Tannehill et al., 2021). However, the quality and content of PE CPD have received increased attention in recent years, with teachers expected to take a more research-informed approach to their lesson planning and delivery (Beni et al., 2021; Osmond-Johnson et al., 2018). CPD in the context of PE refers to a wide variety of specialized training, formal or informal education, or advanced professional learning intended to help teachers improve their professional knowledge, competence, skills, tools and effectiveness in the delivery of quality PE (Lander et al., 2022). Research suggests that current CPD opportunities for PE teachers lack relevance and require more thought to ensure it meets the requirements of the PE teacher (Lander et al., 2020; Makopoulou, 2017). Additionally, there are concerns that PE teachers are not aware of their existing knowledge gaps and, therefore, do not seek out suitable CPD that could enhance or inform their teaching, especially in health pedagogies such as MF activity (Alfrey et al., 2012). The lack of knowledge reported in health-based PE can be attributable to a lack of focus during initial teacher training (Alfrey et al., 2012; Cale et al., 2016) and limited opportunity to engage in related CPD. If PE is to remain a key component in tackling physical inactivity and promoting health in young people, appropriate CPD that enhances the knowledge and competence of PE teachers needs to be developed and disseminated (Armour & Harris, 2013).

PE teachers have reported difficulty accessing CPD, constrained by time and financial requirements of traditional face-to-face training opportunities (Sato et al., 2017). Additionally, insufficient provision and limited accessibility contribute to low levels of CPD (Armour & Harris, 2013; Ward & van der Mars, 2020). In recent years, a move to online CPD has provided an opportunity to overcome time and financial costs barriers (Lantz-Andersson et al., 2018). However, online CPD provision is in the early stages of use, and much work is needed to understand the feasibility and suitability of delivery to PE teachers (Lander et al., 2020). Despite online CPD being in the early stages, recent qualitative research has suggested PE teachers require CPD to be: (1) evidence-based; (2) provide

pedagogical content knowledge and not just content knowledge; (3) be informed by teachers and translatable to practice; (4) facilitate communities of practice; (5) be interactive; (6) be simple to navigate; and (7) be highly visual (Lander et al., 2020). Further research is warranted to better understand the feasibility and acceptability of online CPD delivery to UK PE teachers

2.7 Summary of the literature

The literature review has highlighted the importance of MF as a part of PA. Throughout the literature review the importance of developing MF for short-and-long term health has been established. However, when reviewing the literature, it is clear and indeed acknowledged that MF is an under investigated area of PA. Evidence regarding the demographic of participants who may benefit most from engaging with MF activity suggests that adolescent boys may initially benefit most from further investigation. Furthermore, the school environment is proposed as a suitable setting to conduct MF activity as it provides the setting and staff to deliver MF interventions. However, little is known about the potential efficacy of school-based MF interventions, the thoughts and perceptions adolescent boys ascribe and the competence of PE teachers to deliver MF activity interventions. Further understanding of the whether MF activity delivery in schools is "worth it" and whether schools and PE teachers are "able" may help inform the design of future school-based MF activity interventions.

Chapter 3

Study 1:

Efficacy of School-Based Interventions for Improving Muscular Fitness Outcomes in Adolescent Boys: A Systematic Review and Meta-analysis

The main outcomes of this study have been published in Cox, Ashley, Stuart J. Fairclough, Maria Christina Kosteli, and Robert J. Noonan. 'Efficacy of School-Based Interventions for Improving Muscular Fitness Outcomes in Adolescent Boys: A Systematic Review and Meta-Analysis'. *Sports Medicine* 50, no. 3 (15 March 2020): 543–60. https://doi.org/10.1007/s40279-019-01215-5.

Thesis map

Study	Aim	Outcome
Study 1. Efficacy of School-Based Interventions for Improving Muscular Fitness Outcomes in Adolescent Boys: A Systematic Review and Meta-analysis	To investigate the efficacy of school-based interventions on MF outcomes in adolescent boys	
Study 2. "It's Just Not Something We Do at School". Adolescent Boys' Understanding, Perceptions, and Experiences of Muscular Fitness Activity		
Study 3. PE Teachers' Perceived Expertise and Professional Development Requirements in the Delivery of Muscular Fitness Activity: PE Teacher EmPOWERment Survey		
Study 4. The Feasibility and Acceptability of an Online CPD Programme to Enhance PE Teachers' Knowledge of Muscular Fitness Activity.		

Background: It has been reported that boys' and girls' physical activity (PA) levels decline throughout adolescence. Boys are at risk of physical inactivity during adolescence however, in intervention research they are an under-represented group relative to girls. It is suggested that the school environment may be central to developing interventions that support adolescents in meeting the current PA guidelines. The aim of this systematic review and meta-analysis was to investigate the efficacy of school-based physical activity interventions for improving muscular fitness (MF) in adolescent males.

Methods: This systematic review and meta-analysis followed the preferred reporting systems for meta-analyses guidelines and was registered on PROSPERO (Registration number: CRD42018091023). Eligible studies were published in English within peer-reviewed articles. Searches were conducted in three databases, with an additional grey literature search in Google Scholar. Studies investigating MF outcomes were included.

Results: There were 43 data sets identified across 11 studies, from seven countries. Overall methodological quality of the studies was moderate to strong. Interventions targeting MF evidenced a small to medium effect (g = 0.32, CI 0.17, 0.48, P = <.001). Sub-group analyses of MF delivery method resulted in small to medium effects: Upper limb MF measures (g = 0.28, 95% CI -0.02, 0.58, p = 0.07), lower limb MF measures (g = 0.28, 95% CI 0.09, 0.68, p 0.03), combined MF activities (g = 0.24, 95% CI -0.04 – 0.49, p = 0.05),

plyometric activities (g = 0.39, 95% CI 0.09, 0.68, p = 0.01), body weight (g = 0.27, 95% CI -0.10, 0.65, p = 0.15), and traditional MF methods (g = 0.43, 95% CI 0.09, 0.78, p = 0.01).

Conclusions: School-based interventions which aimed to increase MF outcomes in adolescent boys demonstrated small to moderate effects. Traditional and plyometric methods of resistance training appear to be the most effective form of PA delivery in adolescent males. More quality research is required to assess the impact of MF delivered in the school environment in order to inform future intervention design.

3.1 Introduction

It is recommended that adolescents engage in a minimum of 60 min of moderate-to-vigorous physical activity (MVPA) per day averaged across the week with muscle and bone strengthening exercise (MBSE) to be incorporated 3 times per week (Davies et al., 2019; WHO, 2020). A recent systematic review confirmed the associated health benefits of meeting the recommended MVPA guideline (Joan Poitras et al., 2016). Furthermore, participating in the recommended 3 days of MBSE per week has also been associated with positive physical and mental health benefits in children and young people (Benson et al., 2008; Collins et al., 2018; Padilla-Moledo et al., 2012). Despite this evidence, less than 50% of young people in Europe meet the recommended amount of MVPA suggested by the World Health Organisation (WHO), with this figure declining with age (Moor et al., 2020). There is also an international downward temporal trend in muscular fitness among school children, indicating a lack of activities that support the development of muscular fitness (Albon et al., 2010; Cohen et al., 2011; Sandercock & Cohen, 2019). Muscular fitness is assessed by measuring performance in tests of muscular strength, power and muscular endurance (Sandercock & Cohen, 2019) and forms part of the MBSE guideline for PA. Lower levels of muscular fitness are associated with the development of non-communicable disease in adolescent populations (Artero et al., 2011; Cohen et al., 2014; Smith et al., 2014). Moreover, the development of muscular fitness has been correlated with enhanced bone health, enhanced motor skill and decreased fat mass in adolescents (García-Hermoso et al., 2019; Pullen et al., 2020; Singh et al., 2012).

The benefits of MBSE are well established, supported by position stands from leading organisations (Behm, Faigenbaum, Falk, Klentrou, et al., 2008; Faigenbaum et al., 2010; Lloyd, Faigenbaum, et al., 2014). Despite the growing body of literature supporting the benefits of MF, it is often the overlooked element of PA guidelines. Recent UK estimates for health care costs associated with muscle weakness, defined by low grip strength

according to the Foundation for the National Institutes of Health criteria (men < 26 kg, women < 16 kg), exceed £2.5 billion (Pinedo-Villanueva et al., 2018). Furthermore, the United States reported estimated health care costs associated with muscular weakness at $18.5 billion (Janssen et al., 2004). Poor muscular fitness is associated with sarcopenia, poor quality of life, loss of functional movement and increase the likelihood of contracting a noncommunicable disease (Reginster et al., 2016). The associated health care costs and accompanying pathologies supports the need to address the downward trend in muscular fitness currently witnessed in youth.

The school environment has been shown to be effective in the promotion of PA in adolescents (Kriemler et al., 2011). Adolescents are most active during the school day compared to evenings and weekends (Fairclough et al., 2012). Additionally, the school environment provides access to PA independent of background or socioeconomic status (Love et al., 2019). This may expose adolescents to varying forms of PA that they may not have been exposed to outside of school. However, the efficacy of school-based interventions investigating PA in adolescent males is unclear. Much of the existing research and policy to promote PA is directed towards adolescent girls, suggesting that males are at low risk of not meeting the suggested PA levels indicative of good health (Federal De Pelotas et al., 2012; Hallal et al., 2012). However, boys are reported to be at greater risk than girls of becoming overweight or obese, compromising short and long term health (Hallal et al., 2006, 2012). For male adolescents, healthy behaviours catalysed during adolescence are often carried into adulthood, supporting the need to investigate the efficacy of current interventions (Jachyra & Gibson, 2016).

It is hypothesised that Australian and American male adolescents may respond more favourably towards resistance training (RT) as these activities are perceived as masculine (Gray & Ginsberg, 2008; Lubans & Cliff, 2011). Furthermore, existing evidence supports the role of MF interventions for improving physiological and psychological health (Collins et al., 2018, 2019; Padilla-Moledo et al., 2012). However, research suggests that the development of MF in upper and lower limbs is not homogeneous and may vary throughout growth and maturation (Candow & Chilibeck, 2005; De Ste Croix et al., 2003; Kubo et al., 2001; Radnor et al., 2018). The heterogeneous nature of MF development in adolescent boys may not be accounted for when prescribing RT on a large scale. Understanding how this phenomenon impacts school-based delivery of RT may support future intervention design when attempting to cater for multiple participants. Additionally, appropriate forms of RT delivery may engage overweight or obese adolescents (Hoor et al., 2016). Implementing effective RT interventions in the school environment may allow overweight and obese youth

to excel by taking advantage of their relatively greater absolute strength (Hoor et al., 2016). Therefore, RT may be a way of increasing PA levels and improving health among overweight or obese adolescents. However, RT is often an overlooked element of PA guidelines when considering the development of school-based interventions and requires contextualisation.

When exploring the existing literature that reports on the efficacy of MVPA interventions across both genders and age ranges, mixed outcomes have been reported with small changes of around 4 min per day following school-based interventions (Metcalf et al., 2013). However, it is unclear how adolescent boys respond to school-based RT interventions. To the authors' knowledge, this review is the first to investigate the efficacy of school-based PA interventions to improve MF outcomes in adolescent boys. This systematic review and meta-analysis will include studies that (1) represent adolescent boys and report MF outcomes; and (2) determine the efficacy of RT interventions delivered in school-settings. Thus, the purpose of this systematic review and meta-analysis is to investigate the efficacy of school-based interventions on MF outcomes in adolescent boys.

3.2 Methods

3.2.1 Protocol and registration

This systematic review and meta-analysis were registered with PROSPERO on 15th March 2018 (Registration number: CRD42018091023). The protocol is published online (https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=91023) and follows the PRISMA statement for reporting systematic reviews and meta-analyses.

3.2.2 Search Procedure

A systematic search was conducted in April 2018 using three electronic databases (PubMed, SPORT Discus and Web of Science). A grey literature search of Google Scholar was also conducted to minimise publication bias (Haddaway et al., 2015). Journal articles published in English post May 2010 until the date of the final search in August 2018 were considered for review. During the search design, an experienced librarian was utilised to ensure rigour in the search design and data handling. May 2010 was chosen as the initial reference point in order to capture all interventions conducted following the publication of the WHO PA guidelines (World Health Organization, 2010). WHO guidelines were used as the PA guideline reference to provide a balanced search strategy, accounting for all countries, including those yet to establish their own PA policy and guidelines (Sallis et al.,

2016). The PRISMA flow diagram detailing the procedure can be found in Figure 3.1. Reference lists of relevant articles, including systematic literature reviews, were examined for potential articles which fitted the criteria. A recent systematic review that reflects the target population group and training intervention for this review were also checked for any further literature (Collins et al., 2018). All search results were exported to a reference manager, Covidence (https://www.covidence.org; Covidence, Melbourne, Australia), allowing for central reviewing and collection of all texts for screening.

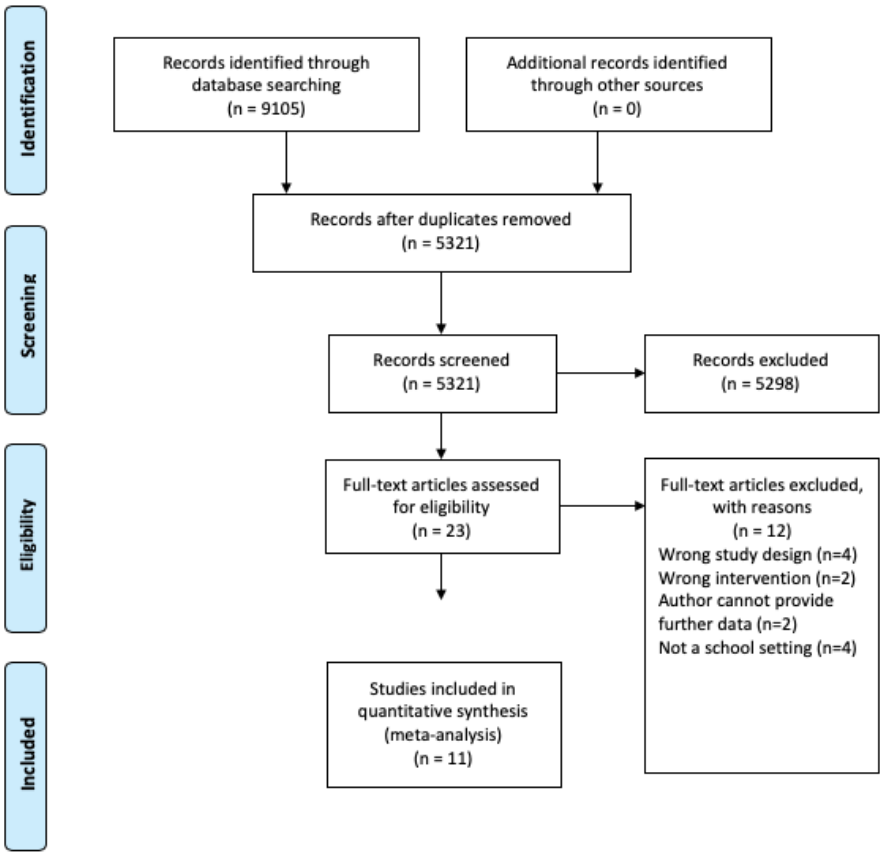

Figure 3.1 PRISMA flow diagram to show each stage of the systematic eligibility process

3.2.3 Study selection

Studies were eligible if they contained an intervention with a control group where the main purpose was to promote PA in the school environment, with the primary outcome of increasing objectively measured MF. Included studies investigated adolescent boys aged 10-18 years. Mixed boys' and girls' data were acceptable if sex-specific results were available and/or accessible. Studies must have been conducted in a school or college between 8am-6pm on weekdays during term-time. Studies were included if MF measures were taken at baseline and at the end of the intervention. Girls, community interventions,

elite sport and thesis/dissertations were excluded. Measures of MF had to have been documented in their use previously in peer reviewed research and could not be novel or first-time iterations of a testing protocol.

Studies could be randomised or non-randomised. Research studies published before 2010 were excluded as were studies that were not published in English. Where full texts were not readily available and where only partial data were reported, the study authors were contacted and asked to provide the full text version with the accompanying data in full. If no response was received after an eight-week follow-up reminder, these studies were excluded as they could not be fully assessed for eligibility. A total of 11 authors were contacted to provide further data and full texts. From the authors contacted, 5 non-responses were recorded, with a further 2 authors unable to provide further data for analysis.

3.2.4 Data extraction and risk of bias

All search results were exported into Covidence (https://www.covidence.org; Covidence, Melbourne, Australia) and duplicates were removed. The first author (AC) screened all titles and abstracts for obvious irrelevance, 10% were also checked by another author (RN). The 10% screening figure is a recognised validation and agreement threshold for systematic reviews (Sikich, 2015). Both authors agreed fully on the 10% sample. The full text of eligible studies were then located and reviewed by two authors (AC and RN). Any disagreements were resolved in a meeting involving three authors (AC, RN, and SF). Study data were extracted into Comprehensive Meta-analysis Software (Version 2.2.064) by AC and included study characteristics (i.e., country, year); participant characteristics (e.g. sample size, age, anthropometrics); intervention components (i.e., setting, duration, intervention); and changes in the outcomes (i.e., change in grip strength). The pre-post outcome data were extracted in the form of mean, standard deviation and sample size. Included studies were assessed for risk of bias using a modified tool (Morton et al., 2016; Pluye et al., 2009) appropriate for PA reviews which included measures for quantitative studies.

3.2.5 Data synthesis and analysis

Random effects meta-analyses were conducted using Comprehensive Meta-analysis Software (Version 2.2.064). Pre-and-post intervention mean results with standard deviations were inputted. As the interventions reported a variety of different scales for measuring MF outcomes, a standardised mean difference approach was undertaken (Borenstein et al., 2010; Higgins et al., 2022). Raw scores were converted to standardised

means Studies that reported more than one measure of assessing a single outcome (i.e., vertical jump height and reactive strength index for lower limb outcome) were converted into a single common effect size for the analysis to avoid inflating sample sizes. A random effects model was considered more appropriate for this review to account for the expected heterogeneity between PA measures (Clark & Linzer, 2015). Hedges' *g* with 95% CIs were used to calculate effect sizes (Cohen, 1988). Pooled weighted standard deviations were used as per the *Hedge's g* formula and based on a positive effect direction (Cohen, 1988). Hedges' *g* was interpreted using Cohen's (Cohen, 1988) effect sizes, as small (0.2), medium (0.5) and large (0.8). Heterogeneity was assessed using I^2 statistic, with values of 25, 50 and 75 representing low, medium, and high heterogeneity, respectively (J. P. T. Higgins et al., 2003). Publication bias was assessed using Egger's statistic, where bias was deemed to be present at p = <0.05 (Egger et al., 1997). Corresponding funnel plots were created for visual interpretation, followed by calculating Egger's statistic to confirm or refute publication bias.

3.2.6 Quality appraisal

Included studies were assessed for risk of bias using a modified tool suitable for PA interventions that included non-RCT designs (Morton et al., 2016; Pluye et al., 2009). The ability to distinguish the nature of the PA outcome assessment method, in addition to the existent randomisation, blinding, and complete outcome data items was accounted for within this tool. This adapted quality assessment tool used a 1-4 scoring system (i.e., 1 = weak and 4 = very strong; see Table 3.1.

Table 3.1 Quality assessment (Risk of Bias)

Study	Appropriate sequence generation and/or randomisation	Allocation concealment and/or blinding	Complete outcome data and/or low withdrawal/drop-out (<20%)	Appropriate measure (PA)	Quality Score
1. De Souza et al. (2015)			**X**	**X**	**2**

2. Eather et al. (2016)	**X**	**X**	**X**	**X**	**4**
3. Giannaki et al. (2016)		**X**	**X**	**X**	**3**
4. Kennedy et al. (2018)	**X**		**X**	**X**	**3**
5. Lloyd et al. (2012)			**X**	**X**	**2**
6. Lloyd et al. (2016)			**X**	**X**	**2**
7. Lubans et al. (2016)	**X**	**X**		**X**	**3**
8. Muehlbauer et al. (2012)			**X**	**X**	**2**
9. Muntaner-mass & Palou. (2017)			**X**	**X**	**2**
10. Weeks & Beck. (2012)			**X**	**X**	**2**
11. Winwood & Buckley. (2017)			**X**	**X**	**2**

X = The study demonstrated appropriate steps to account for the respective risk of bias confounder.

3.3 Results

Extracted studies were conducted in seven countries (UK, Brazil, Australia, Cyprus, Germany, Spain, and New Zealand) (Eather et al., 2016; Giannaki et al., 2016; Kennedy, Smith, Morgan, et al., 2018; Lloyd et al., 2012, 2016; Lubans et al., 2016; Muehlbauer et al., 2012; Muntaner-Mas & Palou, 2017; Santos et al., 2015; Weeks & Beck, 2012; Winwood & Buckley, 2019). The studies included displayed no obvious bias, but rather a lack of depth and detail, which made the risks of bias difficult to detect. Details regarding sequence generation and allocation concealment and/or blinding were found to be the categories that were often not sufficiently reported on. Twenty-seven percent of the studies reported an appropriate sequence generation or randomisation in detail (Eather et al., 2016; Kennedy, Smith, Morgan, et al., 2018; Muehlbauer et al., 2012), with a further 27% reporting allocation concealment or blinding in detail (Eather et al., 2016; Muehlbauer et al., 2012; Winwood & Buckley, 2019). This may suggest selection and reporting bias in the literature. Complete outcome data and/or low dropout rates were present in 81% of the included studies and can therefore be interpreted as having low risk of bias as a result of attrition. Risk of bias through inappropriate outcome measures was not an issue for this review as all studies selected had to demonstrate an objective way of assessing MF.

Forty-three data sets were extracted from 11 studies assessing MF, with studies reporting multiple MF outcomes including a combination of upper and lower limb measures. Upper and lower limb data sets were analysed independently to identify possible intervention effects, categorised by testing site. Further subgroup analyses of MF interventions were conducted, accounting for: bodyweight movements (i.e., push ups and curl ups), combined activities (i.e., the use of multiple forms of resistance exercise such as bodyweight and plyometric within the same intervention), plyometrics, and traditional methods such as weight machines and free weights. Plyometric training studies had to exclusively state that the intervention utilised the stretch shortening cycle to take advantage of the elastic properties of the muscle to produce power (Flanagan & Comyns, 2008; Lloyd et al., 2011). Participants' ages ranged from 11.0-16.9 years, samples were separated into, MF control (n = 1164) and MF intervention (n = 1252). A full breakdown of study summary data is provided in Table 3.2. Identification of possible publication bias was plotted against standard errors to generate funnel plot (Figure 3.2). Egger's analyses for all data sets suggested that publication bias was not present (p = >0.05).

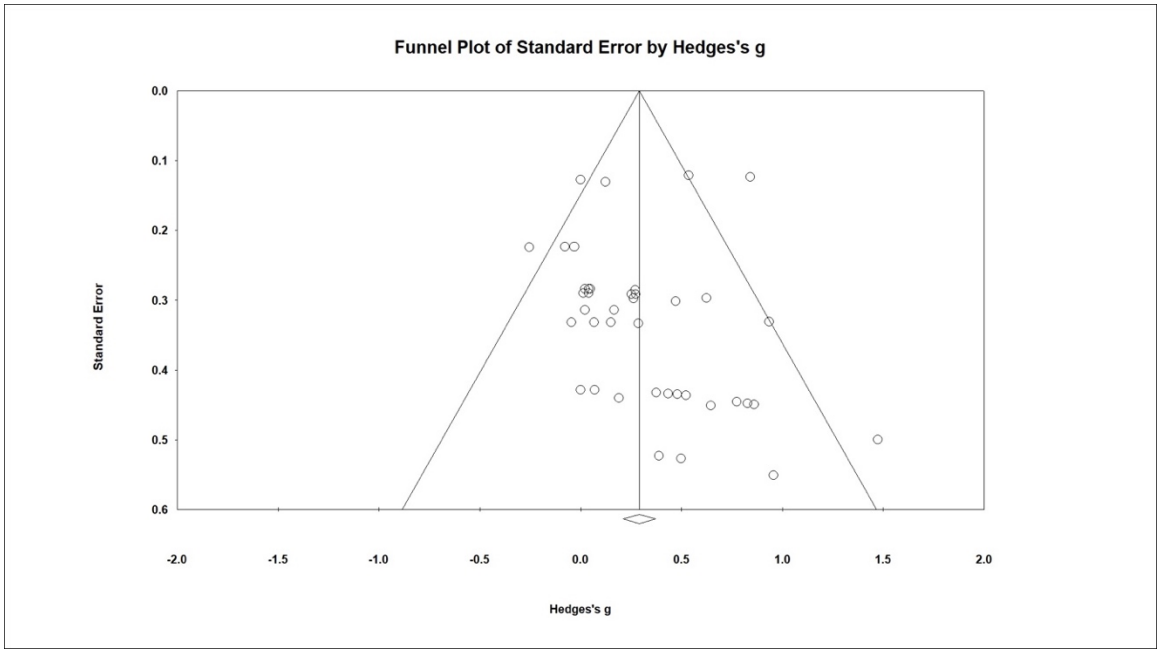

Figure 3.2 Funnel plot of standard error by Hedge's g.

Table 3.2 Characteristics of MF studies included in this systematic review. Letters a-l relate to individual outcome measures and are displayed combined where studies have reported multiple methods for a single outcome in subsequent forest plots.

Study & Quality Rating	Baseline Participant Characteristics	Intervention, Duration and Measurement Period	PA Measurement Method & PA Outcome Measure
De Souza et al. (2015) Brazil	**Total:** n = 19 **Mean age:** 12.8 ± 0.6 **Control:** **Mass**: (Kg) 54 ± 10 **Height:** (m) 1.57 ± 0.7 **BMI:** 22 ± 3 **Intervention:** **Mass:** (Kg) 52 ± 9	12 weeks, completing 2 60 minute sessions per week. The calisthenics exercise group performed a 10-min warm up (running) followed by five calisthenics strength exercises: (a) wide grip push-ups; (b) squat or lunge; (c) fixed bar inverted row; (d) curl-ups; and (e) narrow grip push-ups).	**Muscle/ Bone Strengthening** **a)** Horizontal Jump: The subjects performed the horizontal jump test. The best distance (in centimetres) of three attempts was recorded. **b)** Push-Ups in 1 min: The subjects performed the maximum number of repetitions in 1 min.

	Height: (m) 1.60 ± 0.8 **BMI:** 20 ± 2		**c)** Curl ups: The subjects performed the maximum number of repetitions in 1 min.
Eather et al. (2016) Australia	**Total:** n = 46 **Mean age:** 15.3 ± 0.47 **Mass**: (Kg) 65.1 ± 12.3 **Height**: (m) 1.77 ± 0.72 **BMI**: 21.3 ± 3.4 **Control:** n = 22 **Intervention**: n = 24	8 weeks, completing 2, 60 minute sessions per week. Sessions were delivered by Crossfit coaches. A typical session included a dynamic warm-up (10 min), a technique-based skill session (10 min), a Workout of the Day (10–20 min), a stretching session (5–10 min) and time allocated for organisation, transition and changing into sportswear (10 min).	**Muscle/ Bone Strengthening** **a)** Push up tests (reps) **b)** Curl up test (reps) **c)** Standing jump (m) **d)** Grip strength (Kg) Guided by the FitnessGram protocol.
Giannaki et al. (2016) Cyprus	**Total:** n = 39 **Mean age:** 16 **Control**: n = 19 **Mass**: (Kg) 59.4 ± 13.7 **Height**: (cm) 169.3 ± 8.9 **BMI:** 20.5 ± 2.9. **Intervention:** n = 20 **Mass**: (Kg) 64.5 ± 13.0 **Height:** (cm) 169.8 ± 6.4 **BMI**: 22.3 ± 3.7	8 weeks, completing 2 sessions per week. Circuit training was performed in a group setting, where the students completed 20 minutes consisted of 2 cycles of eight exercises (stations) with 30 seconds exercise – 30 seconds rest between sets and 3 minutes rest between cycles. The circuit training included push ups, tricep dips, step-on-the-box, wall ball (squats holding a 2kg medicine ball and then throwing the ball on the wall on the ascent), bicep curls with elastic bands for resistance, sit-ups, standing calf raises with medicine ball, and back raises. The circuit training programme was altered in the last 4 weeks of the intervention. Changes were made both in the volume and frequency of the exercises, reaching the total number of exercises (stations) to 10 whilst the resting period between each exercise was reduced by 15 seconds.	**Muscle/ Bone Strengthening** **a)** Hand grip strength (Kg) left **b)** Hand grip strength (Kg) right **c)** Vertical jump (cm)

Kennedy et al. (2018) Australia	**Total:** n = 303 **Control:** n = 124 **Mean age:** 14.2 ± 0.5 **Intervention:** n = 179 **Mean age:** 14.1 ± 0.4	10-wk school term, with pre-test and post-test data collection occurring in the preceding and ensuing school terms to the intervention, respectively (i.e., pre-tests occurred in term 2 (April–June), the intervention was delivered in term 3 (July–September), and post-test occurred during term 4 (October–December)). This resulted in an approximate period of 6 months between pre-test and post-test measurements. The structured physical activity program followed a specified session format, including: i) movement-based games and dynamic stretching warm-up; ii) RT skill development; iii) high intensity RT (HIRT) workout; iv) modified game involving fitness infusion, boxing or core strength activity; v) static stretching, reinforcement of behavioural changes.	**Muscle/ Bone Strengthening** **a)** Push ups (reps) **b)** Standing long jump (m)
Lloyd et al. (2012) UK	**Total:** n = 109 **Control 1:** n = 22 **Mean age:** 12.23 ± 0.28 **Mass:** (Kg) 47.38 ± 13.91 **Height:** (cm), 151.67 ± 6.93 **Intervention 1:** n = 22 **Mean age:** 12.29 ± 0.31 **Mass:** (Kg) 44.78 ± 9.42 **Height:** (cm) 151.89 ± 7.94 **Control 2:** n = 24 **Mean age:** 15.29 ± 0.33 **Mass:** (Kg) 63.70 ± 11.43	4 weeks of 2 x sessions per week. Training volume was defined by the number of foot contacts made during each session, starting with 72 contacts in the first session, increasing to 106 contacts in the final 2 sessions. Plyometric drills lasted approximately 5–10 seconds, and at least 90 seconds rest was allowed after each set. Plyometric drills included standing vertical and horizontal jumps, lateral jumps, ankle hops, skipping, single leg hopping, maximal hopping, and low-level drop jumps (20 cm). Measurements taken pre and post intervention	**Muscle/ Bone Strengthening** Reactive Strength Index (millimetres per millisecond). Reactive strength index (RSI) was determined during the maximal hopping test, which involved the participants performing 5 repeated bilateral maximal vertical hops on the contact mat. The participants were instructed to maximise jump height and minimise ground contact time. The first jump in each trial was discounted, whereas the remaining 4 hops were averaged for the analysis of RSI. **a)** Intervention 1, pre peak height velocity **b)** Intervention 2, post peak height velocity

	Height: (cm) 174.11 ± 9.20 **Intervention 2:** n = 20 **Mean age:** 15.33 ± 0.27 **Mass**: (Kg) 64.96 ± 8.89 **Height:** (cm) 174.35 ± 6.63		
Lloyd et al. (2016) UK	**Total:** n = 80 (n = 40 pre-PHV, n = 40 post-PHV). Participants were divided into 4 groups, plyometric training, traditional strength training, combined training and control.	2 sessions per week for 6 weeks. Within traditional strength training sessions, participants completed 3 sets of 10 repetitions of a barbell back squat, barbell lunge, dumbbell step up, and leg press. To enable the prescription of individualized training intensities, 10 repetition maximum (10RM) loads were calculated for participants in the traditional strength training group before the start of the training period. Progressive overload (5%), was implemented following technical competency. Plyometric training prescription included a combination of exercises that were geared toward developing both safe jumping and landing mechanics (e.g., drop landings, vertical jumps in place, single-leg forward hop and stick) and also to stress stretch-shortening cycle activity (e.g., pogo hopping, drop jumps, multiple horizontal re-bounds). Within each session, participants were exposed to multiple sets of 4 exercises to enable sufficient repetition to develop motor control programs. (week 1 foot contacts = 74 per session, week 6 foot contacts = 88 per session). The combined training program involved exposure to 2 traditional strength training exercises (barbell back squat and barbell lunge) and 2 varied plyometric exercises, each session taken from the plyometric training program.	**Muscle/ Bone Strengthening** Squat Jump Height (cm) Pre PHV Post PHV Plyometric training: **a.** **d** Traditional strength: **b.** **e** Combined training: **c.** **f** Reactive Strength Index (millimetres per millisecond) Pre PHV Post PHV Plyometric training: **g.** **j** Traditional training: **h.** **k** Combined training: **i.** **l**

		Measurements taken pre and post intervention.	
Lubans et al. (2016) Australia	**Total:** n = 361. **Control**: n = 180 **Mean age:** 12.7 ± 0.5 **Mass:** (Kg) 53.1 ± 13.4 **Height:** (cm) 160.2 ± 8.4 **BMI:** 20.5 ± 4.1 **Intervention**: n = 181 **Mean age:** 12.7 ± 0.5 **Mass:** (Kg), 54.0 ± 15 **Height:** (cm) 160.9 ± 9.0 **BMI**: 20.5 ± 4.1	20 weeks, 20 x 90 minute sessions delivered by teachers during school sport periods in addition to regular PE. Lunch time sessions run by students, 6 x 20 minute sessions. Each session included the following structure: (i) warm up: movement-based games and dynamic stretches; (ii) resistance training skill development: resistance band and body weight exercise circuit; (iii) fitness challenge: short duration, high intensity Crossfit™-style workout performed individually with the aim of completing the workout as quickly as possible; (iv) modified games: minor strength and aerobic- based games (e.g., sock wrestling, tag-style games) and small-sided ball games that maximize participation and active learning time (e.g., touch football); and (v) cool down. Measurements taken at baseline, 8 months and 18 months.	**Muscle/ Bone Strengthening** **a)** Push up test, FITNESSGRAM protocol. **b**) Handgrip strength (Kg)
Muehlbauer et al. (2012) Germany	**Total:** n = 13 **Control:** n = 7 **Mean age:** 16.9 ± 0.7 **Mass:** (Kg) 66.7 ± 7.5 **Height:** (cm) 182.6 ± 6.3 **BMI:** 20 ± 2.0 **Intervention:** n = 6 **Mean age:** 16.8 ± 0.8 **Mass:** (Kg) 68.8 ± 2.6	8 weeks, 2 sessions per week. Exercises; Squats, leg-press, calf-raise, hip abduction/adduction, leg extension/ flexion. Training volume; 8-week training period with a total of 16 sessions; each session lasted 90 min. (10-min. warm-up, 70 min. resistance training, 10-min. cool-down). Training frequency 2 training sessions a week separated by approximately 48 hr. Training intensity 30–40% of the one-repetition maximum. Training intensity was examined for each participant on a fortnightly basis by means of one-repetition maximum tests; if necessary, the training load was adjusted.	**Muscle/ Bone strengthening** **a)** Maximal isometric force, leg press **b)** Rate of force development, leg press **c)** Counter-movement jump height

	Height: (cm) 181.8 ± 6.5 **BMI:** 21.1 ± 1.7	Measurements taken at pre and post intervention	
Muntaner-mass & Palou. (2017) Spain	**Total:** n = 83. **Control:** n = 35 **Mean age:** 15.8 ± 0.5 **Mass:** (Kg), 64.0 ± 10.8 **BMI:** 21.1 ± 3.0 **Intervention:** n = 45 **Mean age:** 15.9 ± 0.6 **Mass:** (Kg) 64.7 ± 12.0 **BMI:** 21.4 ± 3.3.	5 months, 2 sessions per week. The intervention consisted of a circuit of ten stations, where a high intensity activity was performed at each one. The authors do not provide a list of the activities at each station to discuss the movements utilised. Due to the large number of movements delivered at a high intensity, this study was categorised as combined activities. Measurements taken at pre and post intervention.	**Muscle/ Bone strengthening** **a)** Hand grip strength (Kg) left **b)** Hand grip strength (Kg) right **c)** Standing broad jump (cm)
Weeks & Beck. (2012) Australia	**Total:** n = 46. **Control:** n = 24 **Mean age:** 13.8 ± 0.4: **Mass:** (Kg) 58.6 ± 16.7 **Height:** (m) 1.640 ± 0.086 **BMI:** 20.5 ± 4.3 **Intervention:** n = 22 **Mean age:** 13.8 ± 0.4 **Mass:** (Kg) 55.0 ± 13.8 **Height:** (m) 1.637 ± 0.098 **BMI:** 20.3 ± 3.6.	8 months, 2 sessions per week consisting of 10 minutes. Delivered at the beginning of a physical education lessons. Each bout of jumping comprised at least some of the following manoeuvres: jumps, hops, tuck-jumps, jump-squats, stride jumps, star jumps, lunges, side lunges, and skipping. Each 10 minute session consisted of 300 jumps. Measurements taken at pre and post intervention.	**Muscle/ Bone Strengthening** Vertical jump (cm)

Winwood & Buckley. (2017) New Zealand	**Total:** n = 62 **Control:** n = 23 **Mean age:** 14.3 ± 0.5 **Mass:** (Kg) 63.2 ± 13.2 **Height:** (cm) 174.1 ± 8.7 **Intervention** (Bodyweight and mobility): n = 25 **Mean age:** 14.2 ± 0.4 **Mass:** (Kg) 64.4 ± 12.2 **Height:** (cm) 175.2 ± 8.1 **Intervention** (Combined bodyweight, mobility and free weight resistance): n = 14 **Mean age:** 14.3 ± 0.5 **Mass:** (Kg) 61.8 ± 13.1 **Height:** (cm) 174.0 ± 9.6	7 weeks, 2-3 sessions. The 7-week training intervention involved participants performing 2 body weight/mobility training sessions per week (Table 2), which was in addition to their regular sport training. While session 1 had a focus on improving strength and session 2 on mobility, each session sought to improve fundamental movement skills. The training program required the participants to train for up to 60 minutes biweekly on non-consecutive days. Participants in the combined training group (CBT) performed 2 additional 60-minute RT sessions in the same week but on different days to the BMT sessions. The focus of the training program was to enhance strength and improve fundamental movement patterns using key multi-joint movements. Measurements taken at -1 and +2.	**Muscle/ Bone Strengthening** Push up tests (reps) **a)** Bodyweight and mobility **b)** Bodyweight, mobility and weight resistance Horizontal jump (m) **c)** Bodyweight and mobility **d)** Bodyweight, mobility and weight resistance Medicine ball throw (m) **e)** Bodyweight and mobility **f)** Bodyweight, mobility and weight resistance Counter movement jump (m) **g)** Bodyweight and mobility **h)** Bodyweight, mobility and weight resistance

3.3.1 Pooled analysis, muscular fitness

MF interventions demonstrated an overall small to medium effect (*g* = 0.32, CI 0.17, 0.48, *P* = <.001). Medium to high heterogeneity was present amongst the 43 data sets (I^2 = 71.50). The 43 data sets came from 11 studies accounting for different MF outcomes and measures within each intervention and can be seen in Table 3.2 The overall effect of all

interventions investigating MF can be seen in Figure 3.3.

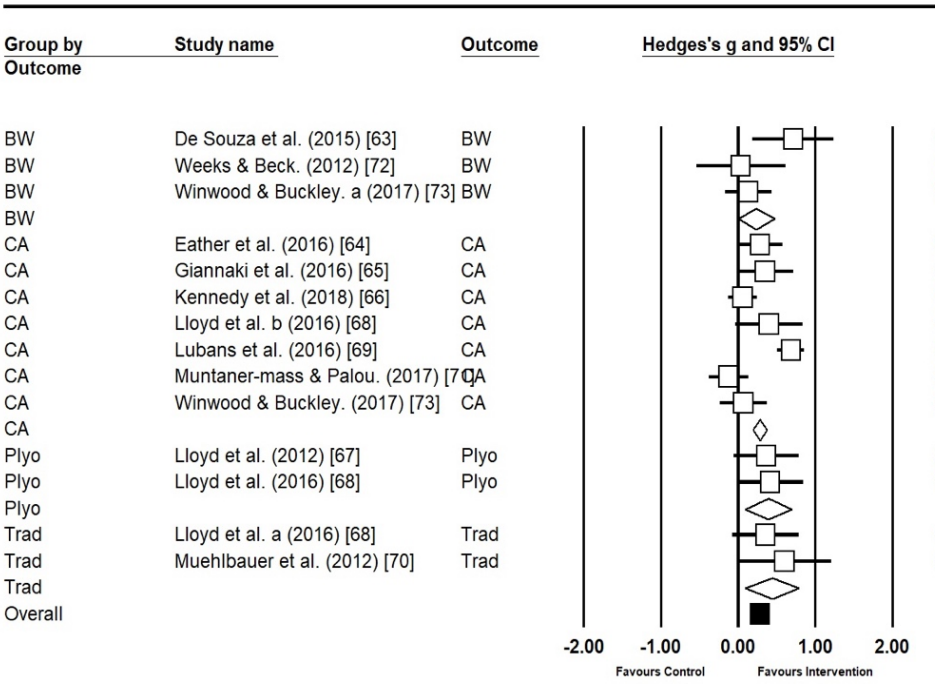

Figure 3.3 Individual study, and pooled results of MF training outcomes. BW: Bodyweight, Trad: traditional, Plyo: plyometric, CA: combined activities. Letters a and b were used to separate studies investigating more than one type of resistance training.

3.3.2 Upper and lower limb activities

MF outcomes were separated into those that assessed upper limb (n = 14) and lower limb muscle outcomes (n = 27). Two data sets measuring core strength were omitted from the analysis as this number was insufficient. Upper limb outcomes presented a small to medium effect, with moderate heterogeneity (g = 0.28, 95% CI -0.02, 0.58, p = 0.07, I^2 = 83.86). Lower limb outcomes displayed less heterogeneity when compared to upper limb (I^2 = 46.41) and elicited a small to medium effect (g = 0.28, 95% CI 0.09, 0.68, p = 0.03). The

corresponding forest plot can be seen in Figure 3.4.

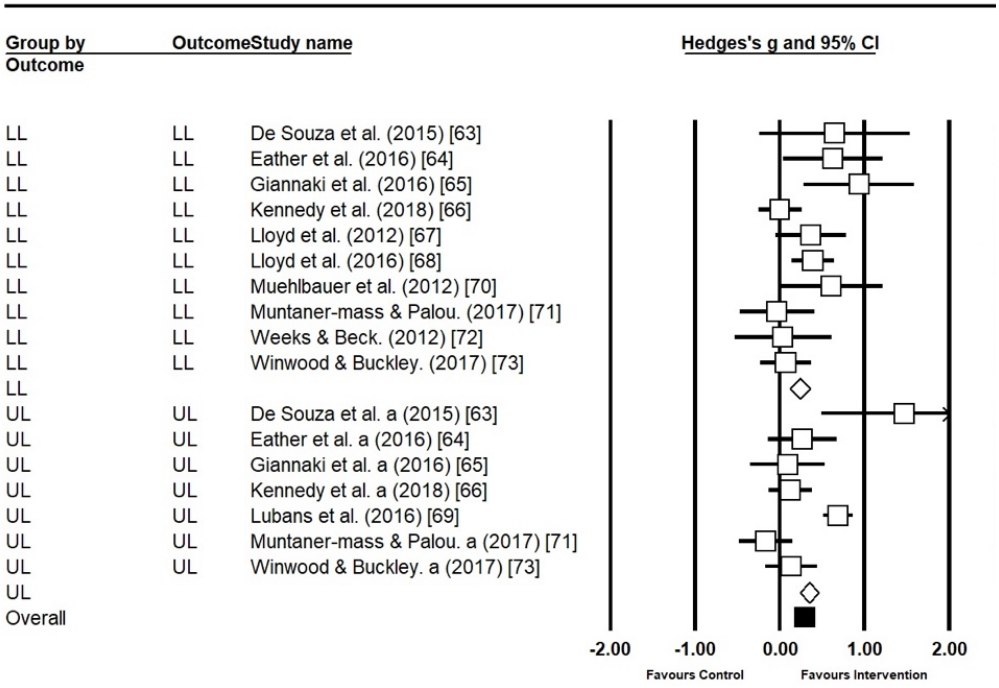

Figure 3.4 Individual and pooled sub-group analyses of upper limb and lower limb MF outcomes. Studies with more than one outcome of MF are reported separately with the letter *a* allowing for separation between LL and UL outcomes. LL: Lower Limb, UL: Upper Limb.

3.3.3 Combined activities

Combined activities (CA) consisted of those interventions that incorporated multiple methods to enhance MF, such as plyometric, bodyweight and traditional methods conducted within the same session (n = 22). There was a small effect for these interventions (g = 0.24, 95% CI -0.04 – 0.49, p = 0.05), which had high heterogeneity (I^2 = 84.86).

3.3.4 Plyometric activities

Plyometric forms of training (n = 6) resulted in a small to moderate effect size (g = 0.39, 95% CI 0.09, 0.68, p = 0.01). Analysis of heterogeneity demonstrated that plyometric forms of training were homogeneous (I^2 < 0.00).

3.3.5 Body weight activities

Interventions utilising body weight (BW) as the resistance elicited a small effect (n = 8, *g* = 0.27, 95% CI -0.10, 0.65, *p* = 0.15). Analysis demonstrated medium heterogeneity (I^2 = 51.53) for all studies utilising BW.

3.3.6 Traditional methods

Traditional methods (TM) were deemed to be those methods that utilised free weights and resistance machines. TM indicated a small to medium effect (n = 7, *g* = 0.43, 95% CI 0.09, 0.78, *p* = 0.01). TM displayed low heterogeneity (I^2 = 0.00) and the greatest effect size in relation to the other outcome groups. The entire breakdown of MF subgroups is presented in Figure 3.3.

3.4 Discussion

To date the literature has primarily focussed on the aerobic MVPA aspect of the PA guidelines, often overlooking MF (Eliakim et al., 2019). Furthermore, adolescent boys are underrepresented in the literature relative to girls (Cooper et al., 2015). This review builds upon the current literature by investigating the MF construct of PA. Our findings demonstrated that MF interventions were effective, which concurs with current literature suggesting adolescent boys may be receptive to MF interventions (Gray & Ginsberg, 2008). However, the small to moderate findings of this review should be interpreted with caution and considered in light of the high heterogeneity and a lack of specificity regarding the desired MF outcome in the studies. Moreover, the use of the term “strength training” within the literature is often misused, disregarding the independent nature of training adaptations to differing exercise modalities and overlooking the principle of specificity (Gamble, 2006). The concern of inappropriate inference to outcome measure has been previously raised (Moran et al., 2017) and the findings of this review suggest that there is also a lack of outcome measure specificity for MF and strength training in school-based studies.

The literature suggests MF interventions lasting 8 to 12 weeks are most effective in adolescent populations (Behringer et al., 2010; Drenowatz & Greier, 2018, 2018; Suchomel et al., 2018). Seventy-two percent of studies investigating MF interventions met or exceeded this, suggesting that intervention duration may not have been long enough in over a quarter of studies to evoke an efficacious response. It is acknowledged that MF must adhere to underlying physiological characteristics that affect muscular strength in order to elicit an efficacious response and/ or adaptation (Suchomel et al., 2018). Furthermore, the

development of strength is underpinned by a combination of neural and morphological factors that may not be specifically catered for by conducting combined activities that involve high intensity circuit-based interventions (Suchomel et al., 2018). Adolescence provides an opportunity for neural and architectural adaptations in the development of strength due to increases in anabolic and hormonal concentrations (Moran et al., 2017). However, 21 of the 43 data sets investigating MF utilised combined activities and may have overlooked the existing evidence-based methods that educe a more favourable response to the development of MF, such as specific set and repetition schemes combined with appropriate rest periods. However, the practicalities, compliance and pedagogical considerations associated with designing an MF programme have not been explored in the literature and may explain the lack of clarity on appropriate MF intervention design for a school-based setting. Moreover, the implementation of school-based RT may be impaired by some teachers reporting a lack of expertise/qualification and low confidence in the delivery of PE (Nathan et al., 2018) which may be further exacerbated through the introduction of RT which currently resides outside of traditional PE (Kennedy et al., 2019).

Interestingly, plyometric RT demonstrated a statistically significant, homogeneous effect. Plyometric training has been evidenced to benefit peak bone mass in adolescent girls (Witzke & Snow, 2000), and though evidence in boys is currently lacking, similar responses may be expected. However, only 2 studies adhered to appropriate plyometric training protocols, supporting the need for further quality research in this method of RT. Plyometric forms of training show promise and may provide a way to enhance muscle and bone strength. However, if such protocols are to be used within schools, appropriate training must be provided to ensure the safety and efficacy of this mode of RT. Moreover, individual variability in biological age, training age, skill and coordination will dictate prescription of training frequency, intensity, velocity and, volume of plyometric RT (Lloyd & Oliver, 2012). The complexities associated with plyometric RT may explain the lack of research. Thus, consideration to pedagogy and practical application beyond the research in a school-based environment requires further investigation.

A key finding of this analysis was that traditional methods of MF were most effective. These are similar to those commonly practiced in commercial gymnasium environments that adolescents may encounter after leaving school. Thus, exposure to traditional RT may allow for preparation towards the transition into a popular form of PA conducted by adults. Recommendations for loading protocols can expect to see loads of 5-10% added once the individual can comfortably perform 15 repetitions of a given movement with good form (Faigenbaum et al., 2010). This method of adding load to progress the intensity of the RT

may allow for greater perceived autonomy, whilst ensuring load increases are controlled through traditional machines and equipment allowing for smaller incremental increases when compared to bands or bodyweight. Moreover, allowing individuals to regulate the load progressions may enhance the intrinsic appeal (Halperin et al., 2018). Furthermore, the potential for enhancing physical literacy through neuromuscular adaptation indicative of RT may allow for previously disengaged adolescents to enhance their competence and participate in PA with greater intent and vigour. Adolescents that are overweight or obese may outperform their leaner peers when conducting traditional forms of RT expressed in an in an absolute manner (Ten Hoor et al., 2016). This may be due to their increased fat mass being indicative of a higher fat free mass, thus obese and overweight individuals may be able to lift or move more weight than leaner adolescents. Collectively, this greater involvement and ability to exercise competently alongside their peer group may allow for the relatedness component of self-determination theory (SDT) to be satisfied. Further research is warranted and should investigate SDT as a psychological construct to inform RT intervention design and content.

Subgroup analyses of muscle group was conducted to explore potential variance in MF outcomes, attributed to growth, maturation and peak strength velocity occurring approximately 2 years after peak height velocity in adolescent boys (Beunen et al., 1992; Carvalho et al., 2012). Evidence suggests that children and adolescents have a reduced ability to recruit type 2 muscle fibres, resulting in a lower voluntary muscle strength, speed and power output (Cohen et al., 2010; Dotan et al., 2012; Falk et al., 2009). Interventions conducted in the school environment, may provide variance as to when students reach PHV and in turn, PSV. School-based interventions delivered to a broad range of youth should focus on developing muscle groups that may produce a homogeneous effect across a variety of ages, abilities, environments and attitudes towards PA. This systematic review and meta-analysis demonstrated that lower limb MF outcomes (n=27) had a homogeneous small to medium effect when compared to upper limb outcomes. This is irrespective of the potential for variance in ability, age and attitude towards PA and suggests interventions targeting lower limb may be more effective than interventions designed to target upper limb. However, these results should be interpreted with caution as seven different measures to assess lower limb strength were used throughout the studies. Future research should standardise the use of lower limb strength measurements in order to assess and contextualise the efficacy of RT and its impact on lower limb development in the school environment. The findings of this review suggest that lower limb strength can be increased in a school-based setting across a broad spectrum of ages, abilities and body types.

Investing more time into the development of lower limb MF may support lowering the high percentage of lower limb injuries currently witnessed in active adolescent males (Faigenbaum & Myer, 2010), allowing those active individuals to continue PA within and beyond formal education. Furthermore, it has been suggested that the loss of muscle mass associated with the ageing process later in life, may result in reductions in PA, with lower limb muscle groups being particularly susceptible to this phenomenon (Candow & Chilibeck, 2005). The findings of this review suggest school-based interventions may contribute to homogeneous development of lower limb MF in adolescent males and contribute towards mitigating age related declines through effective and early development of lower limb MF.

Methods of assessing upper limb strength (n=14) were consistent across all 7 studies. Press ups and grip strength featured in five and four of the studies respectively, with one study assessing medicine ball throw. However, grip strength for upper limb assessment may not be the most reflective of those movements conducted during everyday life or as part of an exercise training regime (Abernethy et al., 1995; Smith et al., 2014). Recently, back leg and chest dynamometry has been validated in adolescents and may provide a cost effective, mobile and simple tool to assess overall limb strength (Smith, Eather, Weaver, et al., 2019; Ten Hoor, Musch, et al., 2016). To date, no school-based interventions investigating MF have utilised back leg and chest dynamometry as a measure to assess overall limb strength. Future research should consider the use of back leg and chest dynamometry to provide a measure of overall strength that may be more aligned to everyday life and as a marker of health (Smith, Eather, Weaver, et al., 2019; Ten Hoor, Musch, et al., 2016). Upper limb MF outcomes did not provide a homogeneous outcome despite the consistency in assessment measures. This may be attributed to the variance in ages, both biologically and chronologically having an impact on force generation of the upper limb due to restriction in type 2 muscle fibre utilisation (Dotan et al., 2013). There may be a pedagogical concern when considering some of the functional shortcomings in adolescent boys, especially when attempting to design intervention and training protocols for this population group (Faigenbaum & Myer, 2010). Although data is limited, it is suggested that upper limb RT may account for a larger proportion of injuries in early adolescence (Faigenbaum & Myer, 2010). Further research is required to account for the heterogeneity in MF outcomes of the upper limb and provide practitioners with appropriate, safe and effective stimulus to enhance MF in adolescent males.

Only two studies objectively measured trunk strength. Trunk strength measures are simple to conduct and may inform the health of the lower back (Moya-Ramón et al., 2018). Although measures of trunk strength are simple to conduct in a field-based setting, researchers may be discouraged by the lengthy familiarisation process (Brotons-Gil et al., 2013). Researchers should explore methods that support a reduced familiarisation period or introduce familiarisation methods before intervention and data collection.

Reporting of the school-based MF interventions is sparse within the literature (Janssen & LeBlanc, 2010). Furthermore, the utilisation of behavioural theory and socio-ecological models to underpin the delivery of MF interventions are not widely used. This may be due to recent work suggesting that these models and constructs may not elicit a favourable outcome in the delivery of PA interventions investigating aerobic MVPA (Kipping et al., 2014; Tymms et al., 2016; van Sluijs et al., 2007, 2011), resulting in a lack of willing to explore behavioural constructs when designing interventions. The school-based environment is unique in providing a largely mandatory setting to a broad range of youth (Beets et al., 2016). Future intervention design may benefit from exploring enhanced, extended and expanded opportunities (TEO) for youth PA and MF development in conjunction with complex behavioural theories (Beets et al., 2016) and avoid repeating the shortcomings evidenced in school-based aerobic MVPA intervention design (Kipping et al., 2014; Tymms et al., 2016; van Sluijs et al., 2007, 2011). TEO allows for a pragmatic approach to intervention design, expanding on PA opportunity by adding to the current PA opportunities, extending PA by adding additional time to current PA opportunities and, enhancing PA by augmenting existing PA opportunities (Beets et al., 2016). Addressing both TEO and motivational psychological constructs may enhance the quality of the PA experience and positively impact intervention outcomes (Beets et al., 2016). At an age where adolescent males may be preparing to leave the formal education environment, providing an opportunity to participate in RT may fulfil both a desire (Corder, Atkin, Ekelund, & van Sluijs, 2013) and a need to explore a mode of PA that supports lifelong PA (Hulteen et al., 2016). Future research should utilise TEO to allow both teachers and students to become familiar with the prescription of RT through the addition of its use within a school-based setting. This may help dispel some of the myths surrounding implementation (i.e. the need for specialist equipment and RT can damage growth) (Steele et al., 2017) and cultivate future intervention design.

Although RT in schools is still a developing concept, examples of periodised implementation have been reported when integrating RT (Pichardo et al., 2019). As discussed, the correct

implementation of a RT programme is reliant upon accurate and appropriate testing to ensure the practitioner can assign the correct volume and intensity to progress the adolescent (Suchomel et al., 2018). Previously, testing protocols in the school environment have been greeted with trepidation from parents (Cohen et al., 2015b). Traditionally fitness testing has been aerobically, or bodyweight centred, which may negatively impact physical self-concept in overweight and obese adolescents (Cohen et al., 2015; Martin et al., 2010; Zhu et al., 2010). However, the nature of assessing MF can provide a way of overweight and obese adolescents to demonstrate their increased absolute strength when compared to their leaner peers (Ten Hoor et al., 2016). Highlighting the areas in which adolescents excel physically may support positive relationships with PA, sport and PE.

In addition to the testing considerations necessary for the implementation of a RT interventions, the timing and period of delivery is equally as important (Drenowatz & Greier, 2018; Faigenbaum et al., 2009). The school environment lends itself well to the development of macrocycles that cover an academic year (Pichardo et al., 2019). Furthermore, the structure of terms within the academic year could provide a way to develop detailed planning lasting between 2-6 weeks in the form of a mesocycle (Haff, 2016). Consideration to time constraints placed upon the school should be taken into consideration when developing future interventions. Typically, exposure to PA is conducted within PE sessions lasting 45-60 minutes (Duehring et al., 2009), allowing for a suitable amount of time to conduct effective RT in the school setting (Lloyd, Faigenbaum, et al., 2014). Overall, methods of constructing long term planning are not only pragmatically appropriate to the school environment, but also widely recognised within RT literature, in both youth and adults (Suchomel et al., 2018). Future research should consider the potential for the academic year to act as a construct for periodisation, whilst adhering to recognised protocols for RT to enhance specific MF adaptations. RT in schools should be approached with an informed appreciation for the nuances involved in programme design, delivery and a clear objective of the MF adaptation required. For delivery success at a larger scale, training must be provided to teachers and school coaches to confidently and effectively deliver RT.

3.5 Strengths of this review and meta-analysis

This review is the first to address the efficacy of school-based PA interventions on MF outcomes in adolescent boys. This systematic review and meta-analysis are novel by way of addressing MF outcomes which are an element of youth PA guidelines. Further strengths were that the process to locate and extract all relevant data was rigorous and utilised an

experienced librarian to ensure a comprehensive search strategy. Moreover, the grey literature search ensured that relevant non-peer reviewed information was not missed.

3.6 Limitations and recommendations for future research

There are limitations to this study that should be considered when interpreting the results. Although this review aimed to provide an international reference based upon the publication of the WHO PA guidelines (World Health Organization, 2010), it should be noted that recommendations for RT were made in the 2008 American PA guidelines (Leavitt, 2008). However, many countries are yet to develop their own PA policy and may utilise the WHO PA guidelines (World Health Organization, 2010) as a global reference to inform their national PA guidelines and policy (Sallis et al., 2016). Furthermore, continuity of assessment method for MF interventions varied greatly, especially in the lower limb. The way in which training regimes were administered may also impact the outcome within the interventions; it is well understood that the end result of MF is determined by how the intervention is delivered and further research should seek to contextualise this to appropriately inform future practice (Suchomel et al., 2018). Future research should investigate how differing MF delivery impacts the efficacy and outcome of the intervention.

Additionally, qualitative measures should be utilised to address the concerns of adolescent boys reported within the literature, with a third reporting a desire to enhance muscular aesthetics and another third reportedly wanting to become leaner (Ricciardelli & McCabe, 2003). Furthermore, it has been hypothesised that adolescent boys may be more inclined to participate in MF activities that are deemed more masculine (Lubans & Cliff, 2011), this may have an impact on habitual PA. To date, the literature investigating the potential effect enhancing MF has on habitual PA has not been appropriately investigated and requires further work. Due to an insufficient amount of studies available reporting MF outcome aim (i.e., muscular endurance and power), analysis of specific adaptation outcomes could not be completed. Future research should be encouraged to provide an outcome measure such as increasing muscular endurance, power or hypertrophy so that future inferences and recommendations can be based upon the intervention outcome.

Future research should standardise MF assessment methods for use within adolescent population groups. Accurate measures of MF outcomes should be a documented within the literature to provide reliable measurement tools. Poor reliability may lead to erroneous conclusions about the MF parameter being measured. Studies investigating changes in MF should consider the whole intervention and how conflicting training modalities may impact

MF outcomes. Finally, analysis of further moderators such as age (chronological and biological) and method of delivery (i.e., teacher or researcher delivered) was not possible due to insufficient detail contained within the literature. Future research should consider the impact of age and delivery method during interventions and report the methods within the study.

3.7 Conclusions

This systematic review and meta-analysis found a significant small effect for school-based MF interventions in adolescent boys. Efforts should be made to investigate the often overlooked MF element of the PA guidelines which promote and support physical and psychological health in youth. Traditional and plyometric methods of RT demonstrated the greatest effect when compared to other forms of RT, such as body weight movements and require further research to draw more generalisable conclusions to inform long term intervention design.

Chapter 4

Study 2:

"It's Just Not Something We Do at School". Adolescent Boys' Understanding, Perceptions, and Experiences of Muscular Fitness Activity

The main outcomes of this study have been published in Cox, Ashley, Stuart J. Fairclough, and Robert J. Noonan. '"It's Just Not Something We Do at School". Adolescent Boys' Understanding, Perceptions and Experiences of Muscular Fitness Activity'. *International Journal of Environmental Research and Public Health* 18, no. 9 (5 May 2021): 4923. https://doi.org/10.3390/ijerph18094923.

Thesis map

Study	Aim	Outcome
Study 1. Efficacy of School-Based Interventions for Improving Muscular Fitness Outcomes in Adolescent Boys: A Systematic Review and Meta-analysis	To investigate the efficacy of school-based interventions on MF outcomes in adolescent boys	This systematic review and meta-analysis found a significant small effect for school-based MF interventions in adolescent boys. Efforts should be made to investigate the often overlooked MF element of the PA guidelines which promote and support physical and psychological health in youth
Study 2. "It's Just Not Something We Do at School". Adolescent Boys' Understanding, Perceptions, and Experiences of Muscular Fitness Activity	To use a combination of qualitative techniques to explore adolescent boys' understanding, perceptions, and experiences of physical activity, and the role muscular fitness plays within boys' physically active lifestyles	
Study 3. PE Teachers' Perceived Expertise and Professional Development Requirements in the Delivery of Muscular Fitness Activity: PE Teacher EmPOWERment Survey		
Study 4. The Feasibility and Acceptability of an Online CPD Programme to Enhance PE Teachers' Knowledge of Muscular Fitness Activity.		

Background: English youth typically do not sufficiently engage in the types and intensities of physical activity that develop muscular fitness. The aim of this study was to use a combination of qualitative techniques to explore adolescent boys' understanding, perceptions, and experiences of physical activity and the role muscular fitness plays within boys' physically active lifestyles.

Methods: Focus group interviews with a write, draw, show, and tell activity were conducted with 32 adolescent boys aged 14–16 years from 3 secondary schools. Three separate sources of data (frequency counts, verbatim transcripts, and visual data) were generated and were pooled together and triangulated. Data were analysed deductively, first using the Youth Physical Activity Promotion model as a thematic framework, and then inductively.

Results: Physical activity was frequently associated with organised sport, and most boys were unaware of current UK physical activity guidelines. Co-participation was frequently reported as a reinforcing factor to physical activity.

Conclusions: There was a perceived lack of opportunity to participate in muscular fitness activities, particularly in school, and knowledge of how to conduct muscular fitness activities was limited. The contribution of physical education was highlighted as being key to facilitating exposure to muscular fitness activities.

4.1 Introduction

Current physical activity guidelines for the UK and other developed countries suggest children and young people should engage in a variety of types and intensities of physical activity across the week to develop movement skills, bone strength and muscular fitness (Bull et al., 2020). Despite the growing body of literature supporting the health benefits of muscular fitness (Chalkley, 2021; Fraser et al., 2020; Janssen et al., 2020), it is often an overlooked element of the physical activity guidelines, with much of the focus towards averaging at least 60 minutes of daily aerobic-based moderate to vigorous intensity physical activity over the week (Bennie et al., 2020; Eliakim et al., 2019). Throughout the last 50 years muscular fitness levels have declined across most developed countries including the UK (Dooley et al., 2020). Low muscular fitness contributes to the development of non-communicable disease risk in adolescents, leading to poor health in adulthood including cardiovascular disease, osteoporosis, and type 2 diabetes (Ortega et al., 2008; Smith et al., 2014). Improving muscular fitness is associated with a range of health markers including cardiorespiratory fitness (Alberga et al., 2016; Chung-Wah Yu et al., 2016), metabolic function (Bea et al., 2017; Meinhardt et al., 2013; Smith et al., 2014), bone health (Torres-Costoso et al., 2020) and mental health (García-Hermoso et al., 2019) in youth.

Adolescent boys have been highlighted as a group that may respond well to muscular fitness activity (Lubans et al., 2016) and recent evidence has confirmed the efficacy of muscular fitness activity when delivered in schools (Cox et al., 2020). However, much of the evidence pertaining to muscular fitness amongst adolescents is quantitative in nature (Smith et al., 2020). Formative research with the target group may overcome key intervention challenges including recruitment and engagement and could improve intervention efficacy (James et al., 2018; Ott et al., 2011). Adolescents have previously suggested barriers to conducting physical activity are lack of facilities, high cost and accessibility to facilities to conduct physical activity (Brophy et al., 2011; Charlton et al., 2014; Filippidis & Laverty, 2016; James et al., 2018), yet none of the studies address muscular fitness activity independently. Moreover, adolescence is key to developing healthy habits and behaviours that carry over into adulthood (Sawyer et al., 2012). Therefore, if future research is to implement muscular fitness activity interventions in adolescent boys, then contextualising their understanding, perceptions and experiences of muscular fitness activity may support intervention success.

The use of qualitative data can provide additional context to key factors that facilitate and hinder adolescent participation to physical activity (Smith & Phoenix, 2019). Socioecological models provide a framework to understand the various personal, social and environmental factors that facilitate and restrict adolescent physical activity (Abdelghaffar et al., 2019; Sallis et al., 2006; Welk, 1999). These influences are represented in the Youth Physical Activity Promotion Model (Welk, 1999). The Youth Physical Activity Promotion Model's socio-ecological approach allows for both the social and built environment to be investigated and provides an appropriate framework to inform intervention design beyond focussing on the individual. To date, much of the qualitative investigation into adolescent physical activity has relied on focus group interviews alone (James et al., 2018; Jong et al., 2019; Martínez-Andrés et al., 2020). However, adolescents are at a vulnerable stage in their development and often have difficulty in expressing their thoughts, feelings and emotions verbally (Kirk, 2007). Therefore, qualitative investigation within this population group requires careful consideration of the methodologies used and may benefit from the use of visual methods to engage participants (Darbyshire et al., 2005; Kirk, 2007). A more appropriate and inclusive approach is to use focus group interviews in combination with drawings, which provides participants greater control over their expression compared to verbal communication alone. Several research studies have utilised drawing techniques within focus group interviews (Morrow, 2001) to engage adolescents in the research process and facilitate communication and discussion around health-related topics (Angell et al., 2015; Buckingham, 2009; Harden et al., 2000). The "write, draw, show and tell" method provides participants with alternative ways of expression thereby enabling a deeper exploration of perceptions and experiences by not limiting participants to verbal communication alone. The multi methods based approach has been shown to foster greater inclusivity and elicit more representative and complete perceptions on physical activity topics compared to singular methods based approaches (Noonan et al., 2016).

The aim of this study was to use a combination of qualitative techniques to explore adolescent boys' understanding, perceptions and experiences of physical activity and the role muscular fitness has within boys' physically active lifestyles. It was envisaged that the contextual information gathered from this study will provide a) novel insights into the meanings adolescent boys ascribe towards physical activity, and b) inform the design of future physical activity promotion strategies targeting adolescent boys.

4.2 Materials and methods

To ensure explicit and comprehensive reporting, the consolidated criteria for reporting

qualitative research were used to guide the reporting process (Tong et al., 2007). Eight schools situated in a range of deprivation areas were provided with study information and invited to participate in the study. Three schools agreed to participate in the study, with data collection taking place during mandatory physical education classes, which provided a mixed physical ability sample.

4.2.1 Participants

All eligible boys had taken part in a previous cross-sectional study and completed a study pack containing parent/carer and child information sheets, parent/carer consent forms, and participant assent forms. For the purposes of this study, 32 consenting adolescent boys (aged 15.23 $\pm$ 0.60 years) from across three schools in North West England were randomly selected to take part via a lottery method. Ethics approval for this study was granted by the Edge Hill University Ethics Committee (SPA-REC-2017-321), and data collection took place between November 2019 and January 2020.

4.2.2. Procedures

Five focus group interviews with a write, draw, show, and tell activity were arranged and conducted by the first author at school sites during timetabled physical education lessons. Each focus group interview comprised between five and eight (seven, five, five, eight, and seven, respectively) participants, and was conducted between 09:30 a.m. and 01:00 p.m. so as to limit participant fatigue and restlessness (Kennedy et al., 2001). Other than participant age, there were no specific inclusion criteria employed. To maintain the interest and enthusiasm of participants and accommodate short attention spans (Colucci, 2007; Gur et al., 2012; Pacheco-Unguetti et al., 2010), each focus group interview comprised a range of different interactive activities and lasted between 19 and 21 (mean = 20.11) min. The 20 min time allocation was stipulated by the first participating school and was utilised in subsequent schools in order to minimise bias and ensure consistency and standardisation across other schools.

Semi-structured focus group interview guides were used to ensure consistency across each focus group interview. The semi-structured focus group interview guides were informed and structured around the multi-methods write, draw, show and tell framework (Noonan et al., 2016) (see (Martínez-Andrés et al., 2020; Noonan et al., 2017; Noonan et al., 2016; Taylor et al., 2018) and Table 4.1 for detail). The multi-methods approach was incorporated into focus group interviews to further stimulate participant's thinking and facilitate discussion around physical activity. The write, draw, show and tell framework has been used in

previous qualitative research investigating young people's physical activity perceptions(Noonan et al., 2017; Noonan et al., 2016; Taylor et al., 2018). Focus group interview questions were underpinned by the youth physical activity promotion model, which acknowledges the various individual, social and environmental factors that influence physical activity (Welk, 1999). Example write, draw, show and tell questions used throughout the focus group interviews are presented in Table 4.1. The Youth Physical Activity Promotion Model describes three factors that predispose, reinforce or enable physical activity behaviour. Predisposing factors include variables that increase the likelihood of engaging in physical activity and are based upon a self-evaluative construct that reduces physical activity behaviour into two fundamental questions: Am I able? and Is it worth it? These two fundamental questions explore attitudes and beliefs about physical activity and perceptions of self-confidence and self-worth. Reinforcing factors include variable that reinforce physical activity behaviour and may include peers, family, coaches and teachers. Finally, enabling factors include variable that allow youth to be physically active and may consist of environmental and biological factors.

Table 4.1 Example write, draw, show, and tell questions

Topic	**Question**
Physical Activity Knowledge	How much physical activity should we do each week? What is the difference between aerobic and resistance activity?
Predisposing	What physical activities do you take part in at school and out of school? Why do you do more of this activity than others?
Enabling	What opportunities do you have to participate in muscular fitness activity?

Reinforcing	When you are physically active, who do you do these activities with? What do parents, friends, coaches, or teachers think of you doing muscular fitness activity?

Focus group interviews were conducted in quiet, non-intrusive school classrooms, where participants and researcher alike could be overlooked but not overheard. A circular seating arrangement was used, with the researcher sat with the children, and the researcher and children addressed one another by their first name (Adler et al., 2019). Following explanation of the procedure, verbal consent was obtained from all participants. During focus group interviews efforts were made by the first author to ensure all individuals participated, for example, by making eye contact with participants to encourage them to contribute to the discussion and asking individuals to expand on their individual responses (Adler et al., 2019).

An icebreaker activity conducted at the beginning of each focus group interview provided participants the opportunity to experience speaking aloud and helped to establish an environment where individual contributions are welcomed, encouraged and respected. Participants were provided with Post-It note© paper and asked to write down '5 words to best describe physical activity to someone else'. Participants then placed their responses on to a centralised whiteboard and were asked to provide further detail on their response. Following the post-it note task, participants were provided with a series of open-ended questions aligned to the aims of the study (see Table 4.1). In order to improve the flow of discussion and engage all participants, open questions starting with 'what' and 'how' were posed to participants. Participants were then provided with the opportunity to discuss topics amongst themselves, with the lead author repeating back responses on their main discussions to ensure correct interpretation and gain clarity regarding group discussions and to further engage shy participants (Lund et al., 2016). This method of respondent validation has been used elsewhere with this age group and helps increase the legitimacy and trustworthiness of the reported findings (James et al., 2018; Torrance, 2012).

To further triangulate data and ensure credibility and dependability of findings participants were invited to express their perceptions of physical activity through a write/draw activity. Participants were asked to independently 'Draw an area, place, space or environment where you are most likely to be active'. The drawing task took the focus away from direct

questioning and consensus, allowing participants to contribute and engage through other means and thus strengthen the study findings. Throughout the draw activity the first author separately engaged children in informal conversations for them to articulate what they were drawing and why. All focus group interview discussions were audio-recorded and transcribed verbatim.

4.2.3 Data management and analysis

The focus group interviews provided three sources of data; frequency count (Post-It note©; show activity), visual data (write and draw activity), and verbatim data (tell activity and participant's write and draw narratives). Frequency counts, visual data and verbatim data were pooled together to explore and expand upon emergent themes and clarify findings. The multifaceted data collection approach allowed for data triangulation which minimised misinterpretation and in doing so enhanced the credibility of the findings (Darbyshire et al., 2005; Smith & Noble, 2014). All data were managed in NVivo12 (Version 12.6.0; QSR International Pty Ltd, Victoria, Australia) and analysed independently. Data were first analysed deductively using the Youth Physical Activity Promotion Model as a thematic framework and then inductively to enable emergent themes to be further explored. Braun and Clarke's phases of thematic analysis were used to inform the coding process once the lead author had become familiar with the transcripts (Braun & Clarke, 2006). This approach to analysis allowed for flexibility and helped examine different perspectives of participants and summarise key points of a large data set (Nowell et al., 2017). Thematic analysis followed a six phase process (Braun & Clarke, 2006a). The phases allowed for a recursive process and provided flexibility as the transcribed data were coded and themed.

Phase 1: familiarisation with the data was conducted by the lead author of the published manuscript. The process involved listening to the audio recording of the interviews twice, transcription of the audio and reading and then rereading of the transcripts to ensure familiarity with the entire data set. Throughout phase 1, notes were taken that aligned with potential codes and added into NVivo 12.

Phase 2: initial codes were generated. Initial coding was theory driven and a set of codes were generated, defined, and named that provide insight into the understanding, perceptions and experiences of MF activity in adolescent boys. The third author of the published manuscript then reviewed the coding process and provided suggestions to ensure the coding was representative of the YPAPM and existing literature terminology.

Phase 3: searching for themes. Once all data were coded and collated broader themes

were developed that aligned to the write, draw, show and tell questions and the YPAPM. Different codes were sorted into broader themes. Where codes were similar e.g., code: *boy participates in football with brother* and code: *boy participates in tennis with his sister*, the broader theme of sibling support that aligns with YPAPM combined the two codes. Thematic maps were used to organise the data and identify relationships between themes and sub-themes. A miscellaneous theme was generated to house codes that did not fit the themes identified during phase 3.

Phase 4: reviewing themes. Reviewing and refining of themes consisted of two levels. The first level involved reviewing at the level of the coded data extract and ensuring the data formed a coherent pattern. If data extracts did not fit the theme, they were removed and considered for use under another theme. Level two consisted of consideration of the themes and sub-themes in relation to the entire data set. Thematic maps from phase 3 were refined to better reflect the theoretical approach underpinning the analysis. Individual thematic maps were then combined with other identified themes to ensure individual maps fitted within the overarching theory as dictated by the YPAPM.

Phase 5: defining and naming themes. Themes were organised to the YPAPM theoretical framework, with sub-themes expanding where the story in a coherent manner. Themes were checked to ensure there was not too much overlap and were considered as a standalone theme and how the theme and any sub-theme related to other themes.

Phase 6: producing the report. To provide a concise, coherent, logical, non-repetitive and interesting account of the story the data tell, verbatim extracts were embedded into the analytical narrative (Braun & Clarke, 2006a). Pen profiles were constructed to present the thematic maps with verbatim quotations to further contextualise themes and sub-themes (Clark et al., 2020). To provide an indication of the prevalence of the themes, the number of times a specific theme was mentioned across all interview data is also presented (Clark et al., 2020; Ridgers et al., 2012). This approach to presenting data is considered appropriate and accessible to researchers and practitioners with an affinity to both qualitative and quantitative backgrounds (Clark et al., 2020).

Researcher triangulation took the form of a presentation of the verbatim quotations and drawings to the third author as a critical friend who had previously independently reviewed the data sources and cross-examined the data sources against the themes in reverse to offer alternative perspectives. This process was repeated until a minimum 90% agreement

level had been reached by the two authors (McAlister et al., 2017; O'Connor & Joffe, 2020; Roberts et al., 2019). Once both authors were in agreement, the final codes were counted and placed into pen profiles for reporting. The pen profile approach has been used in previous physical activity research with young people and adolescents (Charlton et al., 2014; James et al., 2018; Noonan et al., 2016; Ott et al., 2011).

4.3 Results

4.3.1 Ice breaker results

A total of 135 responses were recorded for the icebreaker activity/post it note task. Physical activity was most frequently associated with fun (n = 18), enjoyable (n = 11), and healthy (n = 9); the top 10 responses are presented in Table 4.2.

Table 4.2 Top 10 responses for the icebreaker activity.

Word	Count
fun	18
enjoyable	11
healthy	9
active	7
exercise	4
movement	4
physical	4
running	4
energetic	3
exciting	3
fitness	3
hard	3
interesting	3
sport	3

alive	2

4.3.2. Knowledge of physical activity

Participants' knowledge of physical activity was placed into one of three coding categories and is presented in Figure 4.1. Three themes of physical activity knowledge, no knowledge, and incorrect interpretation of physical activity guidelines were further subdivided into aerobic and muscular fitness activity, to conduct further inductive content analysis and to establish areas of physical activity knowledge. Participants were deemed to incorrectly interpret physical activity guidelines if they could not accurately relay what the current recommendations were.

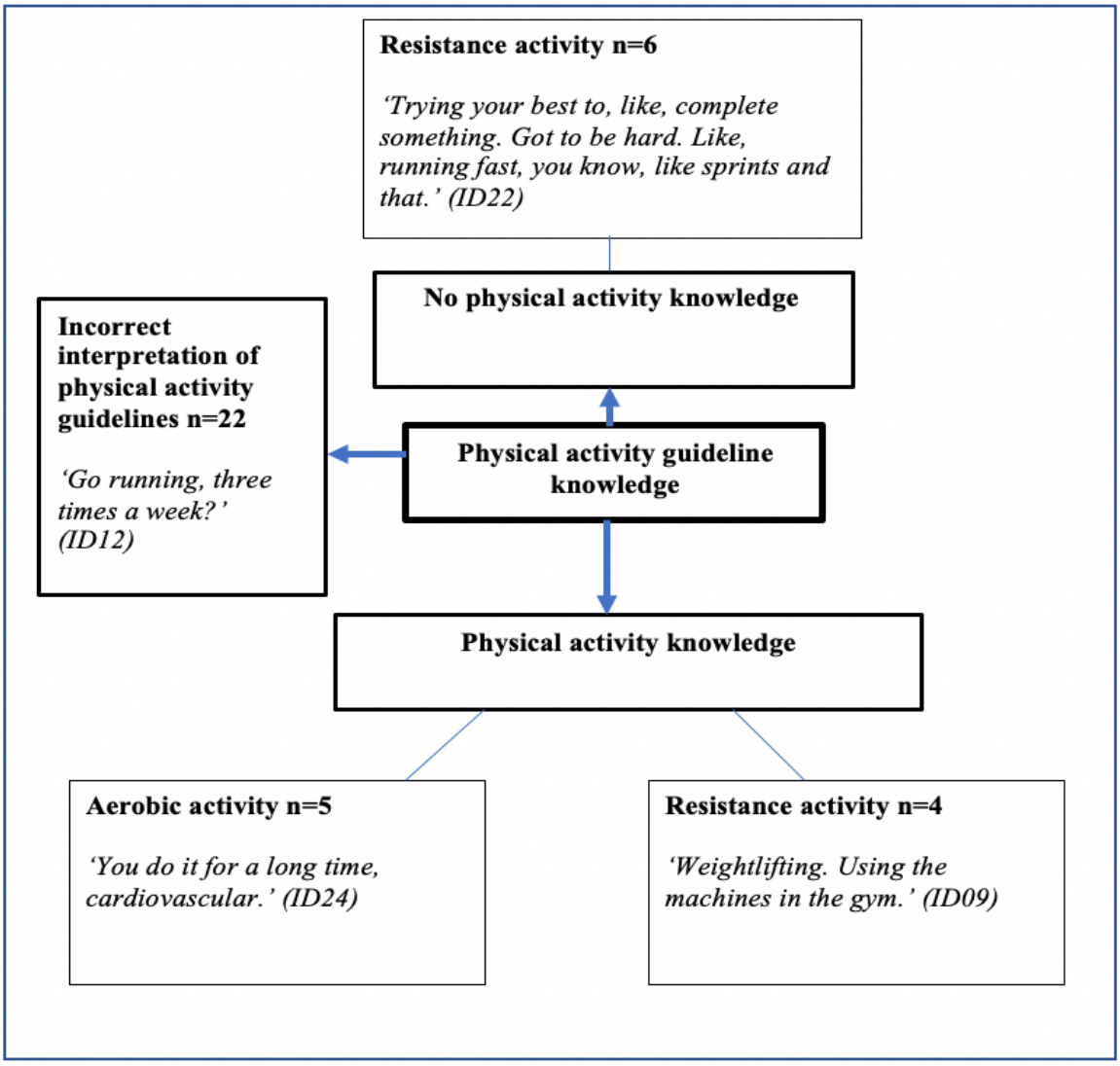

Figure 4.1 Physical activity guideline knowledge.

4.3.3 Predisposing factors to physical activity

Profiles representing boys' perceived predisposing factors to conducting physical activity are displayed in Figure 4.2, with the two fundamental questions of "Am I able?" and "Is it worth it?" utilised to perform coding. Five subthemes of competence +ve (n = 12), competence −ve (n = 6), masculinity +ve (n = 6), enjoyment +ve (n = 8), and enjoyment −ve (n = 3) were linked to predisposing factors to conducting physical activity. Both positive (+ve) and negative (−ve) influences featured in primary predisposing themes.

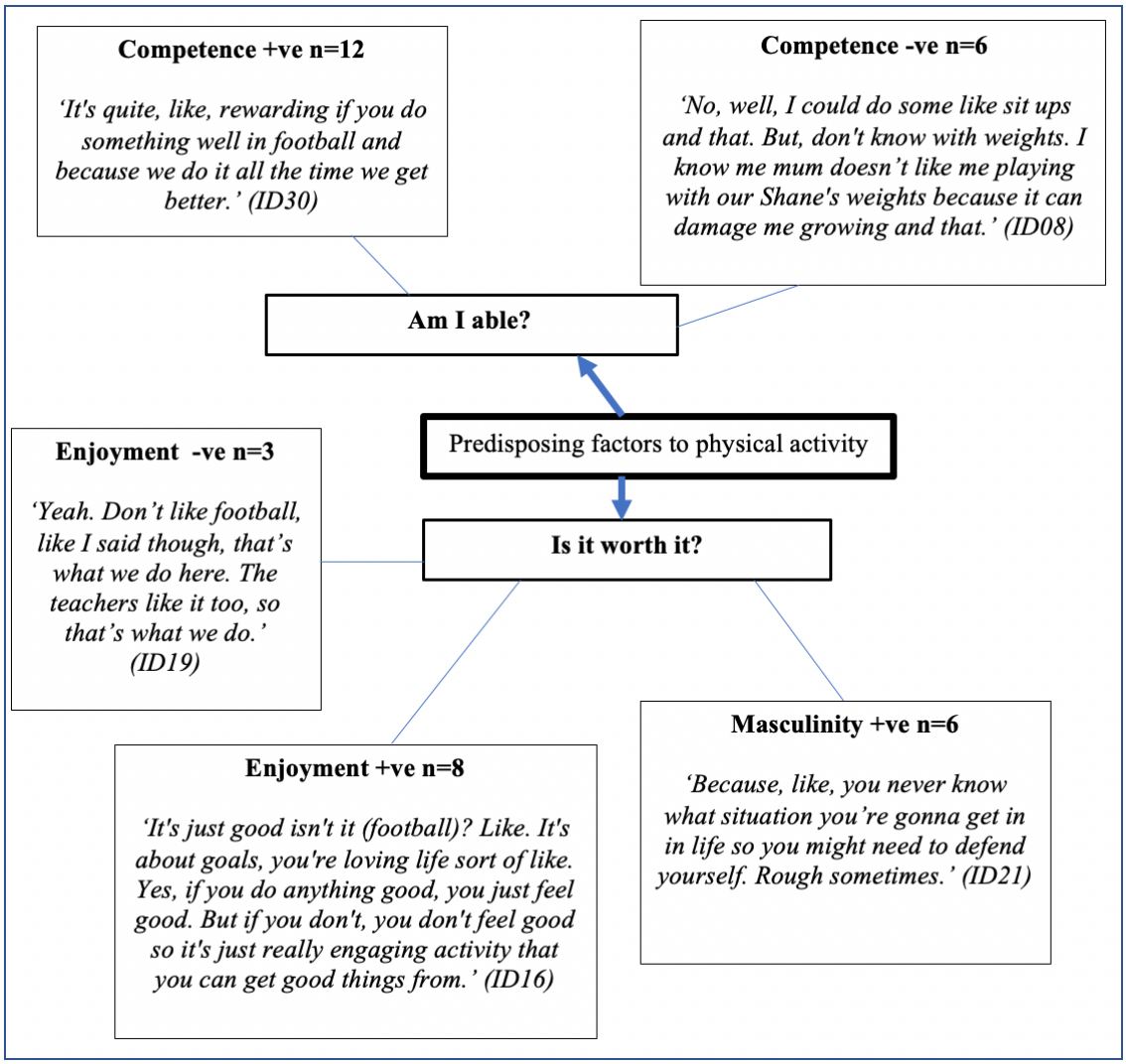

Figure 4.2. Predisposing factors to physical activity. +ve = positive; −ve = negative.

4.3.4. Reinforcing factors to physical activity

Boys' perceived reinforcing factors to physical activity are presented in Figure 4.3, with six primary themes: parental support, parent attitudes/beliefs, teacher support, sibling support, community, and friends. A further nine secondary themes were identified: interest −ve (n =

1), broken family −ve (n = 1), injury concerns −ve (n = 2), logistical support +ve (n = 2), sibling co-participation +ve (n = 4), knowledge development −ve (n = 14), co-participation (teachers) +ve (n = 4), co-participation (friends) −ve (n = 3), and co-participation (friends) +ve (n = 11). Positive (+ve) and negative (−ve) influences featured in both primary and secondary reinforcing themes.

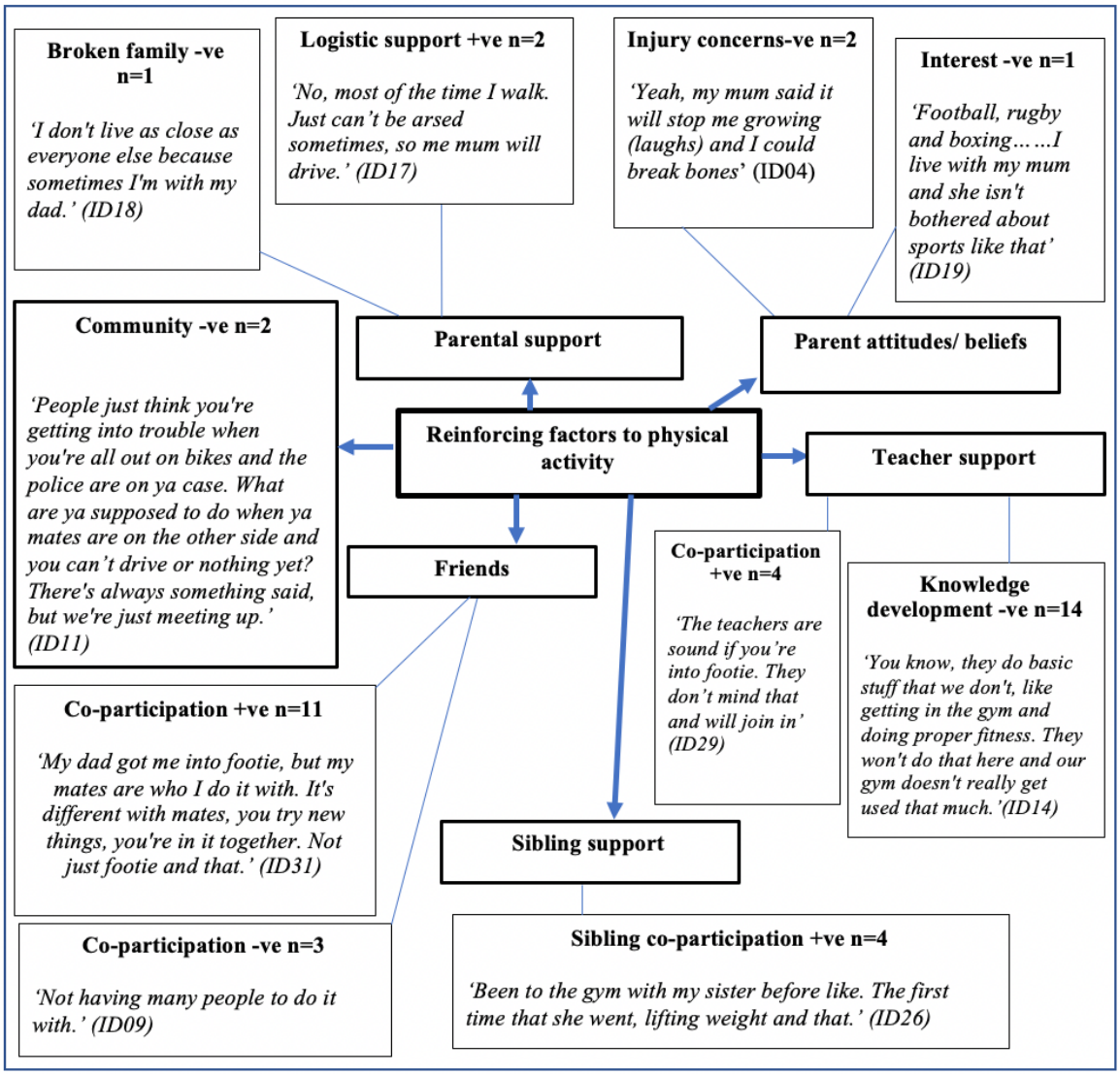

Figure 4.3. Reinforcing factors to physical activity. +ve = positive; −ve = negative.

4.3.5. Enabling factors to physical activity

Boys' perceived enabling factors to physical activity are presented in Figure 4.4. There were four primary themes: environment, fitness, time, and technology; and six secondary themes: crime −ve (n = 4), provision −ve (n = 15), provision +ve (n = 8), proximity −ve (n = 8), proximity +ve (n = 7), and traffic −ve (n = 2). Positive (+ve) and negative (−ve) influences featured in both primary and secondary enabling themes.

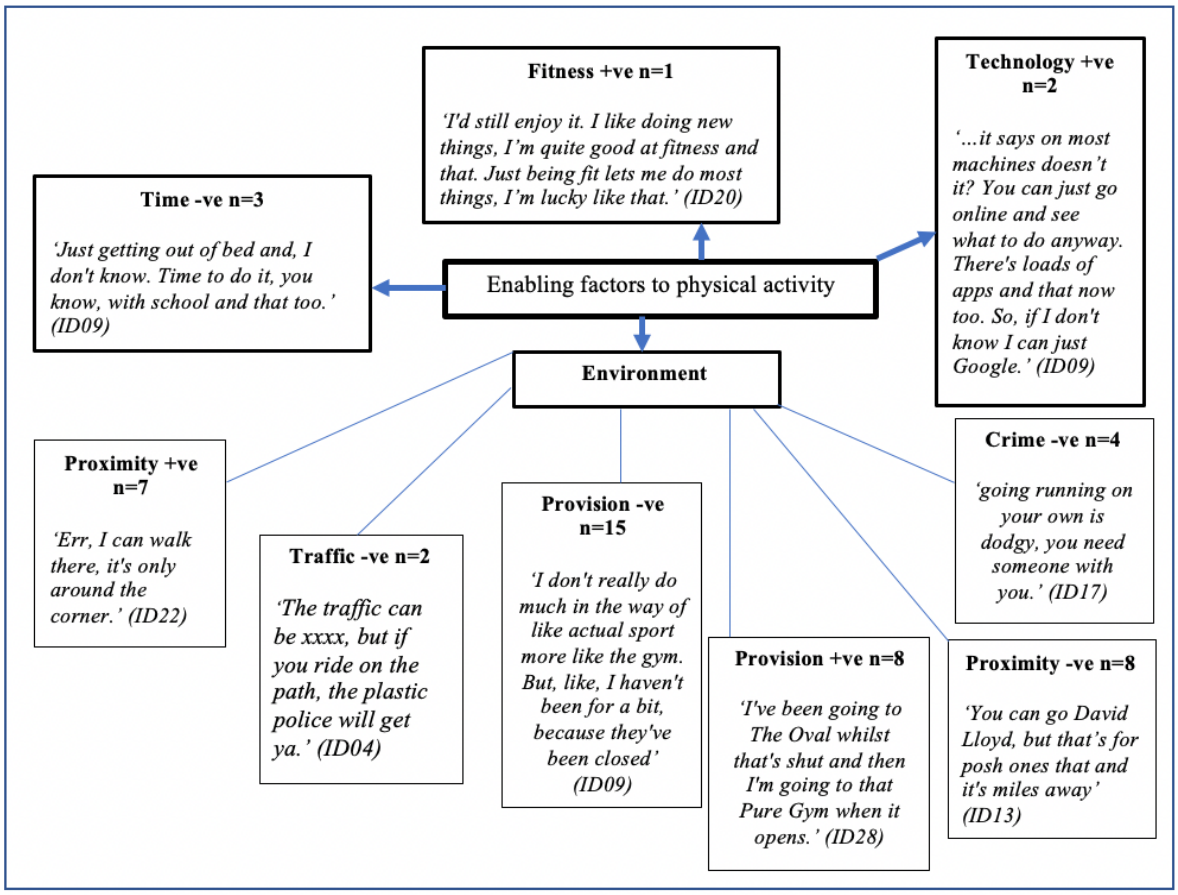

Figure 4.4. Enabling factors to physical activity. +ve = positive; -ve = negative.

4.3.6. Write and draw

Thirty-two boys completed the write and draw task. There were 111 marks from reports on specific themes. Figure 4.5 illustrates themes with five primary themes: activity, co-participation, parental support, coach support, and physical environment. A further 12 secondary themes were identified: siblings, friends, logistic support, verbal encouragement, home, school, sports field, gym, sports facility or leisure centre, muscular fitness activity, aerobic-based physical activity, and traditional team sport.

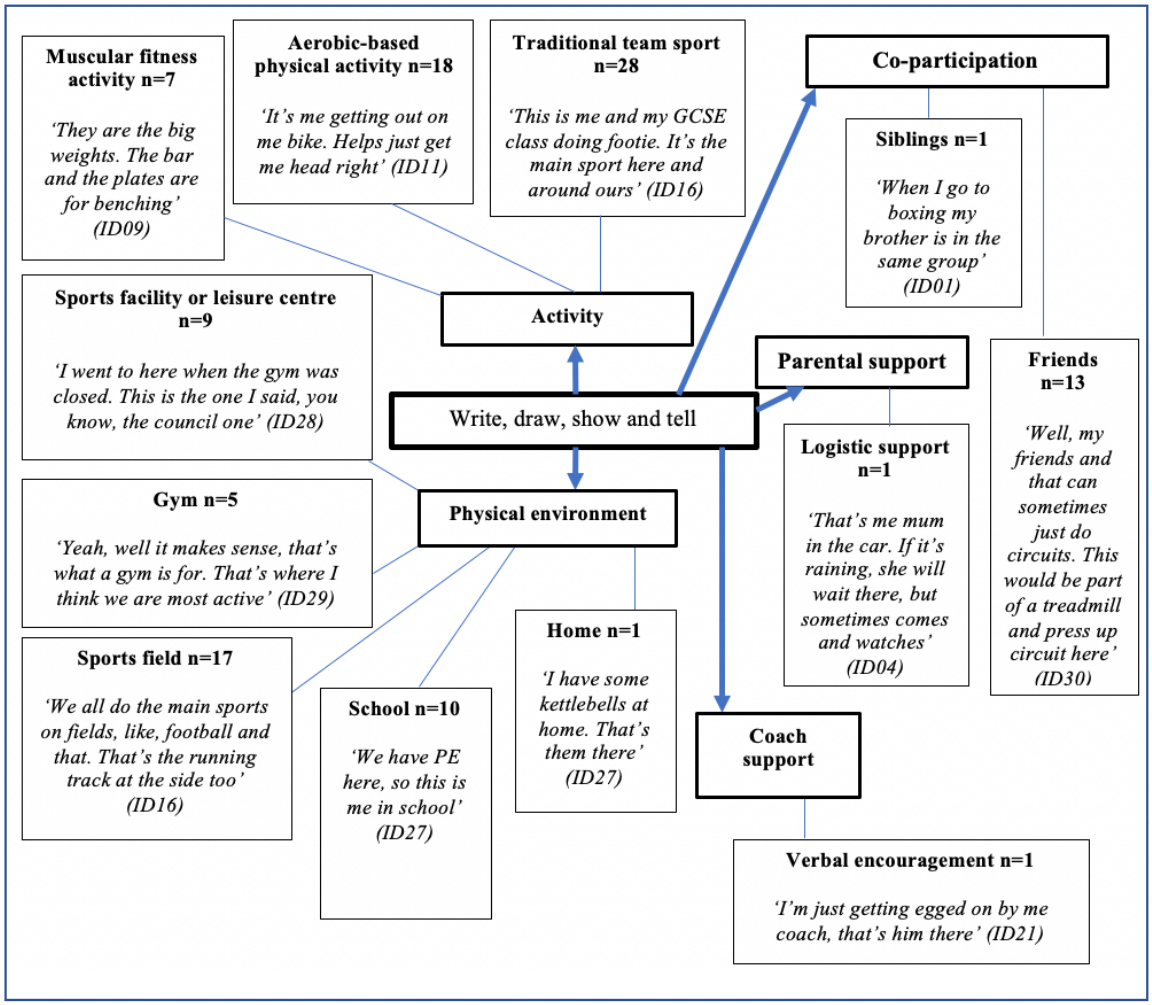

Figure 4.5. Write, draw, show, and tell. +ve = positive; −ve = negative.

4.4. Discussion

The aim of this study was to use a combination of qualitative techniques to explore adolescent boys' understanding, perceptions, and experiences of physical activity, and the role muscular fitness plays within boys' physically active lifestyles. It was envisaged that the contextual information gathered from this study would provide (a) novel insights into the meanings adolescent boys ascribe towards physical activity, and (b) inform the design of future physical activity promotion strategies targeting adolescent boys. Additionally, by investigating the perceptions and experiences of muscular fitness activity through discussing physical activity as a whole, we have minimised the potential for unintentional bias that may arise from discussing muscular fitness activity alone.

4.4.1. Physical activity knowledge

Physical activity guideline knowledge in adolescents has previously focussed on the moderate-to-vigorous physical activity aspect of the current guidelines (Corder et al., 2011).

Limited knowledge of physical activity guidelines in adulthood has been reported and suggests that a lack of knowledge may impact motivation to meet suggested physical activity recommendations to benefit health (Knox et al., 2013, 2015). According to the 'Knowledge, Attitude and Practice' model, individuals may modify their health and lifestyle behaviours if they are provided with specific knowledge to act upon. Our findings suggest an incorrect interpretation and a lack of knowledge surrounding physical activity guidelines amongst adolescent boys, particularly around muscular fitness activity. Given the declines in muscular fitness reported in many developed countries, there may be a gap in the dissemination of physical activity knowledge during a period in time when adolescents begin to form their own attitudes, beliefs and behavioural habits which are carried through into adulthood (Corder et al., 2019; Sawyer et al., 2012). A lack of exposure to muscular fitness activity is likely to result in a limited understanding of muscular fitness activity which was evident in the present study both in adolescent boy's narratives and their drawings. For example,

*"I wouldn't know. Not been told about it [*muscular fitness*] really."* (ID32).

The school environment has been shown to be effective in the promotion of physical activity in adolescents (Kriemler et al., 2011). Interestingly, adolescents in this study attributed the school to be the sole facilitator of physical activity knowledge acquisition. Additionally, the school environment provides access to muscular fitness activity independent of a pupil's background and socioeconomic status (Love et al., 2019). This may expose adolescents to varying forms of physical activity, including muscular fitness activity and enhance their knowledge and understanding surrounding muscular fitness activity. However, our findings suggest there is a perceived lack of understanding and exposure to multiple forms of physical activity in school despite the need for exposure being highlighted within the national curriculum (Barr & Stephenson, 2013). It has been suggested that the school environment and physical education in particular are well placed to enhance young people's knowledge of lifelong health (Penney & Jess, 2004). Therefore, exposure and teaching specific to physical activity guidelines designed to support health may cultivate an awareness of healthy behaviours as adolescents' transition into adulthood. Ensuring acquisition of knowledge regarding muscular fitness activity may support lifelong engagement in a popular mode of adult physical activity and work towards reducing the lack of physical activity knowledge evidenced in adults (Knox et al., 2015). Unfortunately, the participants in this study reported that the development of knowledge surrounding muscular fitness was rarely addressed by teachers.

4.4.2. Predisposing factors

It is well accepted that physical activity enjoyment contributes to adolescent physical activity engagement (Michael et al., 2016). Adolescents within this study associated physical activity with fun and enjoyment, whilst remaining cognisant of the associated health benefits. Furthermore, this study demonstrated that adolescent boys perceive muscular fitness activity as representing a masculine stereotype and an attractive form of physical activity. This is consistent with other studies (Kennedy, Smith, Morgan, et al., 2018; Michael et al., 2016) and further supports the potential role muscular fitness activity has for increasing overall physical activity in adolescent boys. In this study, perceived competence influenced participation both positively and negatively. For example,

"It's quite, like, rewarding if you do something well in football and because we do it all the time we get better." (ID08) and "No. I am not very good at sports and that. I did American football at a summer camp once, but here (school) only does the main sports, like football." (ID21).

Predisposing factors to physical activity reported in this study were predominantly based on traditional team sport competence. Adolescents require an exposure to a variety of physical activity to help them identify a form of physical activity they enjoy and support lifelong physical activity participation (Michael et al., 2016). Although traditional team sports remain popular during childhood and dominate the physical education curriculum, participation in gym-based and less formal fitness activity tend to increase through adolescence (Sport England, 2019). Furthermore, during adulthood fitness and gym-based activities are favoured over traditional team sports (Sport England, 2019) and a lack of exposure during formative adolescent years may result in a lack of competence and enjoyment in adulthood. Given that musculoskeletal issues are the greatest cause of work sickness absence and a primary cause of disability and loss of independence during adulthood (Chalkley, 2021; Versus Arthritis, 2019), efforts should be made to engage adolescents in muscular fitness activity and cultivate a sense of competence. When adolescents spoke about perceived competence specific to muscular fitness activity, they expressed that they were not old enough to conduct muscular fitness activity and suggested that they were only *able* to conduct team-sports safely. This is a misconception that may impact predisposing factors to conducting muscular fitness activity and provides an area worthy of further investigation. The *Am I able?* construct of the Youth Physical Activity Promotion Model is operationalised as the individual's perception of competence in conducting physical activity (Chen et al.,

2014). To date, much of the literature has focussed on aerobic moderate-to-vigorous physical activity and reports the effect of school-based interventions on moderate-to-vigorous physical activity as non-existent and non-significant (Love et al., 2019; Metcalf et al., 2013). Moreover, it is recognised that physical education plays an important role in developing competence (Cronin et al., 2020; Escalié et al., 2019), yet traditional team sports and increasing aerobic moderate-to-vigorous physical activity may not engage the least active and least skilled adolescents who would benefit most from improved perceived competence (Green, 2014; Kennedy et al., 2017). Audio and visual data captured in this study suggest that adolescent boys may not be routinely exposed to muscular fitness activity in school. However, the implementation of muscular fitness in a school setting may enhance the perceptions of competence in adolescents who are less active and less skilled at traditional forms of physical education by providing an alternative form of physical activity, especially in those who are overweight or obese (Schranz et al., 2014). Indeed, the potential for improving 'the self' (e.g., self-esteem, self-efficacy, self-perceptions) through muscular fitness activity has been evidenced in recent research (Collins et al., 2019). Schools provide a unique environment for regular, structured engagement in muscular fitness activity that can develop the skills, knowledge and confidence to conduct muscular fitness activity safely and effectively (Hills et al., 2015; Kennedy et al., 2017). The development of the knowledge, skills, and confidence in conducting muscular fitness may satisfy the *Am I able?* construct of the Youth Physical Activity Model.

4.4.3 Reinforcing factors

Consistent with prior research, friends provided social support in the form of co-participation (i.e., engaging in activity together (Chung et al., 2017; Kirby et al., 2011; Lerner et al., 2017). It has been acknowledged that friend co-participation becomes more salient and critical in adolescents with respect to attitudes, activities decision-making, and emotional well-being (Brown & Larson, 2009). Co-participation can influence physical activity by providing social support and establishing social norms that constrain or enable health promoting behaviours (Andrews et al., 2020; Chung et al., 2017; Kirby et al., 2011). Furthermore, throughout adolescence, time spent with friends increases when compared to time spent with parents (Fuligni et al., 2001; Simpkins et al., 2008). Although the influence of friends on physical activity is acknowledged, much of the work conducted to date focusses on adolescent girl relationships (Coleman et al., 2008; Watson et al., 2015). It has been suggested that interventions to increase physical activity, including muscular fitness activity, should provide adolescents the skills to maintain and develop social networks that support participation (Dunton et al., 2007). However, the findings from this study suggest adolescents do not

view muscular fitness activity as a social activity, often associating the important social contribution with traditional team sports. Furthermore, only one (Figure 4.6) write, draw, show and tell activity provided an example of muscular fitness activity and the potential for co-participation, but this was perceived as only being possible out of school.

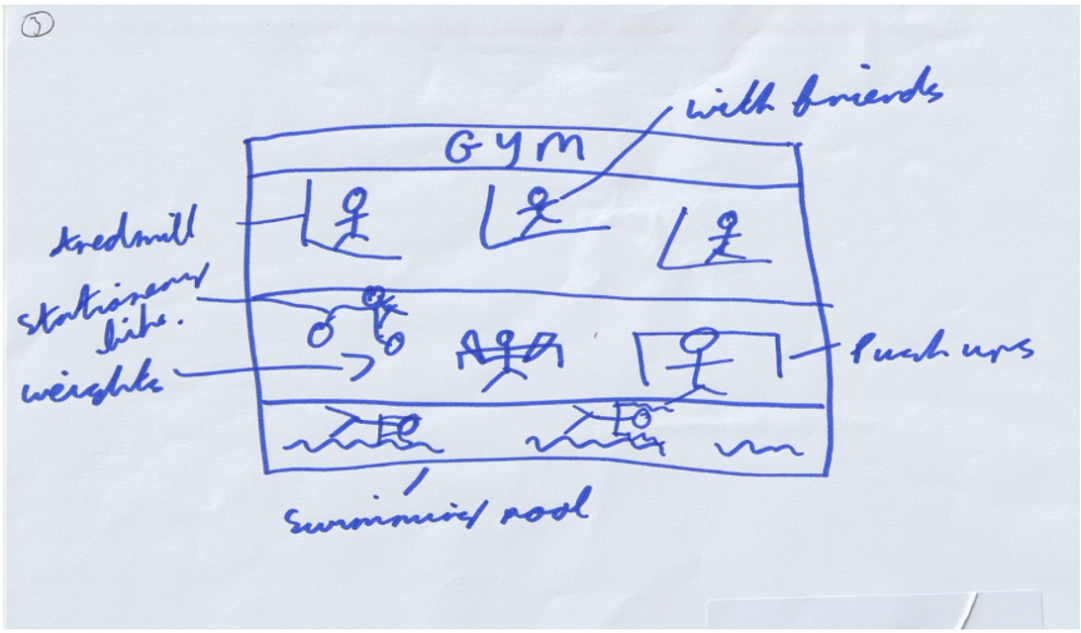

Figure 4.6. Drawing illustrating co-participation in physical activity with friends. (ID30). *"You can like, use the gym here (school), but you probably couldn't do it with your mates and that. They (teachers) don't trust us I don't think. In a gym is sound, no teachers so you can just train properly."*

Given the importance of social networks in physical activity during adolescence, there is a requirement to provide opportunities to conduct muscular fitness activity in a social environment. Additionally, although previous research supports the positive role of friend co-participation (Chung et al., 2017), it generally focusses on traditional aerobic physical activity(Corder et al., 2011; Haidar et al., 2019; Kirby et al., 2011). Given that team sport participation in adulthood decreases and gym-based muscular fitness activity increases (Sport England, 2019), it may be of benefit to provide adolescents with a social environment to align their behaviour with the norms of their group, or the group they want to belong to (Choukas-Bradley et al., 2015). Indeed, it is acknowledged that schools play a key role in the social development of adolescents and provide an environment adolescents can develop friend to friend with the support of teachers (Verhoeven et al., 2019). During adolescence, the sibling influence on physical activity as a family member may be tempered, but the influence of a sibling may contribute to healthier physical activity patterns (Senguttuvan et al., 2014). Interestingly, activity specific to developing muscular fitness was more frequently associated with older sibling co-participation. For example,

“Been to the gym with my sister before like. The first time that she went, lifting weight and that.” (ID26) and “Yes. My brother is a PT so I kind of get it. He shows me and like, has his insta page you can follow.” (ID28)

Previous research has focussed predominantly on the relationship between siblings, moderate-to-vigorous physical activity and team sport elements of physical activity (Kracht & Sisson, 2018). Our findings suggest that sibling co-participation may support involvement in muscular fitness activity. However, siblings reinforcing participation in muscular fitness activity in this study were older and took the role of a teacher and mentor in muscular fitness activity participation. This finding raises concerns over quality of provision and subsequent involvement in muscular fitness activity from the adolescents involved in this study. It is acknowledged that developmental differences and sibling rivalry may have a negative impact on physical activity participation (Hornby-Turner et al., 2014; Kracht & Sisson, 2018). Given that the development of muscular fitness in upper and lower limbs is not homogeneous, and may vary throughout growth and maturation (Candow & Chilibeck, 2005), caution must be exercised by supportive older siblings in order to avoid the risk of injury through overexertion. Further research exploring the role of sibling co-participation in the development of muscular fitness is required.

Relationships between adolescents and their parents evolve from those established in childhood, with adolescents becoming more independent from their parents’ over time (Chung et al., 2017). Within our focus group interviews it was apparent that parents had a role in supporting and influencing physical activity. However, adolescents in this study perceived their parents’ as having no interest or considerable concerns regarding injury when discussing attitudes and beliefs towards muscular fitness activity, particularly when focussing on traditional forms of muscular fitness such as weightlifting. These concerns suggest the knowledge of parents regarding the contribution muscular fitness activity has to their child’s health is limited. Improving parental knowledge regarding the benefits of muscular fitness activity and dispelling unfounded safety concerns may support successful future interventions. Indeed, parent involvement in the design and subsequent implementation of school-based physical activity interventions has been welcomed by parents (Lindqvist et al., 2015). However, there is little research on how parents can help support the implementation of school-based muscular fitness interventions, suggesting further work in this area is required.

Despite the role teachers have in promoting muscular fitness activity, adolescents highlighted teachers as having a negative influence on their muscular fitness activity. For example,

*"I mean, we've been told [*by teachers*] it [*muscular fitness*] can be dangerous. They have a gym here [school], but they [*teachers*] don't really use it that much. The main thing is like sports and that."* (ID31)

Furthermore, it is suggested that teachers may approach muscular fitness activity with trepidation due to outdated misconceptions regarding the risk of injury, highlighting a need for continued professional development for physical education teachers to prescribe muscular fitness activity. Moreover, the risk averse approach to school-based muscular fitness activity is further compounded by fears of litigation, despite governing bodies encouraging the exposure to a wide range of activities provided the appropriate measures have been put in place (DfE, 2014). Adolescents within this study felt as though teachers did not want to conduct muscular fitness activity and provided limited choice of physical activity during timetabled physical education. Some adolescents ascribed a lack of choice and variety during PE to teacher motivation. However, international data suggest teachers rate muscular fitness activity as a priority in physical education (Allen et al., 2016; Kennedy, Smith, Hansen, et al., 2018; Peltier et al., 2008). Further investigation into the thoughts, experiences and perceptions of muscular fitness activity amongst teachers is required to ensure successful implementation of school-based muscular fitness activity.

4.4.4 Enabling factors

Enabling factors include variables that allow adolescents to conduct physical activity (Welk, 1999). Factors include equipment, access to park or facilities and the school environment. Visual and narrative data generated in this study further highlighted the importance of the school environment in supporting physical activity.

During this study schools were suggested to be environments where physical activity was predominantly traditional team sport focussed and muscular fitness activity was reserved for out-of-school (see Figure 4.7). Unfortunately, adolescents did not attribute the school environment to enabling participation to muscular fitness. This supports the notion that muscular fitness development is not catered for adequately in physical education and the school setting in general (Hulteen et al., 2017). Recent literature suggests that the lack of implementation of muscular fitness activity in physical education and the school setting may

be due to a lack of pedagogical understanding(Kennedy, Smith, Hansen, et al., 2018) and further investigation is required to understand the barriers and facilitators to schools implementing muscular fitness activity.

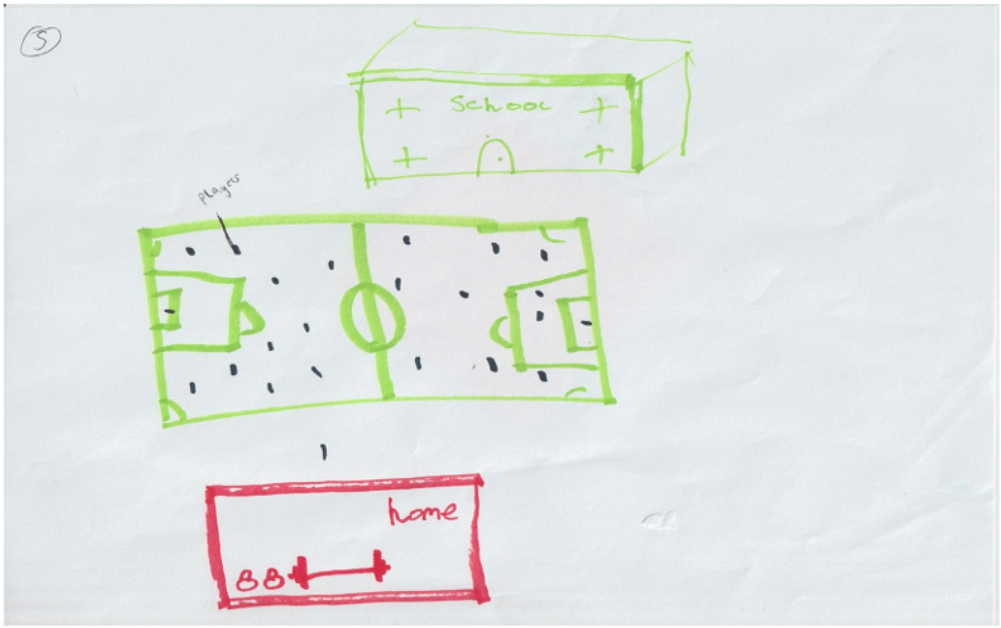

Figure 4.7. Drawing illustrating the perceived difference in activities conducted at school and out of school. (ID27). *"School is mostly football and that. When I go home, I can do weights, it's just not something we do here [school]"*

The majority of adolescents in this study reported provision as a key barrier to out-of-school muscular fitness activity. Although the authors acknowledge the costs of physical activity provision will be determined in part by the physical configuration of the localities in which individuals live, the findings of this study demonstrate the importance of the school setting in providing access to muscular fitness activity. Reductions in local authority budgets across the UK have led to cuts across various municipal sports facilities and leisure centres (Higgerson et al., 2018; King, 2013). Cuts to the provision of local authority leisure facilities were reported within the focus group interviews, with local authority leisure centre closures and a resultant overreliance on grassroots sports presented as a barrier to muscular fitness activity participation. For example,

"I like, I don't really do much in the way of like actual sport more like the gym. But, like, I haven't been for a bit, because they've (local authority leisure centre) been closed." (ID08) and *"I don't do it outside school. Nowhere does it, all mostly football." (ID25)* and *'Yeah, council ones get ruined."* (ID21).

Although access to a gym or leisure facility is not necessary for bodyweight muscular fitness

activity, it may not expose adolescents to the full spectrum of muscular fitness activity that supports strength, power and hypertrophy development (Suchomel et al., 2018). Moreover, recent data suggest that bodyweight movements to develop muscular fitness may not be as effective as traditional forms of muscular fitness activity that would require access to a gym or facility (Cox et al., 2020). Furthermore, the associated costs of accessing a commercial gym resulted in shared memberships from adolescents interviewed in this study. For example,

"That's what I mean, it's just better to go halves and that. It's only a pin and you don't get asked. I don't think we're supposed to be there either really, just with being young." (ID11)

The associated costs with accessing commercial and local authority facilities may prevent individuals from socioeconomically disadvantaged groups accessing muscular fitness activity and further widen health inequalities. It has been suggested that removing user charges from accessing leisure facilities can increase overall physical activity and reduce health inequalities (Higgerson et al., 2018). To date, this has not been explored with regards to muscular fitness activity in adolescents specifically. However, given the interest expressed amongst adolescents to participate in muscular fitness activity, future research may benefit from investigating the feasibility of providing reduced charges to adolescents to access both commercial and local authority facilities. Lack of provision and access to muscular fitness activity out-of-school is further compounded by age restrictions put in place by commercial (*How Old Do I Need to Be to Join?* | *PureGym*, 2017) and local authority facilities (*Teen Gym* | *Www.Wirral.Gov.Uk*, 2018). Future research should explore how commercial and local authority facilities can better cater for adolescents in order to enable muscular fitness activity outside of school and support the transition into adulthood.

4.4.5 Limitations and recommendations

There are some limitations to this study that should be considered when interpreting its results. Although this study utilised a write, draw, show, and tell methodology, this has not been widely used in adolescent populations. However, the participants in this study responded well to this combination of interactive tasks, which provides evidence for future adolescent studies to adopt a similar methodological approach. The dual-methods approach provided the participants with alternative ways of expression, which not only fostered greater inclusivity, but also allowed for a deeper exploration of perceptions and experiences by not limiting participants to verbal communication alone. In doing so, the combination of methods revealed interconnected and complementary findings, which

enhanced data credibility. However, due to curriculum commitments placed upon the adolescents involved in this study, a 20 minute focus group interview length was stipulated by participating schools and was used across all focus group interviews for standardisation. However, due to curriculum commitments placed upon the adolescents involved in this study, a 20-minute focus group interview length was stipulated by participating schools and was used across all focus group interviews to ensure for standardisation. Although this focus group interview duration has been used previously in the literature (Adler et al., 2019), it does however present a potential limitation given that a duration of 45-60 minutes is commonly considered appropriate for adolescent focus group research (C. Kennedy et al., 2001; Krueger & Casey, 2015). Therefore, future focus group research with adolescents may benefit from conducting a pilot focus group to determine the length of time required with the students and agree the allocated time with the school (Krueger & Casey, 2015). Despite this limitation, the results of this study offer novel insights into the experiences, understanding, and perceptions of physical activity and muscular fitness in adolescent boys (Adler et al., 2019). Despite this limitation, the results of this study offer novel insights into the experiences, understanding, and perceptions of physical activity and muscular fitness in adolescent boys, and the 20 min focus group interview length has been used elsewhere in the literature (Adler et al., 2019).

Given the contribution physical education provides to overall physical activity, further investigation into muscular fitness provision in school is required. Future research should investigate the knowledge physical education teachers have regarding muscular fitness and investigate how current knowledge levels influence practice. Furthermore, an understanding into school policy and access to muscular fitness activity in schools may provide insight into the feasibility of muscular fitness activity provision. Finally, our findings suggest that friends are a key reinforcing factor to participating in physical activity. Previous research in adolescent females suggests peer-led physical activity interventions may be effective (Owen et al., 2018; Sebire et al., 2019). However, there is a lack of peer-led physical activity interventions in adolescent boys. Given the importance of co-participation with friends, further research into expanding opportunity to conduct muscular fitness in school and out-of-school is required. Such research should be conducted with schools, government and commercial gym facilities to provide opportunities for adolescents to conduct muscular fitness activity as they transition into adulthood.

4.5 Conclusions

Our results demonstrate a lack of knowledge surrounding physical activity guidelines

amongst adolescent boys, particularly around muscular fitness activity. A desire to demonstrate a level of competency in activities that are deemed masculine may be satisfied through the delivery of muscular fitness activity and may appeal to adolescent boys as an appealing form of physical activity. Despite the importance of muscular fitness in the healthy development of adolescents, there is a perceived lack of opportunities to participate in muscular fitness activity both in and out of school. The contribution of physical education was highlighted as being key to facilitating exposure to muscular fitness activity. Therefore, physical education programmes should ensure opportunities for muscular fitness development through engagement in developmentally appropriate activities. Furthermore, our findings suggest that co-participation with friends is a key reinforcing factor to conducting physical activity, yet opportunities to co-participate in muscular fitness activity are seldom, particularly at school. The significant financial costs and age restrictions associated with commercial gym use and memberships were seen as a barrier to out-of-school muscular fitness activity, reinforcing the need for exposure to this important mode of physical activity in schools.

Chapter 5

Study 3

PE Teachers' Perceived Expertise and Professional Development Requirements in the Delivery of Muscular Fitness Activity: PE Teacher empowerment Survey.

The main outcomes of this study are in the second round of review at Physical Education Review

Thesis map

Study	Aim	Outcome
Study 1. Efficacy of School-Based Interventions for Improving Muscular Fitness Outcomes in Adolescent Boys: A Systematic Review and Meta-analysis	To investigate the efficacy of school-based interventions on MF outcomes in adolescent boys	This systematic review and meta-analysis found a significant small effect for school-based MF interventions in adolescent boys. Efforts should be made to investigate the often overlooked MF element of the PA guidelines which promote and support physical and psychological health in youth
Study 2. "It's Just Not Something We Do at School". Adolescent Boys' Understanding, Perceptions, and Experiences of Muscular Fitness Activity	To use a combination of qualitative techniques to explore adolescent boys' understanding, perceptions, and experiences of physical activity, and the role muscular fitness plays within boys' physically active lifestyles	Despite the importance of muscular fitness in the healthy development of adolescents, there is a perceived lack of opportunities to participate in muscular fitness activity both in and out of school. The contribution of physical education was highlighted as being key to facilitating exposure to muscular fitness activity
Study 3. PE Teachers' Perceived Expertise and Professional Development Requirements in the Delivery of Muscular Fitness Activity: PE Teacher EmPOWERment Survey	To understand PE teachers' perceived knowledge and understanding regarding the delivery of MF in PE. Investigate PE teachers' perceived professional development requirements in the delivery of MF activity during PE and understand how PE teacher gender and teaching experience influences the delivery of MF activity.	
Study 4. The Feasibility and Acceptability of an Online CPD Programme to Enhance PE Teachers' Knowledge of Muscular Fitness Activity.		

Background: Muscular fitness (MF) is an important modifiable factor to improve overall health. Schools offer a unique opportunity to deliver MF activity during physical education (PE) and develop competence to engage in various activities across the life course. However, the implementation of school-based MF activity may be impaired by some teachers reporting a lack of expertise and low confidence in the delivery of MF activity.

Understanding teachers' thoughts and perceptions regarding the delivery of MF in schools may help guide future research and policy to support MF delivery in UK schools.

Methods: Following ethics approval, a survey of secondary school physical education (PE) teachers across the UK was distributed via Twitter. Survey responses were analysed and reported descriptively and thematically.

Results: Completed surveys were returned by 194 teachers (61.9% male) from England, Scotland, Wales, and Northern Ireland. Relative to less experienced teachers, those with at least 5 years' service were 2.2 times more likely to have completed MF activity CPD (OR=2.16; ß=0.77; 95% CI: 1.25-3.74; P <0.01), and 1.8 times more likely to use assessments of MF to inform PE programme decision making (OR=1.83; ß=0.60; 95% CI: 1.18-2.82; P <0.01).

Conclusions: Despite the promising contribution school-based PE may have on developing MF, we report a poor understanding of MF activity amongst UK-based PE teachers. A need to provide CPD is warranted to deliver successful MF interventions in a school setting.

5.1 Introduction

Physical activity (PA) guidelines for the UK and other developed countries recommend children and young people engage in various types and intensities of PA across the week to develop movement skills, bone strength, and muscular fitness (MF) (Bull et al., 2020; Davies et al., 2019). Despite the growing body of evidence (García-Hermoso et al., 2019) supporting the health benefits of MF activity (e.g., improvements in metabolic function, bone health and mental health (García-Hermoso et al., 2019; Smith et al., 2014), much of the focus is towards aerobic-based PA such as walking and team sports (Bennie, Smith, et al., 2021). Throughout the last 50 years, MF levels have declined across most developed countries, including the UK (Dooley et al., 2020; Sandercock & Cohen, 2018). Furthermore, recent data suggest that most European adolescents do not meet the recommended dose of PA to develop MF (Bennie, Faulkner, et al., 2021) with declining levels of adherence to MF activity recommendations reported elsewhere (Bennie, Smith, et al., 2021). This presents a potentially missed opportunity to develop MF and attributes that facilitate participation in a popular form of life-long PA amongst adults (Sport England, 2019) and therefore, it's promotion is warranted during childhood and adolescence.

Schools are suitable settings to promote MF activity and develop MF (Cohen et al., 2015; Cox et al., 2020; Faigenbaum & McFarland, 2016; Lloyd, Faigenbaum, et al., 2014; Pichardo et al., 2019; Ten Hoor et al., 2016). Schools have the facilities and the physical education curricula to embed health promotion programmes irrespective of students' backgrounds (CDC, 2012; Love et al., 2019). However, to date, school-based PA interventions have predominantly attempted to increase aerobic-based PA rather than MF activity. Many aerobic-based PA interventions have resulted in limited success (Love et al., 2019; Ten Hoor et al., 2018), resulting from not reaching the target populations as intended. Providing opportunities for MF activity may potentially cultivate long-term population-level improvements in PA through activities representative of life-long PA (Mäkelä et al., 2017; Van Sluijs et al., 2008). However, recent qualitative research revealed a perceived lack of opportunity for adolescents to participate in school-based MF activity (Cox et al., 2021; James et al., 2018).

Despite the role schools have in offering a diverse PE curriculum that supports life-long PA, there is still a disproportionate global focus on traditional team sports (Hulteen et al., 2016; Kennedy, Smith, Hansen, et al., 2018). Nevertheless, team sports are not representative of adolescents' physical activities during the transition to adulthood and throughout adulthood, with adults favouring activities such as cycling, running, and gym-based activities (Hulteen et al., 2016; Sport England, 2019). Moreover, some evidence suggests a disconnect between the physical activities adolescents want to participate in and the physical activities offered in the PE curriculum (Corder, Atkin, Ekelund, & Van Sluijs, 2013; Cox et al., 2021). Where MF activity is included in the PE curriculum, there is evidence of its effectiveness. Such success has been reported in Australian adolescents considered 'at risk' of obesity based on PA and screen time behaviours (Lubans et al., 2016). Following a 20-week school-based intervention Lubans and colleagues (Lubans et al., 2016) reported sustained positive changes in resistance training skill competency, motivation for school sport, and reduced screen-time. Additionally, MF activity delivered twice a week for one year during timetabled PE classes resulted in improvements in body composition amongst adolescent boys and girls in Dutch secondary schools (Ten Hoor et al., 2018). These findings further support the hypothesis that the school environment and PE in particular, are effective settings for MF intervention programmes to improve adolescent health (Cox et al., 2020). School PE provides a timetabled opportunity to deliver MF activity and maximise the effectiveness of MF activity provision (Pichardo et al., 2019). However, regular, educational, and developmentally appropriate MF assessments are required to assign appropriate volume, intensity, and movements for adolescents to safely develop MF at school (Cox et al., 2020). To support PE teachers in delivering MF activity, foundational

knowledge and ongoing professional development are required to ensure safe and developmentally appropriate practice (McGladrey et al., 2014).

The acquisition of knowledge to inform competent practice in PE is dependent on professional experience and based upon the process of continuous learning through reflective practice (Capel et al., 2009; Griffin et al., 2013; Tant & Watelain, 2016). In recent years, there have been competing perspectives on what constitutes PE (Ekberg, 2021), leading to debate around what knowledge is required to teach PE competently (Macdonald, 2015). A recent qualitative study suggested a lack of research conducted into the knowledge levels of PE teachers and their subsequent suitability to teach health-related PE, including those focussed on MF activity (Santiago & Morrow, 2021). Evidence from the United States (McGladrey et al., 2014) indicate that PE teachers and university PE students lack the required knowledge to safely and appropriately design and deliver MF activity. Furthermore, it has been reported that when school-based MF interventions are implemented, their efficacy may be impaired by a lack of competence and low confidence in the delivery of MF orientated PA (Kennedy et al., 2021; Nathan et al., 2018; Naylor et al., 2015). This is further compounded by negative perceptions regarding the safety and feasibility of MF activity in young people (i.e., MF activity can stunt growth, requires a gym and specific equipment) (Steele et al., 2017). These findings demonstrate a need to identify knowledge gaps in current practice to inform subsequent professional development research opportunities.

In Australia, efforts to support teachers in developing their understanding of MF activity have been successful (Kennedy, Smith, Hansen, et al., 2018). Kennedy and colleagues for example, conducted 1-day workshops with teachers from across 16 secondary schools to equip them with the necessary theoretical knowledge to deliver MF activity. Although this research suggests teachers can be effectively supported to deliver MF interventions, there is presently a lack of evidence regarding PE teachers' MF knowledge and the extent to which perceived knowledge and experience influence school-based MF activity delivery. Furthermore, teacher gender may influence MF activity delivery, given that preconceptions of masculinity surround elements of PE that include strength and can lead to gender stereotyping (Anderson, 2010; Preece & Bullingham, 2020). However, the degree to which teacher gender influences the delivery of MF is presently unknown and requires further investigation. Furthermore, there is also a lack of evidence regarding the perceived opportunities PE teachers have in delivering MF activity, allowing for reflective practice and the opportunities to engage with professional development. It is deemed necessary to conduct teacher-focussed research to understand perceived barriers and facilitators to

programme implementation to enable the adoption and widespread dissemination (Bauman et al., 2006; Nathan et al., 2018). Further understanding of the contextual factors that either support or undermine adoption of school programmes into regular practice is an important area of enquiry (Bauman et al., 2006; Kennedy, Smith, Hansen, et al., 2018).

This study aimed to (1) understand PE teachers' perceived knowledge and understanding regarding the delivery of MF in PE, (2) investigate PE teachers' perceived professional development requirements in the delivery of MF activity during PE, and (3) understand how PE teacher gender and teaching experience influences the delivery of MF activity. The findings of this study may help guide future research, practice, and policy to support MF delivery in schools.

5.2 Methods

5.2.1 Pilot survey development

The first phase of the study involved the development of a web-based pilot survey to gather information on teachers' MF activity teaching experiences, perceptions, and professional development needs. The Checklist for Reporting Results of Internet E-Surveys (CHERRIES) was used to develop the pilot survey (Eysenbach, 2004). University Ethics Committee granted ethics approval for the pilot and main survey. Participant information and consent forms were embedded into the pilot survey platform. Participants were permitted to download the information sheet detailing the research project and retain an electronic copy for their records. Additionally, to fully ensure participants understood the research content and what they were consenting to, three questions were included at the beginning of the survey to assess participant reading and recall of participant information. This method of obtaining informed consent avoids limiting the response options ("I agree" only), providing opportunities to demonstrate that agreeing is more complicated than simply clicking or marking a box. How well participants understand the details of participation through the use of three questions in addition to a traditional "I agree" tick box provided an opportunity to clarify misunderstandings or concerns about participating in the survey (Barchard & Williams, 2008). This method of obtaining informed consent is well recognised and ensures maximum participation (Barrera et al., 2016; Hokke Id et al., 2018; Kadam, 2017; Krotoski & Oates, 2017; Sugiura et al., 2017).

The main content of the pilot survey comprised 21 questions organised into four sections that gathered information about: (1) the respondents and their schools, (2) their policies and practices with regards to the promotion of PA and MF, and their views and perceptions of these, (3) their professional training, and finally (4) their suggestions and thoughts regarding

MF in schools. Survey questions were informed by previous school-based PA research and adapted to reflect MF activity (Cale et al., 2016). Twenty of the questions were closed with finite answer options (i.e., 'Do you feel as though activity to enhance MF is an important element of PE?'). Of the twenty closed questions there were four opportunities to expand on closed responses (i.e., 'other, (please specify)') (O'Cathain & Thomas, 2004). There was an additional open response question ('Please provide any further comments regarding MF delivery in secondary PE') to conclude the 21 questions, allowing respondents to provide further context to their closed responses.

5.2.2 Survey piloting

A pilot study was undertaken to examine the face and content validity of the survey (Ball, 2019). Fifteen PE teachers (66.6% male, aged 37.4 ± 4.3 years) from 5 secondary schools in North West England were approached to provide feedback on the pilot survey's usability and content. The pilot survey received a 73% completion rate. Feedback was provided by the respondents allowing the authors to review and make amendments to improve the clarity of the survey. Respondent feedback and the pilot survey revisions are presented in Table 5.1.

Table 5.1. Pilot survey responses

AREAS TO REVIEW FROM RESPONDENT FEEDBACK	"The consent statements are off-putting" (did not complete)	"There is a lack of clarity on which postcode I need to provide, personal or school?"	"I couldn't return to make changes after submitting my survey"	"I can't see the content of the survey until I have consented"
REVISIONS MADE TO SURVEY	The consent process was explained and detailed information on how participant information would be used was provided at the beginning of the main survey. An explanation that the survey requires informed consent was provided.	The main survey was amended to explicitly request school postcodes.	No action was taken. Respondents could not return to the survey to make changes once they had completed to minimise the chance of receiving multiple responses from the same IP address and thus enhance the credibility of the findings.	The final main survey version included amendments to the participant information sheet to include content overview and average survey completion time.

5.2.3 Main survey distribution and participant recruitment

Following the pilot study, the survey was finalised (Appendix C) , reflecting the participants' feedback. A combination of convenience and purposeful sampling approaches were used to recruit secondary school PE teachers from across the UK to participate in the web-based survey. The web-based survey was administered via Survey Monkey. A study recruitment message detailing the nature of the study, eligibility criteria and a link to the web-based survey was posted and pinned on the first author's Twitter feed. This tweet was re-sent several times "tagging" the second and third authors and key PE, PA, and school sport organisations inviting them to retweet, as well as directly to school PE departments. PE professionals have been reported to perceive Twitter to be highly valuable to connect with others in the profession, learn from others, and share ideas (both within schools and more broadly) via a convenient, usable form of technology, thus enhancing the potential reach and distribution of this survey (Harvey & Hyndman, 2018).

5.2.4 Data collection

Data collection took place between November and December of 2020. In the first round of Twitter posts a picture of the survey cover letter was "tagged" with people who had recent Twitter activity associated with the following hashtags "PE, PHYSED, PEDEPT and PECHAT''. Prominent PE and PA organisations including the Association for PE, PE Scholar, PE4Learning and Youth Sport Trust were also tagged within tweets, resulting in subsequent retweets. The first author asked individuals to retweet the link to ensure a wider group of PE professionals were informed about the survey. Additionally, all authors retweeted the survey link on their respective personal Twitter accounts. The tweet impressions totalled 43,103 with 747 organic engagements and 63 retweets. The survey was closed on the 23rd of December 2020 and after at least two days without any new respondents. Survey completion duration was 10 to 15 min (mean = 13.43 minutes). This timeframe is suggested as suitable to enhance response rates (Fan & Yan, 2010).

5.2.5 Analysis of survey data

The survey generated qualitative and quantitative data. Seven incomplete surveys were omitted from the analysis, and after survey IP address checking identified two potential duplicate entries, these were also omitted from further analysis (Eysenbach, 2004). Descriptive data and frequencies of participant responses were generated, and frequency with relative percentages was calculated.

Quantitative analysis.

Quantitative analyses were conducted using SPSS v. 24 (SPSS Inc.; Chicago, IL), and statistical significance was set at $p < 0.05$. To address study aim 3, a series of logistic regression analyses examined the relationship between sample subgroups (i.e., teaching experience and gender) and survey responses. The teaching experience reference group was teachers with less than five years' experience, and the gender reference group was female teachers.

Qualitative analysis.

Qualitative analyses were conducted in NVivo12 (Version 12.6.0; QSR International Pty Ltd, Victoria, Australia). To address study aims 1 and 2, free text responses were pooled together to explore and expand upon the closed survey responses. A thematic content analysis approach was undertaken consistent with the procedures outlined by Braun and Clarke (2006). After becoming familiar with the data (reading and re-reading pooled open text data), the first author adopted an inductive analytical approach and, in doing so, generated a series of codes that are relevant to study aims 1 and 2. Codes were clustered together to identify higher-level themes and subsequent sub-themes without fitting them to a pre-existing coding frame (Braun and Clarke, 2006). Codes and themes were refined in iterative steps of (a) re-reading the pooled data, (b) identifying codes and subsequent themes, and (c) refining the codes and themes with the second author (Braun and Clarke, 2006). The second author reviewed the coding process and provided suggestions to ensure that the coding was representative of the data and the study aims. This process was repeated until the two authors reached a minimum 90% agreement level (McAlister et al., 2017; O'Connor and Joffe, 2020; Roberts et al., 2019). A frequency count of identified quotes was undertook to establish the consistency of themes. The higher- and lower-order themes, frequency counts, and participant quotations were subsequently displayed in a diagrammatic format using the pen profile approach. The inclusion of verbatim quotations provides context and verifies participant responses (Smith and Caddick, 2012). Another strength of the pen profile approach is that it provides an accurate and concise way of illustrating the consistency of qualitative data themes [as represented by the n = value, rather than over-representing minority participant views. As such, the approach is commonly adopted in PA and PE qualitative research (Cox et al., 2022; Goss et al., 2022; Mackintosh et al., 2011; Ridgers et al., 2012) due to it being accessible to researchers with an affinity for both qualitative and quantitative research (Clark et al., 2020). The iterative approach we took to thematic analysis (Braun and Clarke, 2006) and the audit trail we have presented above detailing and justifying the methodological decisions we took throughout

this aspect of the study provides transparency and trustworthiness allowing for future replication (Nowell et al., 2017).

5.3 Results

5.3.1 Survey closed response results

Completed surveys were returned by 194 teachers (61.9% male), from England, Scotland, Wales, and Northern Ireland with a broad range of experience. Location and experience count can be seen in Table 5.2.

Table 5.2 Geographical location and PE teaching experience count of main survey participants

Descriptor	Count	% of total
Location		
South East, England	24	12.4
South West, England	17	8.8
London	16	8.2
Northern Ireland	9	4.6
West Midlands, England	16	8.2
East of England	9	4.6
North West, England	38	19.6
Scotland	21	10.8
Yorkshire and the Humber, England	16	8.2
North East and Cumbria, England	11	5.7
East Midlands, England	12	6.2
Wales	5	2.6
Duration of PE Teaching Experience (Years)		
<4	53	27.3
5-14	72	37.1
>15	69	35.6

To address study aim 3, a series of binomial logistic regressions were performed to examine gender and teaching experience differences in survey responses. Having at least five years' teaching experience was associated with an increased feeling of PE being valued by colleagues (OR = 2.07; ß = 0.73; 95% CI: 1.41–3.05; p <0.01). Further, greater teaching experience was significantly and positively associated with the likelihood of conducting MF activity in the current term (OR = 1.57; ß = 0.45; 95% CI: 1.08–2.28; p = 0.01) and planning to conduct MF activity in the next school term (OR = 2.23; ß = 0.80; 95% CI: 1.51–3.31; p < 0.01). Relative to less experienced teachers, those with at least five years' servicewere2.2timesmorelikely to have completed continued professional development (CPD) in MF activity (OR = 2.16; ß = 0.77; 95% CI: 1.25–3.74; p <0.01), and 1.8 times more likely to use assessments of MF to inform PE programme decision making (OR = 1.83; ß = 0.60; 95% CI: 1.18–2.82; p <0.01). Compared to female PE teachers, males were 2.02 times more likely to be planning to deliver MF in the next school term (OR = 2.02; ß = 0.70; 95% CI: 1.09–3.76; p = 0.02) and 2.75 times more likely to have conducted some form of CPD in MF activity delivery (OR = 2.75; ß = 1.01; 95% CI: 1.11–6.81; p = 0.02).

5.3.2 MF activity knowledge

Free text responses from open comments were analysed. Participants' perceived knowledge of MF activity is presented in Figure 5.1 and contains 4 primary themes: programme implementation, conceptual, safety, and professionalism. There were 11 secondary themes identified: design -ve (n=16), design +ve (n=10), testing and evaluation +ve (n=5), gender differences -ve (n=4), activity type -ve (n=3), growth and maturation -ve (n=12), health benefits +ve (n=6), injury -ve (n=6), teaching and coaching +ve (n=3), personal bias -ve (n=8). Positive (+ve) and negative (-ve) themes were identified during the analysis.

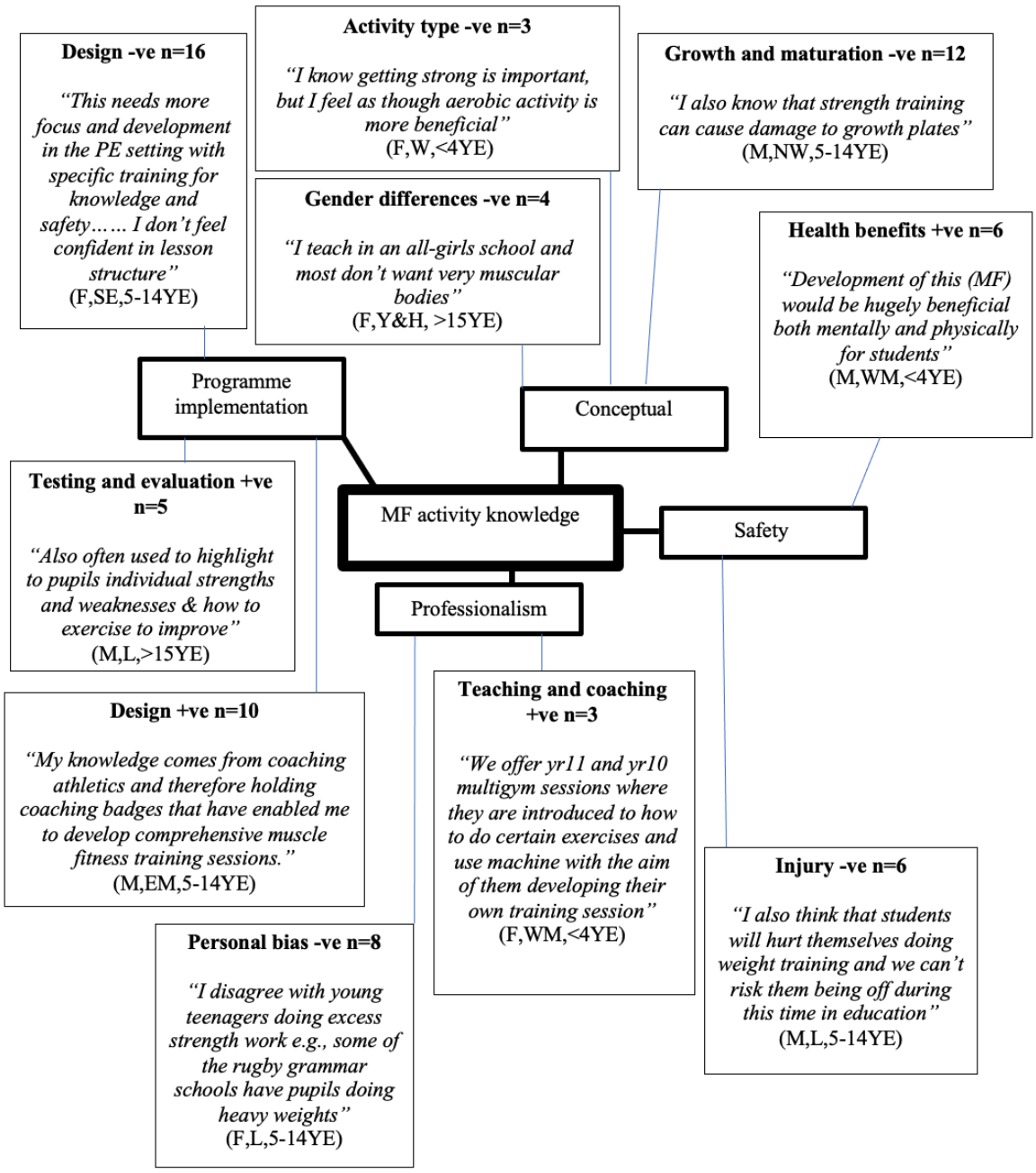

Figure 5.1 MF activity knowledge. +ve = positive; −ve = negative. M = male; F = female. SE = South East England; SW = South West England; London; NI = Northern Ireland; WM = West Midlands, England; EE = East of England; NW = North West, England; Y&H = Yorkshire and the Humber, England ; S = Scotland; NE = North East and Cumbria, England; EM = East Midlands, England; W = Wales. YE = years experience.

5.3.3 Barriers to conducting MF activity

Participants free text responses regarding perceived barriers to conducting MF activity are presented in Figure 5.2, with four primary themes: School related, parent related, student related and teacher related. A further 10 secondary themes were identified: facilities +ve (n=9), facilities -ve (n=16), funding -ve (n=2), funding -ve (n=7), priority -ve (n=18), time -ve

(n=7), fitness -ve (n=4), motivation -ve (n=5), misconceptions-ve (n=4), professional development -ve (n=25). Positive (=ve) and negative (-ve) themes were identified during the analysis.

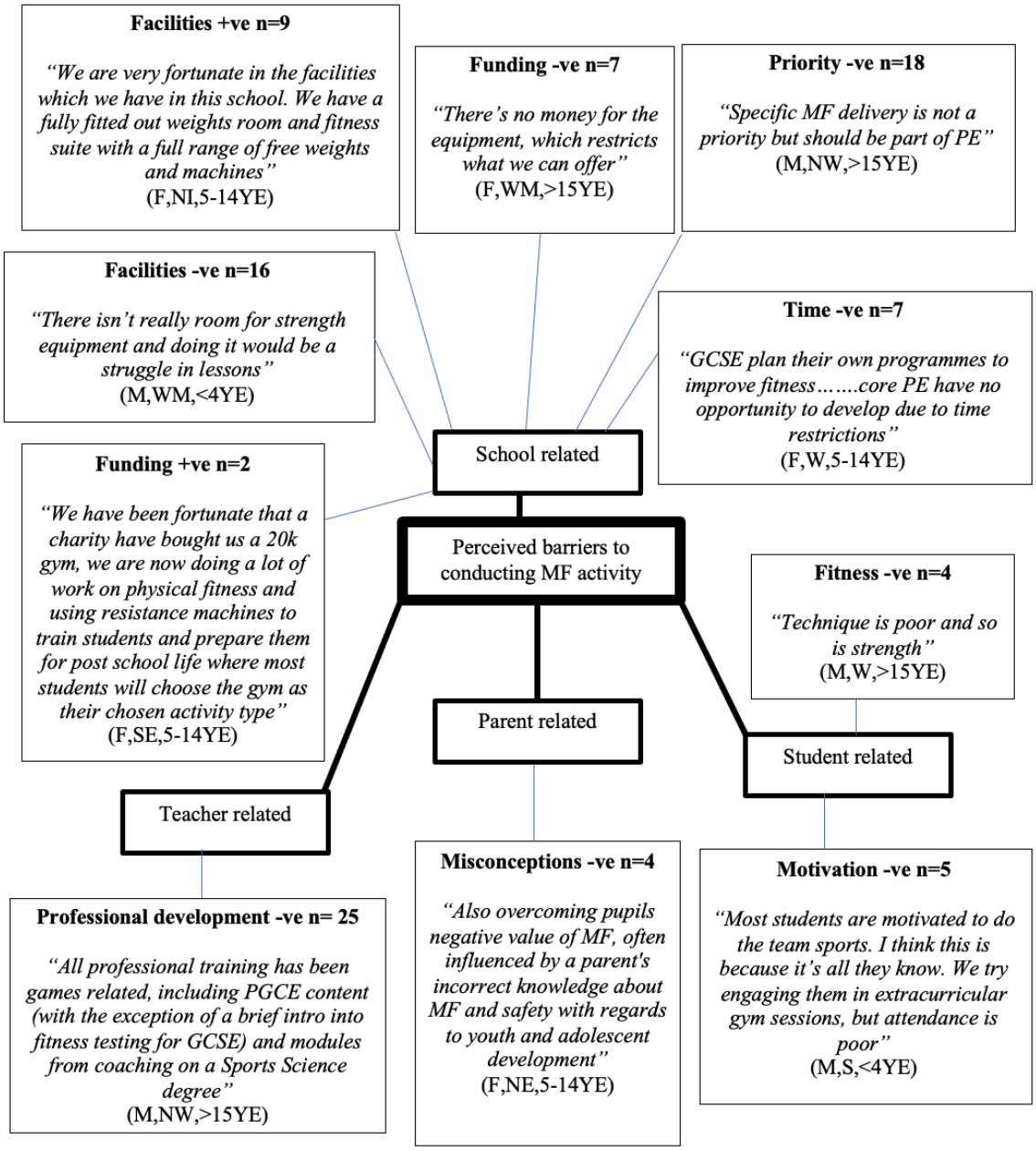

Figure 5.2 Perceived barriers to conducting MF activity. +ve = positive; −ve = negative. M = male; F = female. SE = South East England; SW = South West England; London; NI = Northern Ireland; WM = West Midlands, England; EE = East of England; NW = North West, England; Y&H = Yorkshire and the Humber, England ; S = Scotland; NE = North East and Cumbria, England; EM = East Midlands, England; W = Wales. YE = years experience.

5.4. Discussion

This study aimed to: (1) understand PE teachers' perceived knowledge and understanding regarding the delivery of MF in PE, (2) investigate PE teachers' perceived professional development requirements in the delivery of MF activity during PE, and (3) understand how PE teacher gender and teaching experience influences the delivery of MF activity. Overall, the teachers in this study perceived MF as an important element of PE, but perceived a lack of emphasis and priority on MF activity in the PE National Curriculum and individual schools. Furthermore, our findings highlighted a requirement for MF activity CPD to support teachers in delivering MF during PE irrespective of experience level or gender. Overall, limited knowledge and understanding of MF were evidenced in this study.

5.4.1 PE teacher perceived knowledge and understanding

Participants' perceived knowledge of MF activity was predominantly acquired outside of their day-to-day roles. For example:

"I do coaching at an athletics club and we do strength work there. That's where I got my skills, during my UK Athletics coach qualification" [Female, South West, 5-14 years experience].

This may be due to an emphasis on team sports, games and dance placed upon in-service teacher CPD (Armour & Makopoulou, 2012). However, the extent and source of the knowledge acquired outside of the PE profession is unclear. Furthermore, although participants believed their knowledge was adequate, false misconceptions and personal biases still prevented MF activity from being conducted. For example:

"I wouldn't know where to start. I know that if I got it (MF) wrong, I would damage their growth plates" [Male, Scotland, Under 4 years experience] and *"There is no requirement for kids to do this (MF). The kids enjoy the games and they will get strong as they grow naturally"* [Male, London, 5-14 years experience].

The lack of awareness regarding knowledge gaps may result in teaching practices receiving minimal modification and failing to address contemporary health issues facing young people (Clarke & Hollingsworth, 2002), such as declining MF (Sandercock & Cohen, 2019).

Despite preconceived misconceptions and personal biases regarding the safety and necessity of MF activity in adolescents, 87% of participants conducted MF assessments in school. However, only 27% of participants used MF assessments to inform practice. Safe and effective MF activity relies on accurate and appropriate assessment to ensure the

correct type, volume, and intensity of MF activity is delivered (Suchomel et al., 2018). Previously, some parents have greeted fitness assessments in schools with trepidation (Cohen et al., 2015) and our findings suggested that some PE teachers perceive this as a barrier to conducting assessments of MF. Furthermore, our results suggested that PE teachers have reservations about MF assessments which may explain the lack of implementation or the intention to implement such assessments. Improving teachers' knowledge of MF assessments may improve teachers' understanding of programme implementation, which may enhance the quality of MF activity provision in PE.

While study participants understood the health benefits associated with MF activity, there were concerns regarding the adverse effects on growth and development among adolescents as a result of conducting MF activity. These concerns are unfounded and based on outdated misconceptions (Faigenbaum & Myer, 2010) and demonstrate a lack of current knowledge. Moreover, the perception that a range of complex and specific equipment is needed to conduct MF activity was evident, thus demonstrating a lack of pedagogical content knowledge. Indeed, whilst some types of MF activity may require specialist equipment, such as weightlifting, other types of MF activity such as bodyweight activity (e.g., push-ups, sit-ups, pull-ups, squats) and plyometric activity are not reliant upon specific equipment. Our findings highlighted a lack of awareness of the broad range of activities available to develop MF. Future CPD should focus on developing a broad understanding of what age-appropriate activities can enhance MF safely in the school environment. For example, it is understood that adolescence provides a period during which plyometric activity may be undertaken by adolescents and elicit positive results (Radnor et al., 2017, 2018). However, individual variability in biological age, training age, skill, and coordination will dictate plyometric activity frequency, volume and intensity (Fort-Vanmeerhaeghe et al., 2016; Peitz et al., 2018) and would therefore require teachers to be suitably knowledgeable in this area. Further research into PE teachers' understanding of plyometric training may help identify areas of further investigation to support effective practice. Overall, our findings suggest a lack of knowledge in programme design and implementation underpinned by limited conceptual understanding of conducting MF activity with adolescents.

5.4.2 PE teacher perceived professional development requirements

Opportunities to participate in MF activity CPD were perceived as limited, supporting the overall lack of PE teacher CPD reported in recent literature (Tannehill et al., 2020). There was a perceived high level of self-assessed understanding towards MF activity, but a lack of actual understanding was evident in free text responses. Additionally, many of the teachers had not participated in any formal CPD. This concurs with reported concerns

regarding what sources of information inform the delivery of MF activity in PE (Ward & van der Mars, 2020). Research conducted in the United States revealed that PE teachers would be interested in receiving training about policy and practice to improve and guide PA delivery (Cox et al., 2011). This is consistent with our findings which highlighted a desire to engage in MF activity CPD.

Of the UK nations included in this study, Scotland is the only one reported to have a compulsory obligation for PE teacher CPD (Tannehill et al., 2021). However, despite Scottish PE teachers being mandated to participate in CPD, no differences in CPD between UK nations were reported. The lack of obligation to engage in and complete CPD may explain the observed low levels of CPD engagement observed in this study. Furthermore, where opportunity for CPD was offered, it focussed on team sports. Our findings suggest current CPD opportunities are rare and not reflective of activities that adolescents are likely to partake in as adults, such as MF and gym-based activity. Moreover, they highlighted a need for CPD that covers a broader range activities. For example:

"Most training is around sports and dance. Any CPD we do is usually internal, and we cover any changes in policy to conducting the typical lessons like football, netball and rugby. It would be useful to do fitness type CPD, but we don't really have the knowledge to share. We all go the gym, but what we can do with the pupils isn't really clear." [Female, South East England, Over 15 years experience].

In our study, lack of CPD was regarded as a barrier to the delivery of MF activity, for example:

"It (MF) is not really a priority for PE. Even if it (MF) was a priority I don't think we would do much, we just don't have the knowledge and I wouldn't feel confident. We need the right training to let us do it safely" [Male, North West England, 5-14 years experience].

The reported lack of CPD is paradoxical to the evidence suggesting that school-based MF interventions are efficacious for developing MF amongst adolescents (Cox et al., 2020; D. R. Lubans et al., 2020). The declining levels of youth MF in the UK may benefit from a more structured focus in PE (Kennedy et al., 2017; Pichardo et al., 2019). Thus PE teachers should remain current with the latest developments in pedagogy and practice (Tannehill et al., 2021).

To facilitate the implementation of school-based MF activity, our findings suggest that MF activity CPD is required to ensure safe and effective delivery that caters for teachers' time

demands in and out of formal curriculum time. Medical and health professional education programmes have adopted online delivery formats to account for increasing time pressures, external professional and personal demands, and reduce training costs (McDonald et al., 2018). Teachers may benefit from similar online training that allows for flexible learning. The benefits of online teacher CPD may include cost effectiveness and increased accessibility, flexibility, interactivity, self-direction, and self-efficacy in learning (Cook & Dupras, 2004; J. D. Myers et al., 2012). However, such online delivery CPD interventions for upskilling PE teachers in the delivery of MF are yet to be conducted.

5.4.3 Experience and gender differences

Our findings suggested that PE teachers with less than 4 years experience were less likely to assess, deliver, and plan to deliver MF activity. The lack of intent to deliver MF activity early in their teaching careers could be attributed to secondary school PE teachers' initial training focusing on traditional team sports (Capel et al., 2009; Green, 2014). Furthermore, despite the emphasis on the role of schools in PA promotion, teachers with less than 4 years of experience felt senior leadership were likely to reduce PE provision and allocate protected time to other subjects such as Maths and English. The reported reduction in PE provision may impact the ability to deliver a diverse curriculum which includes MF activity. For example:

"It's hard to run those types of sessions (MF) when timetabled PE gets reduced to one session per week during GCSE years. GCSE PE get more, but the others swap PE for extra intervention English, Maths and Science, they take priority" [Female, North West England, less than 4 years experience].

Such differences in the provision of PE may reduce exposure to MF activity for adolescents and reduce the chance for teachers to deliver, reflect, and adapt teaching practice. Moreover, if teachers are not provided with MF activity knowledge early in their careers, the acquisition of knowledge based upon the process of continuous learning through reflective practice may be compromised (Capel et al., 2009; Griffin et al., 2013; Tant & Watelain, 2016). Despite our findings suggesting early career teachers are less likely to deliver MF activity, all teachers, irrespective of experience, stated their knowledge of MF activity required development. This demonstrated a need to provide CPD opportunities to all teachers throughout their careers to ensure current levels of knowledge to help inform appropriate and safe MF activity delivery.

Our findings contrast with previous research whereby activities perceived as more masculine, such as power and strength-based activity were likely to be delivered by male

teachers (Anderson, 2010; Preece & Bullingham, 2020). We found that differences between teacher gender and perceived expertise were only apparent during perceived equipment requirements. Male teachers were more likely to perceive a lack of equipment available to deliver MF activity and indicated that effective MF activity depended on specific equipment. The lack of gender differences may be attributable to the increased participation of females in sports and exercise that were previously male dominant (Cowley et al., 2021). For example, activities such as weightlifting (i.e., snatch, clean and jerk) to improve MF have been promoted by initiatives such as *"This Girl Can"*(Diaper, 2015), reducing gender bias in the participation and prescription of activities that have been previously regarded as masculine. Our findings are promising and demonstrated a lack of gender bias in MF activity teaching practice which may positively impact student engagement in MF activity (Sánchez-Hernández et al., 2018).

5.5 Strengths and limitations

Limitations of this study relate to the cross-sectional design, imbalanced sample between the four UK home countries, and the risk of self-selection bias. To mitigate bias, steps were taken including survey piloting and the adherence to a recognised set of guidelines specifically for web-based surveys (Eysenbach, 2004). Furthermore, the mixed methods approach to data collection allowed for data triangulation during the analysis, which minimised misinterpretation and in doing so, enhanced the credibility of our findings (Smith & Noble, 2014).

5.6 Conclusion and recommendations

This is the first survey investigating UK secondary school PE teachers' perceived knowledge and understanding of MF activity, and teacher CPD requirements for its delivery in PE. Teachers delivering PE from across the UK believe their knowledge of school-based MF activity needs development, and this lack of knowledge reflected a limited understanding of programme design and concepts of MF activity. Furthermore, we observed that preconceived biases surrounding the safety and efficacy of MF activity exist among UK PE teachers. There is a perceived lack of priority to conduct MF activity in schools, highlighting the need for further work with policy makers and stakeholders to ensure a diverse PE curriculum is on offer to adolescents. Finally, CPD to improve teachers' knowledge and understanding of MF activity is warranted to overcome the perceived barriers to MF activity delivery and ensure implementation fidelity.

Chapter 6

Study 4

The Feasibility and Acceptability of an Online CPD Programme to Enhance PE Teachers' Knowledge of Muscular Fitness Activity

The main outcomes of this study are under review in the International Journal of Environmental Research and Public Health

Thesis map

Study	Aim	Outcome
Study 1. Efficacy of School-Based Interventions for Improving Muscular Fitness Outcomes in Adolescent Boys: A Systematic Review and Meta-analysis	To investigate the efficacy of school-based interventions on MF outcomes in adolescent boys	This systematic review and meta-analysis found a significant small effect for school-based MF interventions in adolescent boys. Efforts should be made to investigate the often overlooked MF element of the PA guidelines which promote and support physical and psychological health in youth
Study 2. "It's Just Not Something We Do at School". Adolescent Boys' Understanding, Perceptions, and Experiences of Muscular Fitness Activity	To use a combination of qualitative techniques to explore adolescent boys' understanding, perceptions, and experiences of physical activity, and the role muscular fitness plays within boys' physically active lifestyles	Despite the importance of muscular fitness in the healthy development of adolescents, there is a perceived lack of opportunities to participate in muscular fitness activity both in and out of school. The contribution of physical education was highlighted as being key to facilitating exposure to muscular fitness activity
Study 3. PE Teachers' Perceived Expertise and Professional Development Requirements in the Delivery of Muscular Fitness Activity: PE Teacher EmPOWERment Survey	To understand PE teachers' perceived knowledge and understanding regarding the delivery of MF in PE. Investigate PE teachers' perceived professional development requirements in the delivery of MF activity during PE, and understand how PE teacher gender and teaching experience influences the delivery of MF activity.	Teachers delivering PE from across the UK believe their knowledge of school-based MF activity needs development, and this lack of knowledge reflected a limited understanding of programme design and concepts of MF activity. CPD to improve teachers' knowledge and understanding of MF activity is warranted to overcome the perceived barriers to MF activity delivery and ensure implementation fidelity
Study 4. The Feasibility and Acceptability of an Online CPD Programme to Enhance PE Teachers' Knowledge of Muscular Fitness Activity.	Assess if an online CPD course can increase PE teacher knowledge of MF activity. Assess the feasibility of an online CPD course to enhance PE teachers' knowledge and competence of MF activity, and assess the acceptability of the content and design of an online CPD course from PE teachers' perspectives	

Abstract: Schools provide an opportunity to enhance muscular fitness of English youth during physical education (PE). Continued professional development (CPD) among teachers may improve muscular fitness activity delivery in schools. This study sought to

assess the feasibility and acceptability of an online CPD programme to enhance PE teachers' knowledge of muscular fitness activity.

Methods: Co-production of an online CPD platform was undertaken with five secondary school PE teachers. A quasi-experimental pre-post control group design for the CPD was adopted (CPD group n=76, control n=32). At the end of the CPD, participants completed an exit quiz consisting of the same questions as the entry quiz. Correct answers and feedback were provided after the exit quiz. Before CPD participants could download their certificate of completion, they received a request for CPD feedback through a private free text box.

Results: Pre-and-post CPD knowledge quiz data were available from 65 participants (55.4% male). The median knowledge quiz change score was significantly higher in the CPD group than in the wait list control group (CPD score vs control score; U =37, z = -5.96, *P* <0.01). Three primary themes reflecting factors associated with the acceptability and feasibility were [1] practical application, [2] support and resources, and [3] knowledge and confidence.

Conclusions: Co-production of an online CPD programme can improve knowledge and affect practice. PE teachers that completed the CPD reported the online platform was beneficial to overcoming the limitations of face-to-face CPD such as time and financial constraints and suggested the content covered was beneficial and appropriate to their teaching. Future work is required to establish links between teachers' learning following CPD, the translation into PE practice and student MF outcomes.

6.1 Introduction

PA guidelines for the UK and other developed countries recommend children and young people (referred to as youth from here) engage in a minimum of 60 minutes of MVPA per day, averaged across the week with three days to incorporate muscle and bone strengthening exercise to develop movement skills, bone strength, and MF (Davies et al., 2019; WHO, 2020). MF activity provides a range of health benefits including improvements in metabolic function, bone health, and mental health (García-Hermoso et al., 2019; Smith et al., 2014). Furthermore, MF is associated with enhanced fundamental movement skills, reductions in injury rates, and increased MVPA (Faigenbaum et al., 2016; Martínez-Gómez et al., 2011; Smith, Eather, Glenn Weaver, et al., 2019). Meeting the recommended amount of MF activity in youth can reduce the likelihood of adverse health outcomes in adulthood and prepare youth for a lifetime of PA participation (Faigenbaum et al., 2019).

Schools have the facilities and the physical education (PE) curricula to promote and support health promotion including fitness programmes independent of a pupils' sociodemographic profile (CDC, 2012; Love et al., 2019). As such, schools are suitable settings to promote and support MF activity (Cohen et al., 2015; Cox et al., 2020; Faigenbaum & McFarland, 2016; Lloyd, Faigenbaum, et al., 2014; Pichardo et al., 2019; Ten Hoor et al., 2016). Notwithstanding this, MF activity seldom features within PE curricular due to perceived barriers among some PE teachers. These barriers tend to centre around factors such as limited confidence, time and a perceived lack of equipment and facilities (Kennedy et al., 2021; Nathan et al., 2018; Naylor et al., 2015). Moreover, research from the US suggests that PE teachers' knowledge required to deliver safe and appropriate MF activity in schools requires improvement (McGladrey et al., 2014). Although the literature surrounding MF activity delivery in UK schools is limited, there is evidence of successful interventions to improve knowledge of MF activity delivery elsewhere. Kennedy and colleagues delivered one-day face-to-face continued professional development (CPD) workshops comprising theoretical and practical MF activity content to school teachers across 16 schools in Australia (Kennedy et al., 2019; Kennedy, Smith, Hansen, et al., 2018). They found that one-day face-to-face workshops increased teachers' confidence in delivering MF activity to adolescents. This study highlighted that PE teachers' knowledge of MF activity can be improved and their perceived barriers overcome through participating in CPD (Cox et al., 2020). However, CPD opportunities tend to be limited in the UK and there is currently a lack of understanding as to the efficacy of PE CPD programmes in the UK.

Traditionally, PE teacher CPD has been constrained by the time and financial demands associated with face-to-face training (Sato et al., 2017). However, these time and financial barriers have been overcome in recent years with the opportunity to deliver training remotely via online platforms (Lantz-Andersson et al., 2018). However, online CPD provision for PE teachers, particularly in the UK, is in its infancy, and further research is warranted to better understand the feasibility and acceptability of online CPD delivery to UK PE teachers (Lander et al., 2020). For the purposes of this study, the term feasibility refers to whether online CPD in MF can be facilitated and provide insight into whether the research area should be developed and how (Eldridge et al., 2016). Furthermore, the term acceptability will refer to determining how well an intervention will be received by the target population and the extent to which the intervention meets the needs of the target population and organisational setting (Ayala & Elder, 2011; Sekhon et al., 2017). Of the few studies that have been conducted in this area, there is some evidence to suggest that PE teachers favour online CPD that: (1) is evidence-based; (2) provides pedagogical content knowledge and not just content knowledge; (3) is informed by teachers and translatable to practice; (4)

facilitates communities of practice; (5) is interactive; (6) simple to navigate; and (7) highly visual. We sought to build on these findings in the present study.

The overarching aims of the present study were to (1) assess if an online CPD course can increase PE teacher knowledge of MF activity (2) assess the feasibility of an online CPD course to enhance PE teachers' knowledge and competence of MF activity, and (3) assess the acceptability of the content and design of an online CPD course from PE teachers' perspectives.

6.2 Methods

6.2.1 CPD development

A user-centred approach (Vaughn & Jacquez, 2020) to the CPD design was undertaken with five secondary school PE specialists who had participated in previous research detailed in Chapter 5. The teachers engaged in a collective process that led to establishing a consensus on the CPD content and knowledge assessment. Three face-to-face meetings with the first author and the five PE teachers were conducted. Three of the teachers joined the first author in person with the remaining two teachers joining via zoom (mean duration: 48 ±7 minutes). This approach to PE teacher CPD and examination design is similar to that previously reported in the US (McGladrey et al., 2014). Brief summaries of each meeting are provided below.

Meeting one

Meeting one consisted of reviewing a survey (Chapter 5) distributed amongst UK PE teachers to assess perceived expertise and CPD requirements for the delivery of MF activity. Open ended queries to solicit recommendations for CPD content were created and these formed indicative CPD content. Following the meeting, the first author developed a CPD content plan, expanding on the points raised in meeting one to propose at the next meeting.

Meeting two

Meeting two occurred four weeks after meeting one. It involved developing the online CPD learning modules and agreeing on CPD content and delivery. CPD was developed and delivered via Talent LMS (Version 4.3), a cloud-based platform which uses open-source code and is publicly available (TalentLMS.com). Information and suggestions provided by the PE teachers were aligned with existing recommendations for online CPD development for PE teachers (Lander et al., 2020). This ensured that the CPD (1) was evidence-based, (2) provided pedagogical content knowledge and not just content knowledge, (3) was informed by teachers and translatable to practice, (4) facilitated communities of practice,

(5) was interactive, (6) was simple to navigate, and (7) was highly visual (Lander et al., 2020).

Meeting three

Meeting three occurred five weeks after meeting two. It allowed PE teachers to review preliminary MF activity knowledge assessment questions proposed by the first author in the form of an online quiz. PE teachers offered suggestions regarding the quiz questions' wording, correct answers, and distractors. Distractors were intended to distinguish between PE teachers who have not yet acquired the knowledge necessary to answer the item correctly from those who understand the content. Therefore, the distractors in the multiple-choice questions were designed to contain plausible but incorrect answers based on teachers' common errors or misconceptions of MF in order to measure teachers' level of knowledge acquisition (Shin et al., 2019).

Following meeting three, the PE teachers reviewed the CPD platform, content, and knowledge quiz content. Once the teachers were satisfied with the platform's feasibility and useability, it was deemed ready for use. A summary of CPD modules can be seen in Table 6.1. Modules were linearly ordered to build knowledge as the teachers worked through the CPD programme. During the design and development process, the PE teachers suggested that professionally recognised CPD points would provide an incentive to complete the CPD programme. Endorsement of CPD points was subsequently sought from the British Association of Sports and Exercise Sciences and approved for five CPD credits on 21/10/2021.

Table 6.1 Summary of CPD modules

Module	Overview
Preliminary Stage	Welcome video, participant information, consent, and the entry knowledge quiz.
Introduction	Brief rationale, definitions of key terminology and a group introduction forum.
Physical Activity	Overview of PA guidelines, health benefits of MF, addressing common misconceptions surrounding MF activity and two discussion forums about MF.
Muscular Fitness Development	Implementation of MF in schools, programming and periodisation, common misconceptions.
Plyometrics	Introduction to plyometrics, safety considerations, programming, plyometric progression model, plyometric discussion forum.
Delivery and Long-Term Development	Teacher conduct in delivering MF activity, delivery and class management considerations, physical development models, discussion forum on MF delivery.
Monitoring and Assessment	Assessing MF, overview of common MF assessment tools, conducting MF assessments, discussion forum for MF assessments.
Round Up	CPD round up, knowledge quiz, exit survey.

6.2.2 CPD participant recruitment and CPD distribution

Data collection took place between November 2021 and January 2022. A combination of convenience and purposeful sampling was used to recruit secondary school PE teachers from the UK to participate in the CPD. A study recruitment message detailing the nature of the study, eligibility criteria, and a link to the CPD was provided to all potential participants following the distribution of an online survey. Teachers were eligible to participate if they were current UK secondary school PE teachers. One hundred and nineteen teachers expressed an interest in taking part. A screening process was undertaken via the CPD platform to ensure that potential participants met the eligibility criteria. One hundred and fifteen PE teachers completed the screening process and provided consent. Seven teachers were identified as not having PE teaching as their current role and were removed from the study, leaving one hundred and eight PE teachers eligible to complete the CPD programme. A quasi-experimental pre-post control group design for the CPD was adopted with teachers assigning themselves a start date for the CPD based on their respective work and time commitments. Teachers that could not complete the CPD by January 2022 were assigned to a wait list control group (n=32) and offered the opportunity to complete the CPD once the study had finished. The remaining 76 teachers were allocated to the CPD group. All participants were asked to complete a knowledge quiz before confirming their acceptance to the CPD or wait list control group. This provided baseline MF activity knowledge data. The CPD group completed the online CPD over 10 weeks (with the understanding that three hours per week time commitment would be needed). A breakdown of the recruitment process can be seen in Figure 6.1.

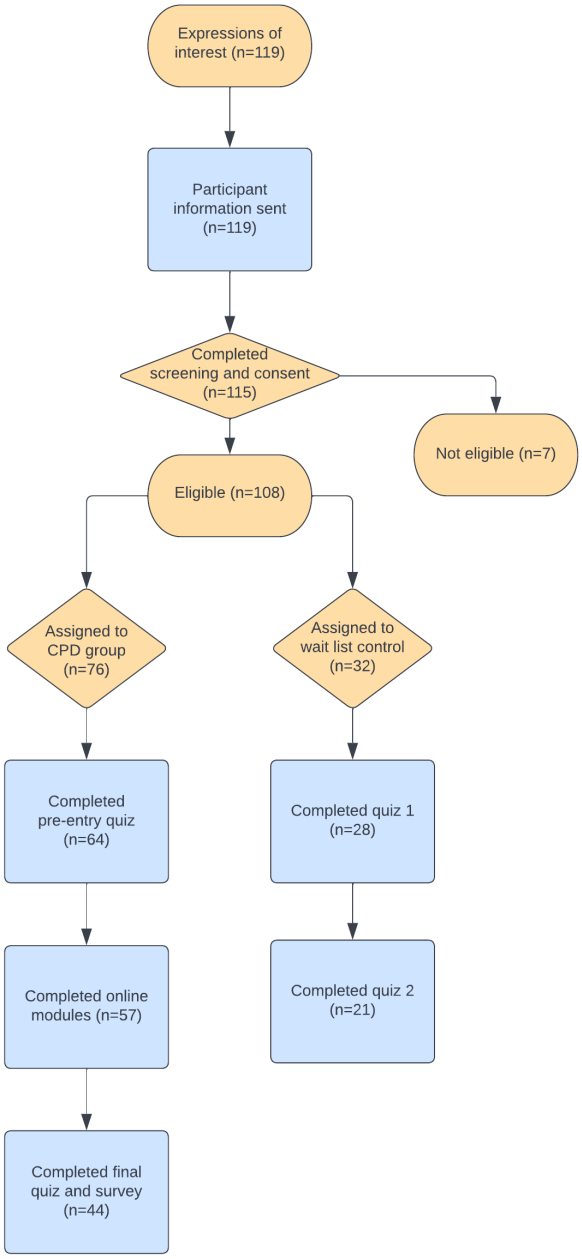

Figure 6.1 Participant recruitment breakdown

6.2.3 Quantitative data collection and analysis

The first author facilitated the online CPD, corresponded with participants through online discussions, and was available through direct messaging via the CPD platform if participants experienced any problems. Participants did not use the direct messaging system for support which suggests that they encountered limited problems on the online platform during the study. Participants were allowed to progress through the CPD at their own pace, completing modules any time during the 10 weeks. Learning tasks ranged from self-directed reading, formative quizzes, and feedback opportunities. For feedback, participants were invited to comment at the end of each module on what they found useful

and to reflect on their learning in an open forum to encourage group interaction and facilitate communities of practice (Lander et al., 2020). At the end of the CPD, participants completed an exit quiz consisting of the same questions as the entry quiz. Correct answers and feedback were provided after the exit quiz. The order of these questions was randomised between participants and from the pre-CPD quiz. Once all CPD participants had completed the exit quiz, the wait list control completed their second quiz.

Pre-and-post CPD knowledge quiz data were available from 44 participants in the CPD group (57.9% completion) and 21 in the wait list control group (65.6% completion). Twenty PE teachers did not complete the CPD despite completing the pre-knowledge quiz, with 13 of them providing a reason (more time required n=6, sickness n=5, pregnancy n=1, change of job role n=1). To address study aim 1 overall CPD knowledge change scores were generated for the CPD and wait list control groups based on pre-and-post knowledge quiz scores. These scores were first examined for normality of distribution by examination of histograms and tests for skewness. Data were not normally distributed therefore a Mann-Whitney U test was conducted to determine differences in CPD knowledge change scores between the CPD and wait list control groups. Analyses were performed using SPSS v. 27 (SPSS Inc.; Chicago, IL) with statistical significance set at $P < 0.05$.

6.2.4 Qualitative data collection and analysis

Free-text qualitative responses were pooled together and analysed thematically to address study aims 2 and 3. Before CPD participants could download their certificate of completion, they received a request for feedback through a private free text box. Three free text boxes with the headings: (1) Could you please provide a brief overview of what the biggest take-home message for you was following this course? (2) What else would you like to see covered in this course? (3) Have you got any further comments regarding the course?

All open response data were managed and analysed inductively in NVivo12 (Version 12.6.0; QSR International Pty Ltd, Victoria, Australia). After the first author became familiar with the data (reading and re-reading the pooled transcription text) (Braun & Clarke, 2006), and inductive analysis approach was taken which included producing initial codes and then searching for and reviewing themes before each final theme was clearly defined (Braun & Clarke, 2006). Themes were generated from the data aligned with the study aims without fitting them into a pre-existing coding frame (Braun & Clarke, 2006). Themes were refined in iterative steps of (1) re-reading the pooled transcription text, (2) identifying emerging codes and subsequent themes (3) refining the codes and themes with the second author (Bogdan S., 2003). The second author reviewed the coding process and provided

suggestions to ensure that the coding was representative of the study aims. This process was repeated until the two authors reached a minimum 90% agreement level (McAlister et al., 2017; O'Connor & Joffe, 2020; K. Roberts et al., 2019). To present consistency of themes in the data, any themes identified and agreed upon by the first and second author that aligned with the study aims and occurred more than once were reported. Final agreed codes were summed and pen profiles were constructed to illustrate key themes (B. Smith & Caddick, 2012).

6.3 Results

6.3.1 Descriptive statistics

A total of 65 teachers (55.4% male) provided complete data. The distribution of the teachers covered all four UK nations, but the majority taught in England (Wales 7.7%, Scotland 6.2%, Northern Ireland 3.1%, England 83%). Teaching experience among the teachers were relatively equally distributed across all three categories. The study characteristics of the PE teachers enrolled in the CPD and wait list control groups can be seen in Table 6.2.

Table 6.2 Characteristics of PE teachers enrolled in CPD and wait list control groups

Characteristics	All (n=65)	CPD Group (n=44)	Wait list Control Group (n=21)
Sex % (n)			
Male	55.4 (36)	56.8 (25)	52.4 (11)
Female	44.6 (29)	43.2 (19)	47.6 (10)
School Location % (n)			
Cymru Wales	7.7 (5)	9.1 (4)	4.8 (1)
East of England	7.7 (5)	4.5 (2)	14.3 (3)
North East and Cumbria	3.1 (2)	-	9.5 (2)
East Midlands	13.8 (9)	15.9 (7)	9.5 (2)
London	7.7 (5)	9.1 (4)	4.8 (1)
North West	10.8 (7)	11.4 (5)	9.5 (2)
Northern Ireland	3.1 (2)	2.3 (1)	4.8 (1)
Scotland	6.2 (4)	4.5 (2)	9.5 (2)
South East	15.4 (10)	18.2 (8)	9.5 (2)
South West	7.7 (5)	6.8 (3)	9.5 (2)
West Midlands	10.8 (7)	11.4 (5)	9.5 (2)
Yorkshire and the Humber	6.2 (4)	6.8 (3)	4.8 (1)
Teaching Experience (years) % (n)			
<5	35.4 (23)	36.4 (16)	33.3 (7)
5-14	33.8 (22)	34.1 (15)	33.3 (7)
>15	30.8 (20)	29.5 (13)	33.3 (7)

6.3.2 Quantitative results

Pre-and-post CPD knowledge quiz data were available from 65 participants (55.4% male). The median knowledge quiz change score was significantly higher in the CPD group than in the wait list control group (CPD score vs control score; U =37, z = -5.96, *P* <0.01). Figure 6.2 provides a graphical representation of change score median values and interquartile range between the CPD and wait list control groups.

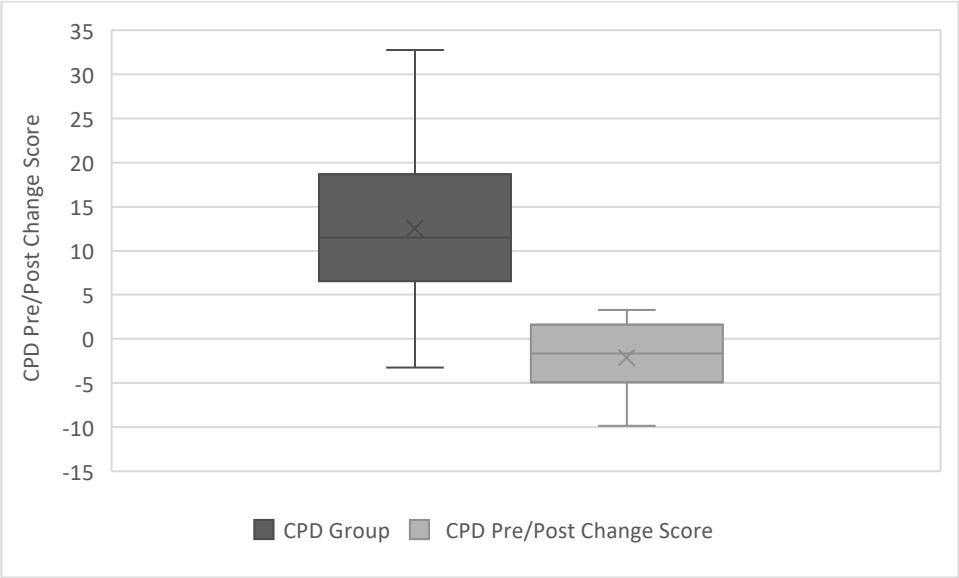

Figure 6.2 Change score median values and interquartile range between the CPD and wait list control groups

6.3.3 Qualitative results

To address study aims 2 and 3, negative and positive themes were identified to support the development of future online CPD courses for PE teachers. Positive (+ve) and negative (−ve) influences featured in both primary and secondary reinforcing themes. Three primary themes reflecting factors associated with the acceptability and suitability of the online CPD were [1] practical application, [2] support and resources, and [3] knowledge and confidence (Figure 6.3). A further 19 secondary themes were identified: cultural change +ve (n=22), application and practice +ve (n=15), understanding of theory +ve (n=25), addressed misconceptions +ve (n=8), contextual examples -ve (n=10), differentiation -ve (n=3), implementation +ve (n=18), testing and assessment +ve (n=9), testing and assessment -ve (n=6), pace +ve (n=4), video support -ve (n=6), in person support -ve (n=7), personal interest +ve (n=6), example lesson content -ve (n=18), example lesson content +ve (n=2), volume and quality of information +ve (n=16), volume and quality of information -ve (n=6), scientifically evidenced +ve (n=10), online CPD platform +ve (n=6). Positive (+ve) and negative (−ve) influences featured in both primary and secondary reinforcing themes.

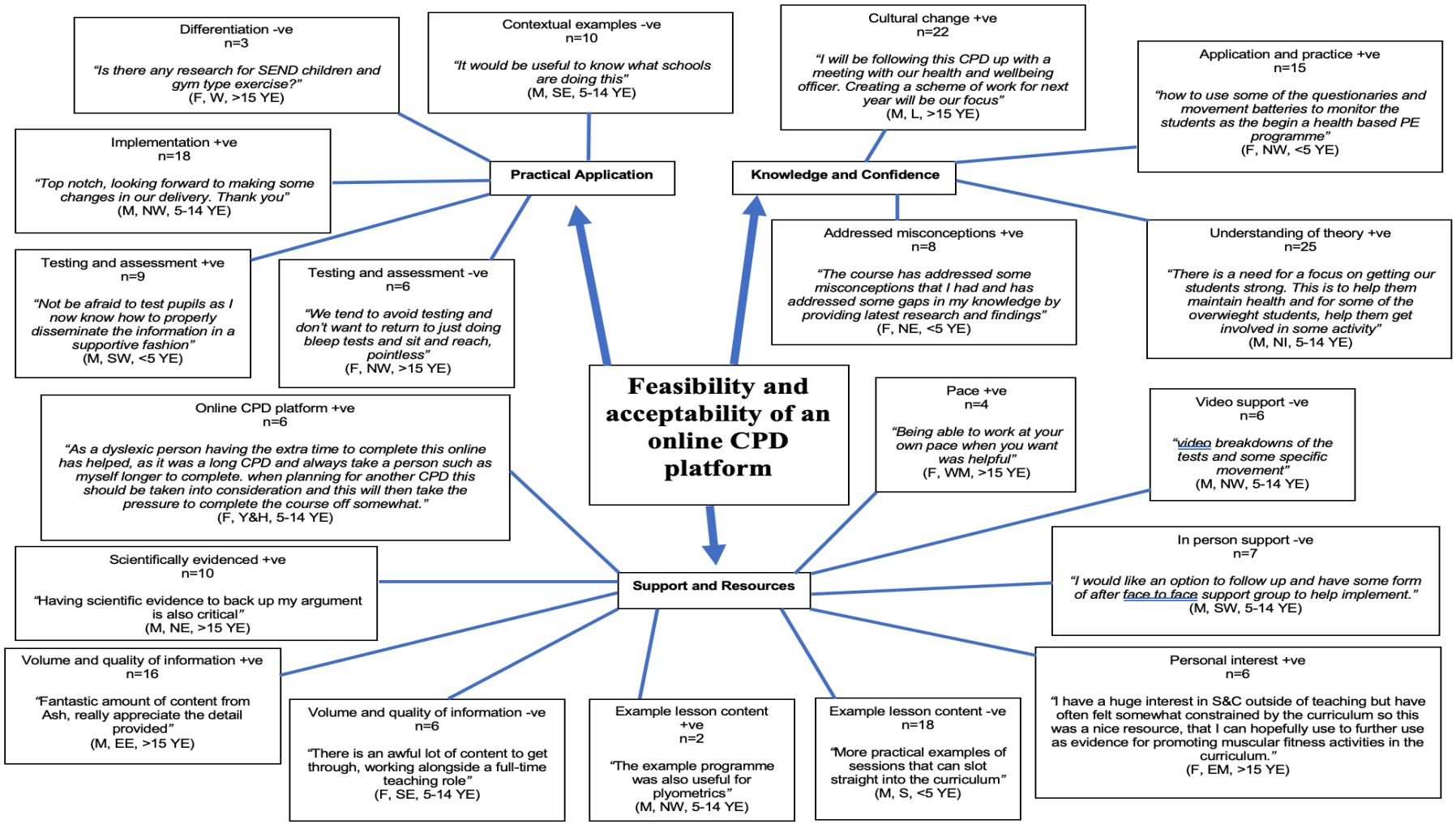

Figure 6.3 MF activity knowledge. +ve = positive; −ve = negative. M = male; F = female. SE = South East England; SW = South West England; London; NI = Northern Ireland; WM = West Midlands, England; EE = East of England; NW = North West, England; Y&H = Yorkshire and the Humber, England; S = Scotland; NE = North East and Cumbria, England; EM = East Midlands, England; W = Wales. YE = years' experience.

6.4 Discussion

The aims of the present study were to (1) assess if an online CPD course can increase PE teacher knowledge of MF activity (2) assess the feasibility of an online CPD course to enhance PE teacher knowledge and competence of MF activity, and (3) assess the acceptability of the content and design of an online CPD course from PE teachers' perspectives. Content knowledge of the PE teachers that completed the online CPD significantly increased while content knowledge scores in the wait-list control group decreased. Reported intent to change practice and integrate MF activity into lessons was evidenced amongst the PE teachers from the CPD group.

6.4.1 Knowledge and confidence

We identified that the CPD programme resulted in increased MF activity knowledge among UK secondary school PE teachers. However, some variability was evident in change scores, with some teachers doing better than others. This may be explained by online learning processes being influenced by several internal, external and contextual factors, including time, information technology, flexibility, existing knowledge, independence and learners' motivation and expectations (Regmi & Jones, 2020). Understanding these factors requires further investigation. Despite some teachers developing more knowledge through the online CPD, our qualitative data revealed that many PE teachers in this study responded positively to the underpinning theory regarding the health benefits of MF activity. For example:

"This has really opened my eyes, not sure why this isn't discussed more. I took a lot away from this and get now why strength is just as important for health as cardio fitness" [Female, North West England, Over 15 years experience].

Improving content knowledge has been demonstrated to increase levels of confidence in teaching practice (Morgan & Bourke, 2008; Rainer et al., 2012). Our findings are consistent with previous research and suggest an intention to translate acquired knowledge into practice with a view to drive cultural change within PE teachers' respective schools. This is a positive finding given the paucity of pedagogical research into the delivery of MF activity in schools and supports the acceptability of online CPD amongst study participants. However, as evidenced in the present study, such success is only achieved if the content delivered is underpinned by empirical evidence and informed by the needs of the teacher (Lander et al., 2022). The theoretical aspects of the online CPD programme and the relevance of the content to teachers' interests may explain the intent to apply newly acquired knowledge into practice. This requirement has been documented elsewhere in the literature and has been suggested to elicit greater CPD engagement and adherence

(Kennedy et al., 2019; Lander et al., 2017). Collectively, these findings further support the need for CPD that is content knowledge centric and underpinned by up-to-date research.

PE teachers are required to be highly qualified in the content of the subject area in which they teach (i.e., high levels of content knowledge) (Lander et al., 2017). However, expertise in content alone is inadequate and an understanding of pedagogical content knowledge is required to successfully plan and implement MF activity that aligns with individual student learning styles and needs (Craft, 2016; Lander et al., 2017). Due to a lack of MF activity research and practice in schools (Dos Santos et al., 2021), there was limited school-based pedagogical knowledge research to underpin the CPD content. However, when provided with content knowledge alone, our findings suggested that PE teachers could adapt content knowledge to their existing pedagogical knowledge. To overcome the paucity of pedagogical research in MF activity, this CPD relied on existing frameworks to deliver MF activity that have primarily been developed for athletic development processes. The models used as frameworks in this CPD were long-term athletic development models that focussed on specific modes of MF activity (Pichardo et al., 2018). There was an emphasis on plyometric movements in the form of the plyometric progression model to align the content with the needs and requirements identified in the CPD development process (Lloyd et al., 2011). Furthermore, the models were presented alongside a theoretical periodisation plan that was aligned to a secondary school term to provide insight into how MF activity could be implemented in schools (Pichardo et al., 2019). Despite the lack of pedagogical knowledge specific to MF activity, PE teachers in this study found the athletic models presented useful to add context to implementation. For example:

"The athletic models were useful and something we can use for our lessons. They will feature in our GCSE class next year to help pupils understand periodisation and we can use them to plan our lesson progressions" [Male, London, 5-14 years experience].

Our findings are supportive of providing PE teachers with content knowledge they can translate into practice based upon their existing pedagogical knowledge. Therefore, future MF CPD can utilise a similar authentic pedagogical approach to PE teacher learning. Authentic pedagogy is a systematic learning strategy which helps the learners (PE teachers) to develop solutions in real-world problems guided by proper instructional approaches (Deyasi et al., 2021). Such approaches may allow CPD providers to focus on up-to-date content knowledge whereby there may be a dearth of existing literature on pedagogical approaches to new developments.

6.4.2 Practical application

PE teachers in this study suggested they would make changes to their PE provision to include MF activity following the online CPD. Previous work has suggested that a lack of interaction with CPD facilitators may hinder practical application of learning (Healy et al., 2020; Lander et al., 2022). Our findings may contrast with previous literature following the co-production of the CPD programme with current teachers. The online CPD accounted for suggestions provided by PE teachers during the CPD development and included plyometric movements such as jumping and bounding to allow schools with minimal equipment to put learning into practice. Such movements are underpinned by existing literature as being effective school-based MF activities (Cox et al., 2020) and are movements most teachers are familiar with. This ensured MF activity was coherent with other aspects of the PE curriculum and may explain the intent to integrate MF activity into practice alongside existing pedagogical knowledge (Armour & Yelling, 2004; Garet et al., 2001). For example:

"I already knew about plyometric exercise through my UKA (UK Athletics) *course*. *The CPD helped take what I know and put it into a gym lesson. It makes sense to use the plyometric progression model and help pupils work towards their own plan and fitness, something they can even use for GCSE work. Thank you"* [Male, North East England, over 15 years experience].

However, our findings suggested that a lack of contextual examples from other schools that are delivering MF activity. Previous work has highlighted that teachers will need to see evidence of initiatives resulting in improved pupil outcomes before changing attitudes and beliefs prior to implementing new learning (Armour & Yelling, 2004). This is a concern regarding the fidelity of MF activity in schools given the lack of contextual examples to refer to and may lead to hesitancy in implementing MF activity among PE teachers. Our findings suggested that PE teachers require contextual examples during CPD. For example:

"Who else is doing this (MF activity)*? It would be good to see how others have used it* (MF activity) *in their PE lessons"* [Female, East of England, under 5 years experience].

Our findings demonstrated that future online MF CPD courses may benefit from providing contextual examples from other schools to further support the translation of CPD content into practice. One approach may be to develop Professional Learning Communities. Professional Learning Communities provide an opportunity for collective learning and application and, shared individual practice (Vangrieken et al., 2017), which are suggested to improve practical application of acquired knowledge. A benefit to the Professional Learning Community structure for MF activity CPD is the top-down structure and obligatory

involvement (Parker et al., 2022). This may break the cycle of teachers engaging in CPD that aligns with their interests and not of their developmental requirements (Patton et al., 2015). However, this approach would require further collaboration with school policy makers to overcome barriers that preclude such initiatives and ensure policy makers understand the benefits of MF activity.

PE teachers in this study expressed that they were more likely to conduct tests and assessments of MF to inform their MF activity lessons when provided with a rationale and standardised protocols. The efficacy of MF activity is underpinned by appropriate testing and assessment to progress individuals safely (Cox et al., 2020). Therefore, developing an understanding of testing and assessments of MF may lead to increases in the quantity and quality of MF activity and provide a non-invasive objective assessment of the impact of school-based MF interventions (Cohen et al., 2015; Keating et al., 2020). However, in schools, tests and assessments in PE have been highly contested (Cohen et al., 2015; Yager et al., 2021) and some PE teachers in this study were hesitant to implement testing and assessments due to preconceived biases surrounding broader testing beyond MF. PE teacher concerns centred around the value of testing and assessment in other areas of PE such as the bleep test for cardiorespiratory fitness and suggests more work is needed in this area. Despite our findings suggesting an intent to conduct MF activity, it is difficult to conclude this will translate into action. Future research should jointly monitor student outcomes and teacher learning following CPD to establish a link between acquired knowledge and the impact this has on student outcomes of MF.

6.4.3 Support and resources

One of the challenges of online CPD is the provision of meaningful support (Armour et al., 2012). PE teachers have reported a lack of time to remain current with research developments and report feelings of isolation (Armour & Yelling, 2004). To ensure the online CPD allowed for teachers to ascribe their own meaning and understanding of the newly acquired MF activity knowledge, collaborative engagement was encouraged in this study through discussion points during each module (Patton et al., 2015). This process encouraged participants to be active learners and reflect on how the delivered content knowledge could be adapted to suit their respective pedagogical practices in PE (Garet et al., 2001; Patton et al., 2012). Unfortunately, the discussion opportunities did not generate meaningful discussion around the application and pedagogical approaches to delivering MF activity, with teachers requesting further support and clarity on lesson delivery in schools. Future CPD may benefit from co-delivery, utilising a PE teacher experienced in MF activity delivery alongside a university's research-based knowledge and expertise to drive discussion.

Teachers who are satisfied with CPD content are likelier to adopt and implement programs as intended (Lander et al. 2017). Therefore, this study ensured the online CPD met PE teacher needs and interests through the co-production of CPD content. This was evidenced in our findings whereby participants suggested they had a personal interest in the content and appreciated the scientific underpinning in which it was delivered. This aligns with suggestions made in existing literature that accounting for personal needs and interests is a key component for CPD success (Patton et al., 2015). These findings demonstrate that although concerns regarding online CPD lacking nuance and individualisation exist (Higgins et al., 2012; Lander et al., 2022), teacher interests and needs can be met through online CPD. This may be explained by the co-production of the CPD and highlights the need for future research to adopt a similar approach. Another explanation for the positive CPD experience could be attributed to the course delivered by a trusted individual working within a university. It has been suggested that the delivery of CPD by an individual or organisation with appropriate expertise may increase the likelihood of CPD content resonating with the teacher (Armour & Yelling, 2004). This is supportive of PE teachers reporting links with universities providing stimulating and interesting interactions that extend beyond their routine teaching (Armour & Yelling, 2004) and suggests that similar higher education and PE teacher relationships should be sought.

A key strength of the online delivery was extending content delivery beyond one day, allowing for a greater amount of content to be digested over a number of weeks (Avalos, 2011). Moreover, the extended and flexible training allowed the pace of delivery to suit a range of individuals, particularly individuals who wanted to review and revisit content to either cement learning or assist in the learning process. For example:

“Going at my own pace in my own time was great. I could work it around work and home life. I have struggled with workshops in the past, especially with having issues around my learning ability. I have to go over things and take my time” [Female, Yorkshire and the Humber, 5-14 years experience].

Extending CPD across 10 weeks allowed for a sustained approach typically defined as extending beyond one day (Armour & Yelling, 2004). This extended approach may help support MF activity implementation (Lander et al., 2017). However, our findings also highlighted that although PE teacher content knowledge increased, there was still a requirement to be provided with lesson plan templates. A lack of example lesson content in this study may impact MF activity implementation. Future online CPD content should ensure downloadable lesson content is provided to help support lesson or activity implementation

and increase the feasibility of MF activity CPD.

6.5 Limitations

Limitations of this study relate to the imbalanced sample between the four UK home countries, and the risk of self-selection bias. However, steps were taken to limit such bias, including co-production of the CPD content and the application to gain CPD point recognition. Furthermore, findings from this study should be interpreted with caution as the study design cannot claim causality. The sample size for the quantitative analysis was modest and as such, statistical power may have been lacking. However, upon reflection and taking into account some of the available suggestions in the literature (Hoenig & Heisey, 2001; Kraemer et al., 2006; Levine & Ensom, 2001) we have decided to not conduct such an analysis. It has been suggested that a posthoc power analysis is conceptually flawed and analytically misleading (Zhang et al., 2019).

However, the mixed methods approach to data collection allowed for added context to support the quantitative data.

6.6 Conclusion

This is the first study in the UK to investigate the feasibility and acceptability of an online MF activity CPD programme Overall, MF activity knowledge of the PE teachers that completed the online CPD increased while it decreased in the control group. Evidence that an online CPD programme results in increased MF activity may help overcome the reported barriers to MF activity implementation in schools and provides a feasible way to deliver MF activity CPD to PE teachers. Furthermore, PE teachers that completed the CPD reported the online platform was beneficial to overcoming the limitations of face-to-face CPD such as time and financial constraints and suggested the content covered was beneficial and appropriate to their teaching. Whilst the online CPD was on acceptable method of delivering CPD, the benefit to co-production should not be overlooked. This approach allowed the CPD to align to teachers' requirements and future research should adopt a similar approach. Finally, future work is required to establish links between teachers' learning following CPD, the translation into PE practice and student MF outcomes.

Chapter 7
Summary of findings

7.1 Introduction

The physical and mental health benefits of MF are well recognised (García-Hermoso et al., 2019; Smith et al., 2014). However, it is acknowledged that MF has been an overlooked element of the PA guidelines (Chalkley, 2021). Schools provide an established setting to deliver PA interventions (Cassar et al., 2019). To date most PA interventions in schools have focussed on aerobic MVPA with limited success (Love et al., 2019). Schools present a suitable setting to promote MF as part of PA promotion. However, teachers' contextual understanding of MF activity implementation is currently limited. To fill this gap, this thesis presented four studies that each make novel contributions to the existing body of literature on school-based MF activity.

The studies included furthered scientific understanding of (1) the current evidence base on the efficacy of school-based MF interventions, (2) adolescent boys' perceptions, understanding, and experiences of MF activity, (3) teachers' understanding and experiences of MF activity delivery in schools, and (4) the feasibility and acceptability of an online CPD course to improve teachers' knowledge and competence in the delivery of MF activity. This chapter will synthesise the findings and critically discuss them in the context of existing research. The concluding chapter will provide practice related recommendations and areas for future research that have been identified during the process of this thesis.

7.2 Thesis models

In Chapter 1, various models were presented as having informed or made contributions to the existing MF activity literature. Whilst the models occupying PA an MF activity literature helped inform thesis conception and direction, the degree in which they did varied considerably. In Chapter 1, SDT was presented as a framework commonly utilised to examine the relationship between motivation and PA (Owen et al., 2014). The development of positive self-perceptions deriving from fulfilling the three tenants of SDT may contribute to increases in habitual LLPA (Weiss & Ebbeck, 1996). However, given the infancy of MF activity research (Chalkley, 2021), this thesis had to first establish the efficacy of MF activity in schools before expanding upon and investigating psychological models such as SDT. As the thesis developed, SDT, although central to motivation to PA and PE research (Fernández-Espínola et al., 2020; Teixeira et al., 2012; White et al., 2021) was exchanged in favour of the YPAPM. This allowed for examination of a broad range of commonly reported correlates/variables of interest: demographic, predisposing, reinforcing, to ensure

the novel work presented in this thesis was thorough, informed thesis direction and provided the foundations for future research in MF activity.

The studies within this thesis were theoretically underpinned by the YPAPM (Welk, 1999). The YPAPM acknowledges the input of various personal, social and environmental influences on PA and affirms the importance of the broader social and institutional support (Belton et al., 2014). This allowed the studies to adopt a bottom-up approach and account for multidimensional factors contributing to PA, with a focus on MF activity throughout. Furthermore, the YPAPM informed the qualitative analysis of Study 2 whereby qualitative coding and theme generation were representative of YPAPM elements, adapted and expanded upon to align specifically with MF activity. During the online CPD presented in Study 4, the YPAPM formed part of the PA module and provided PE teachers with a framework to explore, evaluate and reflect on their students PA and MF engagement.

A final model presented in Chapter 1 was the RTSC framework to help translate theory into practice. The RTSC framework provides recommendations for MF activity progression based on a participant's competency and muscular strength. Additionally, the supporting RTSC checklist can be used to assess exercise performance and communicate the specific actions and behaviours that are required for MF activity. Whilst tools to assist PE teachers and youth sport coaches exist in the literature, it is not fully understood if and how these tools are applied and the extent of the ability and knowledge of the same practitioners to prescribe MF activity safely and effectively. This thesis identified a lack of MF activity knowledge among PE teachers in Study 3. Therefore, the RTSC was used to help inform the practical and applied presentations during the CPD delivered in Study 4. The RTSC presented to PE teachers in Study 4 may help inform PE teachers MF activity delivery and decision making. However, the extent of how the RTSC informed PE teacher decision making is beyond the scope of this thesis and further work is required to test the suitability and long-term adoption of the RTSC in a PE environment.

7.3 Summary of findings

Study 1 (Chapter 3) was the first systematic review and meta-analysis to examine the efficacy of school-based MF amongst adolescent boys. The systematic review and meta-analysis investigated the available evidence base for school-based MF activity in adolescent boys to inform the direction of future research and identify gaps within the existing literature. Study 1 focussed on adolescent boys as this population group at the time of conducting the research were considered a suitable target group for MF activity in response to the perceived masculine nature that adolescent boys ascribe to MF activity (Lubans et al., 2016; D. R. Lubans & Cliff, 2011). Study 1 found a significant effect for

school-based MF interventions in adolescent boys, suggesting that this form of PA warrants further investigation. Study 1 was unique in that it split the outcomes of MF into the type of MF activity conducted (i.e., traditional, bodyweight, plyometric or combined activity) and by general anatomical location (i.e., upper and lower limb). Overall, Study 1 demonstrated that MF delivered in a traditional manner, such as weight machines and free weights, may have a greater effect on enhancing MF than other forms of MF delivery such as bodyweight activities. Additionally, it was discovered that plyometric forms of MF delivery demonstrated significant homogeneous effects and warrant further investigation to assess their application in the school environment. The importance of recognising the methodology and prescription of MF activity and the interaction with subsequent adaptation is well understood and acknowledged in the adult literature (Suchomel et al., 2016, 2018), but is less understood in youth. Overall, the findings in Study 1 provided contextual understanding into the efficacy of MF interventions delivered to adolescent boys in schools. Of note, the work conducted in Study 1 has influenced further investigation into MF amongst youth, with the study methodology replicated and published elsewhere(Villa-González et al., 2022). Furthermore, Study 1 identified several gaps in the existing literature beyond the scope of this thesis, providing areas for future research and are summarised in section 7.4.

Study 1 identified a lack of qualitative investigation into adolescent boys' perceptions and understanding of MF. Existing qualitative research had reported a lack of facilities, cost, and accessibility as barriers to PA (Brophy et al., 2011; Charlton et al., 2014; Filippidis & Laverty, 2016; James et al., 2018). However, none of the previously conducted studies addressed MF activity independently.

Study 2 was undertaken to better understand adolescent boys' understanding, perceptions, and experiences of physical activity and the role MF plays in boys' physically active lifestyles. It was envisaged that the context provided would help support future MF activity intervention development (Smith & Phoenix, 2019). Study 2 adopted a combination of qualitative techniques to investigate adolescent boys' understanding, perceptions, and experiences of physical activity and the role MF plays in boys' physically active lifestyles. Study 2 used focus groups in combination with drawings, which allowed for greater control over participant expression compared to verbal communication alone (Darbyshire et al., 2005; Kirk, 2007). The data triangulation allowed for the boys' thoughts and perceptions to be analysed from multiple angles and provided credible and trustworthy data for interpretation (Darbyshire et al., 2005; Morrow, 2005).

Study 2 concluded that adolescent boys want to participate in MF activity. However, adolescent boys in this study perceived that there was a lack of opportunity to engage in

MF activity both in and out-of-school. Furthermore, Study 2 highlighted that outside-of-school access to MF activity was limited due to budget cuts and local leisure centre closures which is in agreement with existing literature investigating access to PA facilities (Higgerson et al., 2018). Such constraints reinforce the importance of PE and its role in reaching a range of adolescents irrespective of their background and individual characteristics (Love et al., 2019). The findings reported in Study 1 contributed to a recent Rapid Evidence Review for Public Health England (Chalkley, 2021), reinforcing the importance of MF activity delivery in schools as a health-promoting form of PA. However, Study 2 suggested that there was a lack of exposure to MF activity which the study participants attributed to a lack of willingness from PE teachers to provide MF activity orientated PE lessons. The perceived lack of willingness of PE teachers to deliver MF activity may be explained by previous research which reported perceived barriers among PE teachers, including a lack of facilities, teacher confidence, and time (Kennedy et al., 2021; Nathan et al., 2018; Naylor et al., 2015). Such perceived barriers can be overcome through appropriate delivery of MF activity, such as utilising plyometric training which requires little to no equipment and has been proven effective for improving MF when delivered during school-based PE as suggested in Study 1. However, as Study 1 also identified, achieving MF activity outcomes depends on their specificity and delivery, requiring some knowledge of MF activity which may explain some of the hesitation from PE teachers to deliver as identified by the participants in Study 2.

Overall, Study 2 provided a novel contextual understanding of the predisposing, reinforcing, and enabling factors for adolescent boys' MF activity. Furthermore, Study 2 contributed and expanded upon the existing PA evidence base by specifically investigating MF activity. Paradoxically, PE was deemed to be an enabling factor to MF activity engagement amongst adolescent boys, whilst PE teachers' support and knowledge development was perceived as restricting MF participation. Study 2 revealed a need for school-based MF interventions. However, the implementation of MF activity is likely mediated by PE teachers' ability, knowledge, and willingness to deliver MF activity during structured PE. Study 2 concluded that research should investigate PE teachers knowledge of MF and investigate how current knowledge levels influence practice The findings from Study 2 informed the rationale for Study 3 (Chapter 5).

Study 3 used an online survey to investigate PE teachers' perceived expertise and professional development requirements for delivering MF activity in schools. The findings presented in study 3 build upon the findings reported in Study 1 and Study 2 and provided further evidence regarding a lack of priority placed upon MF activity delivery in schools. Specifically, Study 3 found that PE teachers from across the UK perceived that their knowledge of MF was lacking and required development. Although this is the first study to

explore perceptions of UK PE teachers, the findings agree with existing literature from the US and Australia which suggest a perceived lack of expertise and confidence in MF activity delivery (Kennedy et al., 2021; Nathan et al., 2018; Naylor et al., 2015). Study 3 further suggested that PE teachers had preconceived biases related to safety concerns in the delivery of MF activity. These barriers to MF activity were further compounded by a perceived lack of policy and stakeholder support in the delivery of MF activity, leading to concerns from PE teachers surrounding MF activity implementation fidelity.

Activities to develop MF have previously been considered highly gendered; as such, there could be differences in the delivery of MF activity between male and female PE teachers (Anderson, 2010; Preece & Bullingham, 2020). However, the degree to which teacher gender influences the delivery of MF activity was unknown and required further investigation. Interestingly, quantitative analyses conducted in Study 3 revealed a lack of gender bias in MF delivery. This contrasts with previous research whereby such activities were perceived as more masculine, for example, power and strength-based activity were likely to be delivered by male teachers (Anderson, 2010; Preece & Bullingham, 2020). These findings are promising and further highlight the growing popularity of MF across all genders and may be explained by increasing participation rates in females, largely reported during the course of conducting and writing this thesis (Cowley et al., 2021).

Additionally, teacher experience has been suggested to influence levels of knowledge and subsequent practice (Griffin, Dodds and Rovegno, 2013; Tant and Watelain, 2016). Quantitative data in Study 3 found that PE teachers with more experience were more likely to plan and integrate MF activity into their lessons, which concurs with existing literature (Capel et al., 2009; Griffin, Dodds and Rovegno, 2013; Tant and Watelain, 2016). However, additional qualitative findings in Study 3 suggested a lack of knowledge and understanding to MF activity implementation irrespective of teaching experience. These findings raise concerns over the quality of current MF activity provision in schools and suggest a need to further investigate and standardise MF activity knowledge and pedagogical delivery.

Study 4 (Chapter 6) was informed by the findings from all three previous studies (Chapters 3, 4 and 5). Collectively these studies identified the current evidence base regarding MF activity and whether school-based delivery of MF activity among adolescents would be a suitable intervention strategy to increase PA and MF activity amongst this population group. Study 4 took into consideration previous research whereby PE teachers have reported difficulty accessing CPD, constrained by the time and financial requirements of face-to-face training opportunities (Sato et al., 2017). Overall, Study 4 found that an online course to

improve the knowledge of MF activity amongst secondary PE teachers was feasible and resulted in significant increases in PE teacher knowledge.

Study 4 observed an improvement in PE teacher knowledge following completion of the online CPD. The mixed methods approach also provided contextual understanding regarding the acceptability of the online MF CPD course and provides a basis to ensuring future MF CPD development is relatable and translatable into practice. Study 4 identified that PE teachers were able to develop an understanding MF theory during the CPD and address preconceived misconceptions. It also demonstrated that once the health and developmental benefits of MF were explained, PE teachers were willing to pursue a cultural change to help integrate MF activity into the curriculum. However, future work should be cognisant that the knowledge imparted during CPD must be underpinned by scientific evidence and where possible, provide examples of lesson plans, resources and school examples of MF activity to help the implementation process.

7.4 Synthesis

To date, research to improve PA levels has largely focussed on aerobic MVPA with limited success (Love et al., 2019). Moreover, existing research has overlooked the MF element of the current PA guidelines, resulting in a limited understanding of MF activity and its effectiveness amongst adolescents (Chalkley, 2021). This thesis has enhanced understanding of MF activity with a focus on school delivery. Importantly, the research has contributed to the scientific literature by establishing that amongst adolescent boys, MF activity can effectively be delivered in schools. However, as demonstrated in Study 1, careful consideration to how MF is delivered is required to ensure improved MF outcomes. For example, providing MF activity in the form of bodyweight resistance alone, might be an ineffective way to enhance MF amongst adolescent boys whereby conducting plyometric of traditional MF activity may result in more favourable improvements in MF. The findings from Study 1 suggested that the delivery of MF activity in schools may be better structured around activities and movements that are either plyometric or traditional (i.e., free weights). These activities may form part of structured PE or extracurricular opportunities during the school day and would require PE teachers to be knowledgeable in the design and implementation of MF activity that is safe and developmentally appropriate.

Within this thesis, it was evident that PE has a key role in facilitating PA. Moreover, PE has a crucial role in providing supervised and developmentally-appropriate opportunities to engage in MF activity. Findings from Study 2 demonstrated that adolescent boys want the opportunity to participate in MF activity. However, out-of-school provision is limited due to poor facilities, cost, and their relatively young age which prevents them from accessing

commercial gym facilities. Given the declines in MF (Dooley et al., 2020), future collaboration with young people, teachers, policy makers, and parents are critical to translate research into practice and provide options to enable MF activity provision in the interests of healthy development. Findings from Study 2 also reinforced the importance of developing social networks to ensure MF intervention success and long-term fidelity. Indeed, it is acknowledged that schools play a key role in the social development of adolescents and provide an environment in which adolescents can develop their friend-to-friend interactions with the support of teachers. This should be capitalised upon and prepare adolescents for leaving formal PE and ensuring the friend-to-friend and social networks are in place to visit commercial gymnasiums and facilities as emerging adults.

Study 3 demonstrated that teachers delivering PE from across the UK believe their knowledge of school-based MF activity needs development. This lack of knowledge is reflected in a limited understanding of programme design and concepts of MF activity. Furthermore, preconceived biases surrounding the safety and efficacy of MF activity still exist among some UK PE teachers. Such gaps in knowledge of MF activity may explain in part, the lack of exposure to MF activity reported in Study 2. Improving PE teachers' knowledge of MF activity may support aligning mandated PE lessons to an element of PA that has previously been overlooked.

Study 4 revealed that an online form of CPD was a feasible way to enhance PE teachers' knowledge in the delivery of MF activity. Furthermore, the findings highlighted the importance of PE teacher involvement in the design and development of CPD to ensure CPD content is appropriate and relatable to their teaching practice. Additionally, PE teachers suggested that having a link with the underpinning scientific theory was critical in providing a rationale to their learning and subsequent teaching. As evidenced in Study 3 the importance of providing evidence around the safety and efficacy of MF activity delivery is key to dispelling existing myths and misconceptions.

Study 4 also demonstrated the value of co-production of interventions at the earliest opportunity to improve intervention outcomes. Finally, Study 4 evidenced that if PE teachers are to implement their learning from an online CPD course, there needs to be ongoing practical support. Aligning the CPD content with real-world and contextual examples derived from schools that are already delivering MF activity would support future CPD opportunities and subsequent translation into practice. Study 4

7.5 Recommendations for future work

Based on the findings presented in this thesis there are several recommendations to further the line of research on the delivery of MF in schools. These recommendations have been organised below into priorities for research and practice and CPD development.

7.5.1 Recommendations for research

- Where feasible, future MF studies should ensure consistency of measures, for example, type of jump used to assess lower limb power
- Future MF research should be encouraged to generate a consensus for core outcome measures of MF
- Qualitative research with adolescents should employ participatory research techniques to elicit adolescents' voices, facilitate the exploration of a wide range of research topics and enhance data credibility through limiting researcher biases and triangulating data sources. Mobile technology and apps may also support this process
- Future out-of-school MF interventions should seek to work in partnership with local authority gymnasiums and commercial facilities
- Further implementation and process evaluation of the online CPD platform is warranted to inform future research and practice

7.5.2 Recommendations for practice

- Where MF activity is delivered in PE, a focus on plyometric and traditional forms of MF activity should be included where possible
- Assessing MF in PE should be conducted to inform lesson design and term-time programming
- Extracurricular opportunities to engage in MF activity should be available to help address the lack of opportunity in the community
- PE teachers should be offered CPD that aligns to their needs and requirements
- Communities of practice to support MF activity implementation need to be established
- Individuals and organisations with recognised expertise should work in conjunction with schools and PE teachers to develop CPD that improves knowledge and competence in all aspects of PA, including MF
- A greater emphasis on PE teacher CPD and allocated time to complete mandated annual CPD is required to ensure successful MF activity delivery in schools

7.5.3 Recommendations for CPD design

- Identify effective ways to build communities of practice to provide mutual support and best practice amongst schools. An online approach or application may help expand reach and bring PE teachers together to share knowledge
- Provide resources that are easily and freely accessible to support translation into practice
- Use a mix of media for CPD delivery including pre-recorded presentations, presenter led videos, and example videos with embedded knowledge checks to ensure engagement
- Ensure knowledge check quiz and assessment questions are randomised in order
- Embed discussions forums after topics to stimulate conversation
- Where theory-heavy topics are delivered, provide simple bullet-pointed summaries delivered on camera to break up delivery

7.6 Thesis contribution

The research presented in this thesis imparts a new narrative on the role MF activity in schools and has shed light on the broader aspects of PE. In doing so it provides recommendations that extend beyond traditional team sports and the tendency to focus on aerobic MVPA in an attempt to enhance levels of PA and health in young people. As demonstrated through the 4 studies conducted, MF activity in schools is “worth it” when seeking to engage adolescents in PA that may result in improved health outcomes. Furthermore, PE teachers are “able” to improve their knowledge of MF to enhance their pedagogical application during mandated PE and extracurricular activities.

The findings presented in this thesis have added to the limited evidence base regarding MF activity among adolescents. However, it should be acknowledged the contribution has focussed on the role of schools and specifically PE. Prior to the conception of this thesis the role of schools, PE and their contribution to PA was under scrutiny (Love et al., 2019). Previous work had focussed on the aerobic MVPA element of the PA guidelines and suggested implementation fidelity in schools required further work (Love et al., 2019). However, Study 1 of this thesis suggested school-based MF interventions are effective among adolescent boys. Unfortunately, the conception of this thesis was based on the available literature which suggested adolescent boys would benefit most from MF activity interventions and further work is required to investigate the efficacy of MF interventions among adolescent girls. Additionally, Study 1 identified a lack of consistency in MF activity measurement which may lead to outcome heterogeneity when interpreting future research collectively. Therefore, further research is required to establish best practice when measuring MF in both lab and school settings to expand on the current evidence base and contribute towards understanding the efficacy of MF activity. Improvements in research

design, exposures used, population groups studied, measurement techniques employed and reporting of protocols would help to strengthen the evidence base.

Despite the favourable initial findings presented in Study 1, it would be remiss to not acknowledge the lack of research in community-based MF interventions that may further support MF activity engagement. Whilst community-based MF interventions were not the focus of this thesis, future work should investigate the how out-of-school participation contributes to overall MF activity. Adolescence is a period whereby individuals take greater ownership of their PA behaviours and seek out new opportunities to be active, some of which may be provided by third party and external providers (van Sluijs et al., 2021). Some insight is provided in Study 2 whereby adolescents expressed difficulty in accessing facilities that may facilitate MF activity such as commercial gymnasiums and leisure centres. This may be attributable to factors such as cost barriers associated with low SES as some participants in Study 2 suggest and research investigating aerobic MVPA would be supportive of this hypothesis (Higgerson et al., 2018). However, this thesis cannot infer low SES is responsible for perceived out-of-school MF opportunity and engagement and further work is required to investigate this hypothesis. Additionally, it is understood that a range of barriers exist to community-based PA engagement including cost, logistics and time to the individual (Higgerson et al., 2018). This affirms the role schools in developing MF as part of the National Curriculum, by providing structure and opportunity free of cost to the individual. Moreover, the adolescents in Study 2 reported that they rely on school and PE to help inform their PA choices through the exposure and instruction to competently take part in MF activity provided by PE teachers.

Despite Study 1 suggesting MF activity delivery in schools is effective there is still a paucity of literature to inform research direction in schools. To avoid some of the shortcomings reported regarding school-based intervention fidelity in relation to aerobic MVPA, further formative research to inform MF activity was conducted. Prior to Study 3, factors affecting MF activity implementation in schools were unclear as no formative investigation had been conducted with PE teachers. Study 3 attempted to fill this gap by conducting a survey with PE teachers. Whilst Study 3 provided some initial insight into knowledge gaps in MF activity among the participating PE teachers, further work with teacher training organisations and trainees may provide greater insight and broaden the evidence base. The findings from Study 3 were supportive of the need to develop PE teachers knowledge of MF activity and highlighted the need for further research in this area. Study 3 further suggested that PE teachers had preconceived biases related to safety concerns in the delivery of MF activity. These barriers to MF activity were further compounded by a perceived lack of policy and stakeholder support in the delivery of MF activity, leading to concerns from PE teachers

surrounding MF activity implementation fidelity. Study 3 was the first to be conducted in the UK and resulted in the delivery of Study 4.

Study 4 built upon previous online CPD research by being the first to focus on MF. To date, there is no other investigation into the development of online CPD to enhance PE teachers' knowledge of MF activity. The content of Study 4 was informed by all preceding studies presented in this thesis, each contributing novel findings to improve the current MF activity knowledge base. Study 1 provided a rationale to focus on plyometric training to enhance MF, further supported by findings from Study 3 that suggested PE teachers may have foundational knowledge of how to deliver plyometric training. However, it is acknowledged that MF activity is broader than just plyometric training and whilst the CPD covered MF activity with a further focus on plyometrics, future MF CPD may benefit from a concentrated focus on isolated modes of MF activity such as traditional, bodyweight and plyometric. This may help ensure the CPD is not overwhelming and aid retention of new information. Furthermore, whilst the online CPD was a feasible way to enhance PE teachers' knowledge in the delivery of MF activity, there were requests for face-to-face follow up. Unfortunately, this was beyond the scope of this thesis. However, MF CPD research is in its formative stages and this identifies a need to investigate the feasibility and acceptability of facilitating additional face-to-face CPD for PE teachers. Finally, Study 4 demonstrated that online MF CPD was feasible and accepted by the end users as a way of enhancing knowledge to inform practice. Future research would benefit from refining the CPD and providing options for multiple means of content representation, action and expression, and engagement to ensure the CPD is inclusive and accessible (Rao, 2021). Consideration of how to incorporate User Design for Learning (UDL) principals may improve future online CPD interventions. UDL has three principals: multiple means of engagement, multiple means of representation and multiple means of action and expression (Dalton et al., 2019; Rose & Meyer, 2002). Although Study 4 enhanced the knowledge of PE teachers, some limitations were reported by participants. Some of these limitations such as a requirement for more videos and lesson examples were reported to support the learning process. UDL may help address these limitations in future CPD design.

7.7 Reflection

From start to finish, the learning and developmental process has been challenging and provided extensive opportunities to develop professionally and personally. My knowledge base and research expertise have expanded tremendously using a range of quantitative and qualitative research methodologies. These have now carried across into my job role, particularly in supporting and supervising undergraduate student research. Furthermore,

during my research, I have had the opportunity to learn and complete a range of data collection methods including anthropometry measurements, questionnaires, accelerometry, and MF measures. The exposure I received to such a broad range of methodological processes may not be clear when reading this thesis. This is due to the thesis direction changing due to COVID-19 restrictions limiting access to schools. For example, the initial PhD plan was to work alongside teachers in the school setting and deliver a plyometric MF programme. Before the pandemic, I collected formative data including accelerometry data. The global pandemic forced a change of direction, but the skills acquired during this process were utilized in the CPD development of my thesis, during my work delivering health modules at Edge Hill University and some of the accelerometry data contributed to a joint publication with my supervisors (Fairclough et al., 2022). Whilst the pandemic restrictions may have hindered the progress of my PhD, I feel the skills acquired that did not contribute directly to this thesis will support other aspects of professional development.

Throughout my PhD, my supervisors have supported me in the development of my academic writing, which has resulted in two 1st author publications. Additionally, I have also been provided with the opportunity to present my work both in person and at virtual conferences. My supervisors continuously supported my development and I attribute my award of “best presentation” following a conference communication at Coventry University to their support. Personally, I have developed a broader understanding and empathy for the challenges children and PE teachers face when trying to conduct or deliver PA, particularly MF activity. This has led me to establish the BASES Pediatric Special Interest Group Twitter feed and podcast (which will be continued post PhD), conduct voluntary community work and establish professional links with PE teachers, networks, and local authority. The process and journey of constructing this thesis has ultimately changed my outlook across many aspects of life and I am extremely grateful for having the opportunity.

Whilst I have enjoyed the PhD process, it has not been without its hardships. Indeed, making the decision to pursue a PhD was one fraught with self-doubt and imposter syndrome. Having come from an impoverished background and a product of the care system, it is statistically and socially unusual, perhaps unacceptable for me to accomplish such an academic feat. During the last five years, I have proudly welcomed two more children into the world, faced two redundancies, lost two close friends to suicide because of PTSD, faced a diagnosis of PTSD myself and finally, navigated a global pandemic. Upon reflection, the attributes and social status I thought would put me at a disadvantage when pursuing a PhD have indeed supported me completing the process. I believe the hardships I have faced throughout my lifetime have allowed me to take the setbacks in my stride. Moreover, I have connected with adolescents and teachers during data collection on a

personal level, allowing me to produce rich data sets during the qualitative aspects of this thesis because of trust and relatedness resulting in a unique rapport.

I will admit, when embarking upon a PhD, I had misconception of what I thought I had to become during the process. Looking back and indeed forward, whatever direction that might be, I have never felt more comfortable in my own skin. My colorful background, life experience and emotional intelligence has allowed me to connect with research participants, peers and collogues irrespective of social and professional status. Whilst I understand this might sound dramatic, the PhD process has given me fresh purpose and a sense of identity I thought was lost when leaving one of the UK's most elite units following 13 years of service.

7.8 Thesis conclusion

This thesis aimed to: (1) establish the efficacy of school-based MF interventions and the varying forms in which MF activity can be delivered, (2) to explore perceptions of MF activity amongst adolescent boys to better understand the ability and acceptability of participating in MF activity, (3) investigate PE teachers' knowledge and understanding of MF activity delivery to better understand MF activity implementation fidelity in the school environment and (4) design and assess the feasibility and acceptability of a suitable intervention to enable delivery of MF activity in schools.

Overall, this thesis has demonstrated that MF activity is an effective complementary activity to traditional team sports and aerobic MVPA among adolescents in schools. Indeed, the qualitative data provided by the adolescent boys suggests that MF activity is an aspect of PA they would like to engage further with. The findings further support the need to expose adolescents to MF as a mode of PA they are likely to engage in after formal education and ensure they are adequately prepared to engage in MF activity throughout the life course. As demonstrated in this thesis, there may be a lack of knowledge among PE teachers to provide opportunities to engage in MF activity during secondary school PE. However, the lack of knowledge can be overcome through co-produced online CPD that accounts for the pedagogical needs and requirements of the PE teacher.

Section 8

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Chapter 9

Appendices

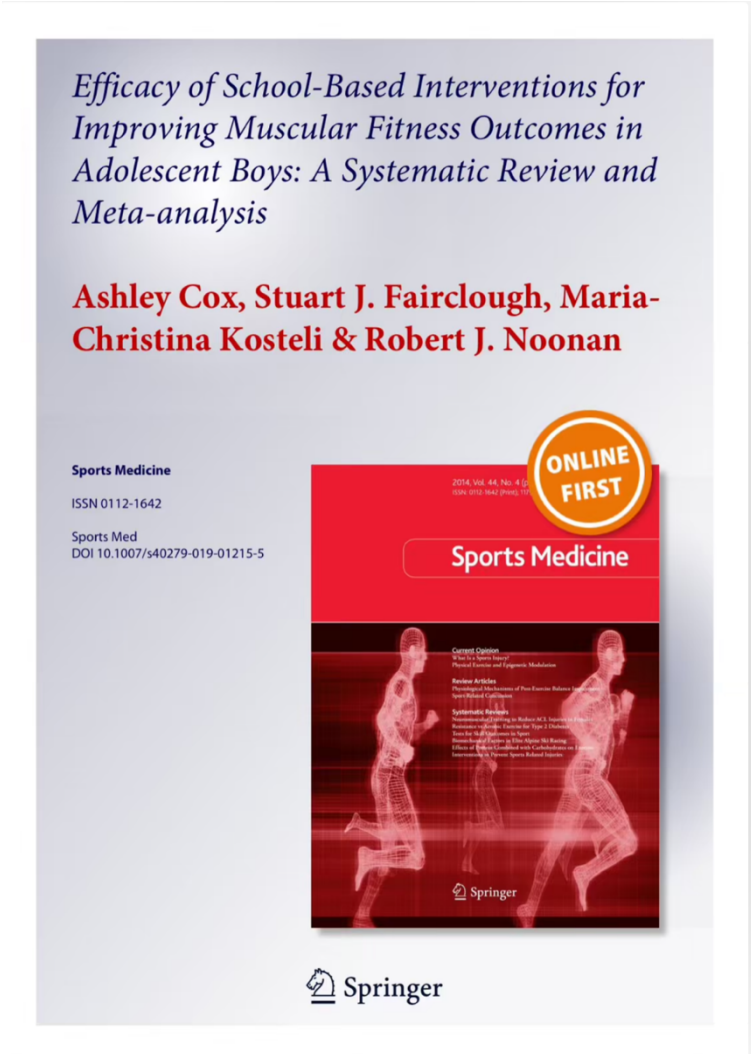


Figure A1 Study 1 publication

Figure A2 Study 2 publication

Appendix B

Study 1 Search strategy

Systematic Search

Search 1

Resistance

Term	PubMed	SPORT Discus	Web of Science	Google Scholar
Resistance Training	18,393	10,521	22,633	4,490,000
Resistance Activity	139,626	4,071	188,035	4,160,000
Resistance Exercise	26,801	11,665	30,855	2,530,000
Strength	273,912	68,777	956,191	5,700,000
Muscle Strengthening	3,109	2,075	4,060	217,000
Bone Strengthening	1,062	23	1,884	188,000
Strength Training	31,755	31,151	31,947	4,740,000

Strength Exercise	29,754	30,312	29,986	2,820,000
Weight Training	22,917	22,838	40,256	4,390,000
Weight Lifting	6,325	8,972	6,247	1,190,000
Weight Bearing Exercise	4,820	968	2,373	638,000
Bodyweight Exercise	531	301	420	30,700
Bodyweight Training	410	247	257	30,500
All Fields (OR)	283,2157	84,718	967,050	336,000

Search 2

Institution

Term	PubMed	SPORT Discus	Web of Science	Google Scholar
School	3,458,408	192,659	489,958	4,990,000
High School	615,001	44,598	153,514	5,100,00
Secondary School	284,623	12,565	40,161	4,830,000
Free School	165,474	4,635	9,007	4,040,000
Pupil Referral Unit	10	2 (n/a)	28	33,700
Grammar School	616	247	1,707	2,070,000
Comprehensive School	74,913	3,877	11,136	4,150,000
Private School	29,279	2,140	10,776	2,650,000
State School	289,910	43,269	55,211	2,820,000
All Fields (OR)	3,462,607	192,864	490,753	3,850,000

Search 3

Age

Term	PubMed	SPORT Discus	Web of Science	Google Scholar
Adolescen*	1,939,179	32,573	387,033	2,970,000
Teen*	27,758	36,867	35,812	1,220,000
Puberty	37,120	2,021	26,936	735,000
Pubescent	1,903,269	174	1,402	90,100
Youth	1,923,384	28,190	125,165	3,350,000
Children	2,269,186	103,373	1,395,651	4,380,000

All Fields (OR)	3,282,399	153,670	1,679,889	2,970,000

Adjust all further searches for date (2010) as per the initiation of the latest PA guidelines from the WHO

Search 4

1 AND 2

Term	PubMed	SPORT Discus	Web of Science	Google Scholar
Search 1 & 3	34,607	7,369	5,774	1,770,000

Search 5

1 AND 3

Term	PubMed	SPORT Discus	Web of Science	Google Scholar
Search 2 & 3	62,984	30,762	18,147	1,432,000

Search 6

1 AND 2 AND 3

Term	PubMed	SPORT Discus	Web of Science	Google Scholar
Search 1 & 3 & 4	4,453	1,239	3,214	3,657,000

Adjust for English Language Only

Final search (7) for *activities that are strength based*

("Resistance Training" OR "Resistance Activity" OR "Resistance Exercise" OR Strength OR "Muscle Strengthening" OR "Bone Strengthening" OR "Strength Training" OR "Strength Exercise" OR "Weight Training" OR "Weight Lifting" OR "Weight Bearing Exercise" OR "Bodyweight Exercise" OR "Bodyweight Training") AND (School OR "High School" OR "Secondary School" OR "Free School" OR "Pupil Referral Unit" OR "Grammar

School" OR "Comprehensive School" OR "Private School" OR "State School") AND (Adolescen* OR Teen* OR Puberty OR Pubescent OR Youth OR Children)

Term	PubMed	SPORT Discus	Web of Science	Google Scholar
As above	4,392	1,168	3,045	500*

*First 500 results from Google Scholar were used as per the guidance of Haddaway et al (2015).

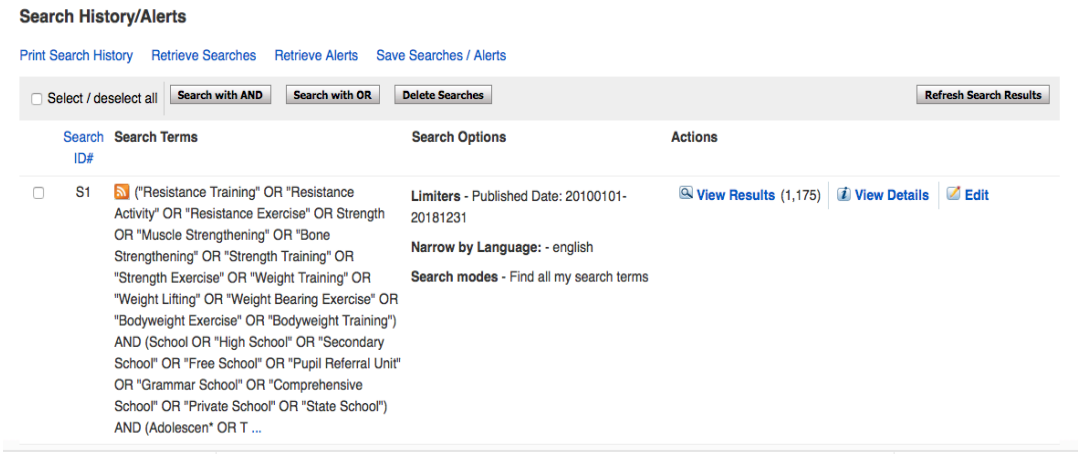
Haddaway, N. R., Collins, A. M., Coughlin, D., & Kirk, S. (2015). The Role of Google Scholar in Evidence Reviews and Its Applicability to Grey Literature Searching. *PLoS ONE*, *10*(9), e0138237. http://doi.org/10.1371/journal.pone.0138237

As per the PRISMA guidelines a link has been provided to one search conducted via SPORTDiscus:

http://edgehill.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=s3h&bquery=(%26quot%3bResistance+Training%26quot%3b+OR+%26quot%3bResistance+Activity%26quot%3b+OR+%26quot%3bResistance+Exercise%26quot%3b+OR+Strength+OR+%26quot%3bMuscle+Strengthening%26quot%3b+OR+%26quot%3bBone+Strengthening%26quot%3b+OR+%26quot%3bStrength+Training%26quot%3b+OR+%26quot%3bStrength+Exercise%26quot%3b+OR+%26quot%3bWeight+Training%26quot%3b+OR+%26quot%3bWeight+Lifting%26quot%3b+OR+%26quot%3bWeight+Bearing+Exercise%26quot%3b+OR+%26quot%3bBodyweight+Exercise%26quot%3b+OR+%26quot%3bBodyweight+Training%26quot%3b)+AND+(School+OR+%26quot%3bHigh+School%26quot%3b+OR+%26quot%3bSecondary+School%26quot%3b+OR+%26quot%3bFree+School%26quot%3b+OR+%26quot%3bPupil+Referral+Unit%26quot%3b+OR+%26quot%3bGrammar+School%26quot%3b+OR+%26quot%3bComprehensive+School%26quot%3b+OR+%26quot%3bPrivate+School%26quot%3b+OR+%26quot%3bState+School%26quot%3b)+AND+(Adolescen*+OR+Teen*+OR+Puberty+OR+Pubescent+OR+Youth+OR+Children)&cli0=DT1&clv0=201001-201812&type=1&site=ehost-live&scope=site

Search ID#	Search Terms	Search Options	Actions
S6	S1 AND S3 AND S4	**Search modes** - Find all my search terms	View Results (2,169)
S5	S1 AND S2 AND S4	**Search modes** - Find all my search terms	View Results (2,565)
S4	Adolescen* OR Teen* OR Puberty OR Pubescent OR Youth OR Children	**Search modes** - Find all my search terms	View Results (153,617)
S3	School OR "High School" OR "Secondary School" OR "Free School" OR "Pupil Referral Unit" OR "Grammar School" OR "Comprehensive School" OR "Private School" OR "State School"	**Search modes** - Find all my search terms	View Results (192,711)
S2	School OR College OR "High School" OR "Secondary School" OR "Free School" OR "Pupil Referral Unit" OR "Grammar School" OR "Comprehensive School" OR "Private School" OR "State School"	**Search modes** - Find all my search terms	View Results (323,399)
S1	"Resistance Training" OR "Resistance Activity" OR "Resistance Exercise" OR Strength OR "Muscle Strengthening" OR "Bone Strengthening" OR "Strength Training" OR "Strength Exercise" OR "Weight Training" OR "Weight Lifting" OR "Weight Bearing Exercise" OR "Bodyweight Exercise" OR "Bodyweight Training"	**Search modes** - Find all my search terms	View Results (84,692)

Limiters Applied



Sense Check Search

Relevant systematic review is sense checked to verify any key literature missing from search. Reference lists from the below reviews were cross-referenced. No additional literature added to covidence.

Collins, H., Fawkner, S., Booth, J. N., & Duncan, A. (2018). The effect of resistance training interventions on weight status in youth: a meta-analysis. https://doi.org/10.1186/s40798-018-0154-z

Appendix C

Study 3 Survey

Edge Hill University

Muscular Fitness Activity Delivery During Physical Education In The UK: A Teachers Perspect

Welcome to the PE Teacher EmPOWERment (PETE) survey

Hello, my name is Ash Cox and I am a PhD candidate at Edge Hill University. I am currently investigating adolescent muscular fitness and would like to understand your perceptions on muscular fitness delivery in a school environment.

This current survey is specific to those working within secondary school education. The survey will last approximately 10 minutes and will support research regarding the design and implementation of muscular fitness activity in a school setting.

Your support is very much appreciated and by completing this survey, you may contribute to the healthy development of future generations. If you would be interested in participating in some further research to enhance your professional development specific to understanding adolescent muscular fitness, then please provide your details at the end of this survey.

Please read the participant information sheet. You may download a copy for your records. Download participant information by clicking this link. Once you have read and understood the participant information a series of questions will be asked to gain your informed consent to continue.

* 1. I consent to participate in this survey and have read the participant information

- [ ] Yes
- [ ] No

* 2. I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

- ( ) Yes
- ( ) No

* 3. I understand that my participation in the study is voluntary and I am free to withdraw at any time, without giving a reason and that this will not affect me in any way.

- ( ) Yes
- ( ) No

1

Edge Hill University

Muscular Fitness Activity Delivery During Physical Education In The UK: A Teachers Perspect

PE Teacher EmPOWERment (PETE) survey

4. Where is your school located?

- Cymru Wales
- East of England
- North East and Cumbria
- East Midlands
- London
- North West
- Northern Ireland
- Scotland
- South East
- South West
- West Midlands
- Yorkshire and The Humber

5. Are you male or female?

- Male
- Female

6. Including yourself, how many full-time physical education teachers are at your school?

- I am the only PE teacher
- 1
- 2
- 3
- 4+

7. How many years have you been teaching physical education at any school?

- 1-4 years
- 5-9 years
- 10-14 years
- 15-19 years
- 20 years or more

8. How many times a week do students at your school conduct physical education?

- 1
- 2
- 3
- More than 3
- 0

9. Are key stage 3 and key stage 4 allocated the same time for physical education? If not, what are the differences?

- ◯ Yes
- ◯ No

Please provide further information on differences.

10. Below is an overview of the current physical activity guidelines.

Physical activity guidelines for Children and Young People

* Children and young people should engage in MVPA for an average of at least 60 minutes per day across the week.

* Children and young people should engage in a variety of types and intensities of physical activity across the week to develop movement skills, muscular fitness, and bone strength.

* Children and young people should aim to minimise the amount of time spent being sedentary, and when physically possible should break up long periods of not moving with at least light physical activity.

To what degree do you plan physical education to align with the current physical activity guidelines?

- ☐ All of the time
- ☐ Most of the time
- ☐ Rarely
- ☐ Not sure how to

11. Do you feel physical education is a valued element of the school curriculum by your colleagues?

- ◯ Yes
- ◯ No

12. Do you feel as though activity to enhance muscular fitness is an important element of physical education?

- ◯ Yes
- ◯ No

13. Please choose a statement that aligns best with your ability to conduct the following

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I am confident in assessing aerobic fitness	○	○	○	○	○
I am confident in assessing muscular fitness	○	○	○	○	○
I am confident in assessing growth and maturation	○	○	○	○	○
I am confident in the delivery of team sport activities	○	○	○	○	○

14. Please choose the statement that aligns best with your belief

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Activity to develop muscular fitness is just as important as aerobic moderate to vigorous activity	○	○	○	○	○
Aerobic moderate to vigorous activity is more important than activity to develop muscular fitness	○	○	○	○	○
Muscular fitness activity is more important than aerobic moderate to vigorous activity	○	○	○	○	○

15. Below are some statements regarding muscular fitness activity in children and adolescents. How well do those statements align with your opinion?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Development of muscular fitness is injury preventive	○	○	○	○	○
Muscular fitness activity can damage bone and growth plates	○	○	○	○	○
Muscular fitness is important for health	○	○	○	○	○

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Muscular fitness activity can help build self esteem	◯	◯	◯	◯	◯
Muscular fitness activity is dangerous during adolescence	◯	◯	◯	◯	◯
Muscular fitness activity should feature more in the curriculum	◯	◯	◯	◯	◯
I have the skills and knowledge to safely and appropriately deliver muscular fitness activity	◯	◯	◯	◯	◯
Good muscular fitness can help reduce the likelihood of developing non-communicable disease such as type 2 diabetes	◯	◯	◯	◯	◯
Muscular fitness activity can help develop motor control and movement competence	◯	◯	◯	◯	◯
I have the necessary equipment to deliver muscular fitness activity in school	◯	◯	◯	◯	◯
My knowledge surrounding muscular fitness would benefit from development	◯	◯	◯	◯	◯

Other (please specify)

16. Was muscular fitness activity conducted in the previous school term?

◯ Yes

◯ No

17. Are you planning to deliver muscular fitness activity in the next school term?

◯ Yes

◯ No

5

18. What kind of equipment or movements do you use in your physical education lessons to develop muscular fitness? Enter all that apply.

- [ ] Exercises with machines
- [ ] Exercises with free weights, e.g. barbells, dumbbells and kettlebells
- [ ] Exercises with other kinds of equipments producing resistance, e.g. rubber bands and medicine balls
- [ ] Exercises using the body weight as resistance, e.g. climbing exercises, push-ups and sit-ups Different kinds of jump exercises
- [ ] We don't conduct any sort of activity to develop muscular fitness

Other (please specify)

19. Have you ever assessed muscular fitness in school? Assessments could include handgrip strength, vertical jump height or press up ability, please provide any details of assessments carried out.

- ○ Yes
- ○ No

Assessments of muscular fitness carried out by me include:

20. Have assessments of muscular fitness ever guided your decision making processes (eg, this student requires more lower limb power development)?

- ○ Yes
- ○ No
- ○ I don't currently conduct any muscular fitness assessments.

21. Have you participated in any professional development education specific to muscular fitness activity for children and adolescents?

- ○ Yes
- ○ No
- ○ I am not sure/ I don't remember

22. Do you feel that being provided with some form of education to deliver muscular fitness activity during physical education would be beneficial?

- ○ Yes
- ○ No

23. Please provide any further comments regarding muscular fitness delivery in secondary physical education.

6

24. If you would like to participate in some free online professional development in adolescent muscular fitness, then please provide your contact details below. Further details are in your Participant Information Sheet.

Name

School

Postal Code

Email Address

Phone Number

Appendix D

Study 4 BASES CPD points

No available tickets

This event is now fully booked.

About

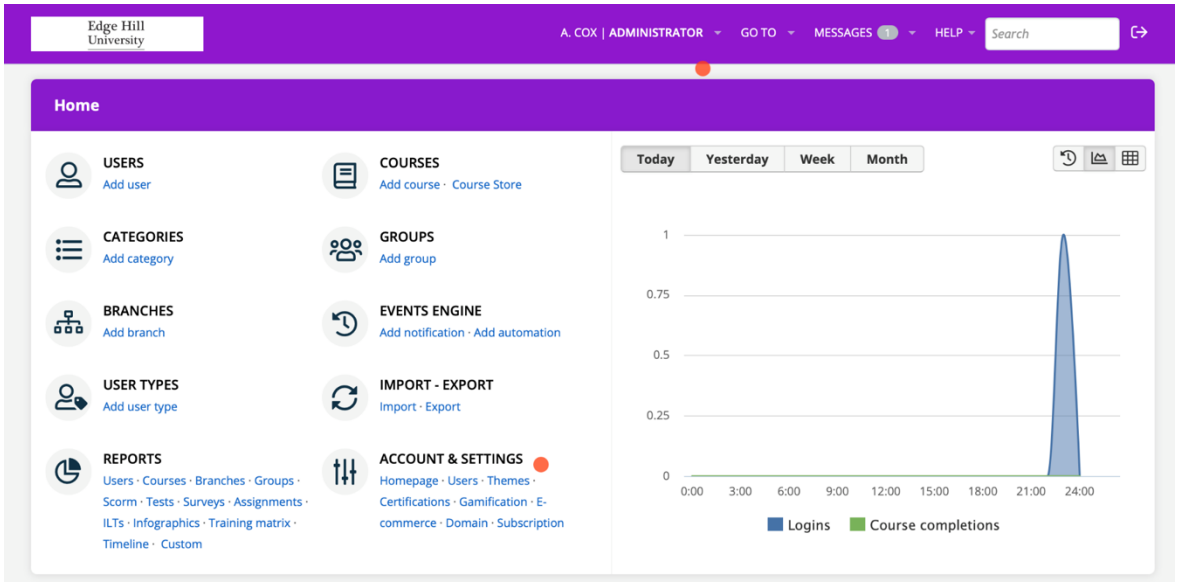
Location: Online

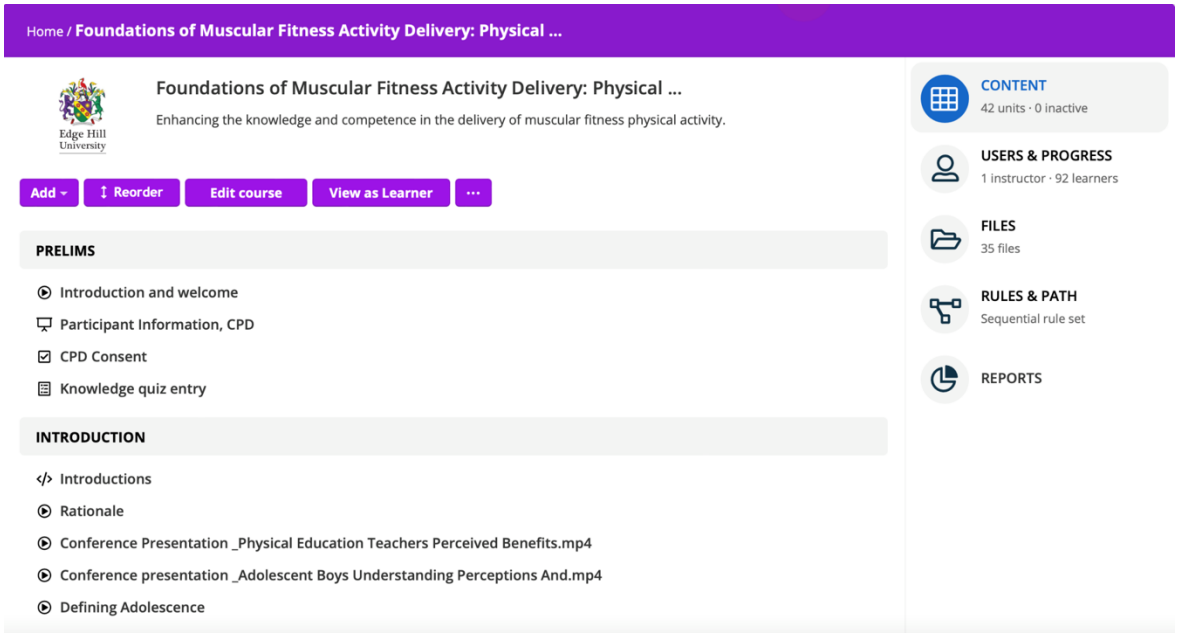
BASES Credits: 5

Booking deadline: 31st December 2021

Appendix E

Study 4 CPD platform





PHYSICAL ACTIVITY

- Physical activity
- Health Benefits of Muscular Fitness
- Discussion about muscular fitness for health
- Muscular Fitness is Associated with Future Health Benefits
- Dispelling the myths surround youth muscular fitness activity
- Youth physical activity promotion model
- Youth Physical Activity Promotion Model Recap
- Review of physical activity module

MUSCULAR FITNESS DEVELOPMENT

- Delivery of muscular fitness in schools
- Summary of muscular fitness risks and misconceptions
- Delivering resistance based exercise to develop muscular fitness
- Volume and load recap
- Review of muscular fitness module

PLYOMETRICS

- A focus on plyometrics
- Are Plyometrics Safe?
- Programming for plyometrics
- Plyometric progression model
- Plyometric activity recap
- Plyometric activity discussion

DELIVERY AND LONG TERM DEVELOPMENT

- Teacher conduct in delivering muscular fitness activity lessons
- Considerations to the delivery of muscular fitness activity
- Discussing LTAD and other models for physical development
- Physical development models: Long Term Athlete Development
- Youth Physical Development Model
- Will you make changes to your muscular fitness delivery following this unit?

MONITORING AND ASSESSMENT

- Assessing muscular fitness
- Overview of common muscular fitness measurement tools
- Getting started with assessing muscular fitness
- Will you assess muscular fitness in the future?

ROUND UP

- Farewell and round up
- Strength Training in schools
- Knowledge quiz exit
- Exit Survey