Effects of Plyometric-Based Program on Motor Performance Skills in Primary School Children Aged Seven and Eight

Andrew Sortwell

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Effects of Plyometric-Based Program on Motor Performance

Skills in Primary School Children Aged Seven and Eight

Andrew Sortwell

Supervisors: Dr Dana Perlman and Dr Michael Newton

This thesis is presented as part of the requirement for the award of the degree of Doctor of Philosophy

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University of Wollongong
School of Education

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Declaration

I, Andrew Sortwell, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Social Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Signed:

23rd August 2020
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Abstract

Over the last decade, the Australian Curriculum has focused on providing a rich and engaging quality Physical Education (PE) experience for students in primary schools. An area of debate within PE has been around the need to balance engagement in physical activity with the development of motor performance skills early in life. Motor performance skill proficiency in young children is a critical determinant of participation in games, sports and physical activity. During childhood, brain development is rapid and neuroplasticity is high, making childhood a crucial time to develop motor performance skills in children. A mode of movement that has been recently adopted by coaches to enhance motor performance skills in youth and adult athletes is plyometrics. In recent years, literature demarcates plyometric activities in children and youth to be an efficient and safe form of physical movement. However, little is known about the potential physiological and psychomotor benefits related to young children aged seven and eight years associated with a plyometric-based program. School-based physical education programs could provide a medium for children to engage in meaningful movement-based activities such as plyometrics, that have the potential to enhance neuromuscular performance (e.g. muscular power) and motor performance skills.

The purpose of this study was to examine the effects of the inclusion of plyometrics into the warm-up phase of PE practical lessons on motor performance skills. In addition, this study aimed to examine the effect of a plyometric warmup on students’ muscular power and the association between muscular power and motor performance skills.

This study involved students between the ages of seven and eight years from Year Two PE classes, which were cluster randomised into a plyometric (n= 31) or comparison group (n= 30). The eight-week plyometric-based intervention was performed twice per week as part of the
lesson warm-up. Due to the nature of this research, the study utilised a quantitative approach with a quasi-experimental design. Students’ motor performance skills proficiency, muscular power and reactive strength index were measured pre- and post-test. These tests were used to measure the dependant variables of the study in relation to the effect of plyometric warm-up.

The FMS-Polygon was used to collect data on motor performance skills. Squat jump and medicine ball chest throw were used to collect data on upper and lower body muscular power. The final measurement was a drop jump from 10cm, 20cm and 30cm boxes to collect data on reactive strength. Analysis of data was conducted using (2 x 2) (Group X Time) repeated measures of analysis of variance. For any significant effects associated with each dependent variable (i.e. motor performance skills, reactive strength index, lower and upper body muscular power), Bonferroni pairwise comparisons were used to examine between and within conditions (plyometric / comparison group) as the post-hoc assessment.

The statistical analysis indicated the plyometric group elicited significant increases across all dependent variables. A significant interaction group by time effect whereby the plyometric group had demonstrated significant improvements in motor performance skills, reactive strength index, estimated peak power, upper body muscular power, and lower body muscular power were identified. The statistical analysis also indicated that the plyometric group produced significantly greater changes in the FMS-Polygon, medicine ball chest throw, squat jump, and estimated peak power compared with the comparison group. This research highlights the potential benefits of integrating plyometrics into the early years of primary school PE as evidenced in measures of motor performance skills and muscular power. These findings may make contributions to future strategies that could be implemented within the school setting to enhance motor performance skills and adherence to a lifelong participation in physical activity.
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List of Abbreviations

ACARA: Australian Curriculum, Assessment and Reporting Authority

AHKA: Active Healthy Kids Australia

AIHW: Australian Institute of Health and Welfare

ACSM: American College of Sports Medicine

BMI: Body Mass Index

CM: Centimetres

DJ: Drop Jump

HREC: Human Research Ethics Committee

K-6: Kindergarten to Year 6

KLA: Key Learning Area

MPS: Motor Performance Skills

NESA: New South Wales Education Standards Authority

NSW: New South Wales

PA: Physical Activity

PDHPE: Personal Development, Health and Physical Education

PE: Physical Education

RQ: Research Question

RSI: Reactive Strength Index

SSC: Stretch Shortening Cycle

SCS: Sydney Catholic Schools

UOW: University of Wollongong

WHO: World Health Organization
Definitions of Key Terms

Key definitions of terms used throughout this thesis are included in this section. These definitions provide clarity about how the terms are used in this thesis and help focus the research.

**Adaptation:** Refers to the changes in physiological properties as a result of a stimulus (Radnor et al., 2018).

**Adolescence:** A period of life between childhood and adulthood (Faigenbaum, 2000).

**Childhood:** The period of life between the end of infancy and the beginning of adolescence (Faigenbaum, 2000).

**Concentric Contraction:** Shortening of muscle while under tension (Franchi, Reeves, and Narici, 2017)

**Critical Window of Opportunity:** A period of heightened plasticity during child development and accelerated growth during childhood (LeGear et al., 2012)

**Eccentric Contraction:** Lengthening of muscle while under tension (Franchi et al., 2017)

**Goal-directed Human Movement:** A voluntary movement that is performed to achieve an outcome (Hulteen, Morgan, Barnett, Stodden, and Lubans, 2018)
Growth: Refers to the measurable changes in child’s and adolescents’ body size, physique and body composition (Malina, Bar-Or, and Bouchard, 2004)

K-6: An abbreviation for the Years in school from kindergarten through to sixth grade. K-6 stands for primary school within the Australian education system.

Maturation: Qualitative changes in functional and structural, in the body’s progress from infancy to adulthood (Lloyd, Oliver, Faigenbaum, Myer, and De Ste Croix, 2014)

Motor Performance Skills: Fundamental motor activities or precursor movement patterns that underlie more complex movement activities such as sport-specific skills (Behringer, Vom Heede, Matthews, and Mester, 2011).

Neuromuscular Training: Defined as ‘training which enhances unconscious motor responses by stimulating both afferent signals and central mechanisms responsible for dynamic joint control’ (Benis, Bonato, and La Torre, 2016, p. 689).

Physical Education (PE): A mandatory component of Personal Development, Health and Physical Education in NSW schools from K-10. PE is commonly associated with educating students to instil a lifelong commitment to physical activity. PE involves an educational process that uses physical activity as a means to help students acquire skills, fitness, knowledge, and attitudes that promote optimal development and well-being (Walton-Fisette and Wuest, 2017).
Physical Education Pedagogy: Teaching and learning processes of physical literacy and physical activity which emphasises curriculum and teacher instruction (Institute of Medicine, 2013).

Physical Literacy: a new concept in physical education relating to ‘building the skills, knowledge and behaviours to lead active lives. It includes the holistic learning that gives children and young people: physical skills and fitness, the attitudes and emotions that motivate you to be active, the social skills to be active with others, the knowledge and understanding of how, why and when you move’ (Sport Australia, 2019, p. 6).

Plyometric Exercises: Type of resistance exercise that involves rapid movements preceded by an eccentric action to train the nervous system resulting in improved muscular power and stretch-shortening cycle of the muscle (Konukman, Erdogan, Yilmaz, and Gumusdag, 2018).

Primary School: Mandatory schooling for children from Kindergarten to Year Six.

Proficiency: Attainment of a higher degree of skills to perform a movement task (Jüirimäe and Jüirimäe, 2001).

Quality Physical Education: Programs focused on increasing physical capability, skill and health-related fitness, self-reliance, engaging physical activity experiences for a diverse range of students (Williams and Pill, 2019).
**Quality Teaching:** Is defined as ‘set of professional attributes and practices that influence student outcomes. Teachers make decisions ‘about their context and the actions they take bring improvements to student outcomes’ (Zammit, 2007, p. 1).

**Reactive Strength Index:** Measurement of change from eccentric to a concentric contraction (Flanagan and Comyns, 2008).

**Recent Research:** Published within the last ten years from the submission of this thesis.

**Resistance Training:** A method of physical conditioning that involves the use of a wide range of resistive loads, variety of movement velocities and training modalities such as weight machines, free weights, elastic bands and plyometrics (Faigenbaum and Myer, 2010).

**Skills Themes Approach:** Curriculum model focused on developing competence in movement skills and concepts, which emphasises learning the critical elements of a skill (Quay and Peters, 2008).

**Stage One:** Two years of work undertaken by students in Years one and two, in Australian, New South Wales (NSW) primary schools. Students in this stage typically range in age from six to eight years old.
Stretch-Shortening Cycle: The stretch-shortening cycle (SSC) is the foundation of plyometric exercises and training. SSC is a nature of muscle function in which an eccentric muscle contraction occurs immediately before a concentric contraction, producing a greater power output than an isolated concentric action (Turner and Jeffreys, 2010).

Youth: A universal term which refers to children and adolescents (Lloyd et al., 2014).
Chapter One – Introduction

1.1 Introduction

The World Health Organization (2018) recognises physical inactivity as a leading risk factor for mortality worldwide. Fewer children engage in modes of physical activity with participation in recreational physical activity declining in children (Kohl and Cook, 2013). This decrease in physical activity levels of children (de Villarreal, González-Badillo, and Izquierdo, 2008) has been associated with the trend of decreasing motor performance skills (MPS) proficiency (Bremer and Cairney, 2016; de Villarreal et al., 2008; Diallo, Dore, Duche, and Van Praagh, 2001; Hollis et al., 2016). Consequently, poor motor performance skills can result in a downward cycle of physical inactivity and/or limited engagement in physical activity (Aaltonen et al., 2015; Diallo et al., 2001).

Quality physical education (PE) supports children to develop adequate motor performance skills proficiency and behaviour patterns that can support lifelong participation in physical activity (World Health Organization, 2015). The attainment of motor performance skills leads to functional movement patterns critical for adequate participation in structured and unstructured physical activities for children and adolescents (Fisher et al., 2005; Gallahue and Ozmun, 2006). Motor performance skills are a fundamental component of movement skills that also underlie more complex motor activities such as sport-specific skills (Behringer et al., 2011). Motor performance skills include motor activities such as: jumping; running; skipping; hopping; kicking; throwing; balancing skills. These skills form the basis of many movements or physical activities that children and adults may engage in. For example, a layup in basketball involves the following sequence of a variety of motor activities:
- catching the ball;
- dribbling;
- raising the hand with the ball;
- effectively jumping off one foot;
- then extending the arm and releasing the ball.

The development of these skills traditionally occurs during childhood and then later is refined into contexts such as refined in game and sport skills contexts (Adolph and Franchak, 2017; Clark and Metcalfe, 2002; O’Brien, Belton, and Issartel, 2016; Stodden et al., 2008). Mastery of motor performance skills is also increasingly recognised as an important factor contributing to a child’s foundation for an active lifestyle, social, cognitive, emotional and physical development (Barnett, van Beurden, Morgan, Brooks, and Beard, 2009; Clark and Metcalfe, 2002; Lloyd, Saunders, Bremer, and Tremblay, 2014). Hence, PE is a key learning area that could influence children’s abilities associated with motor performance and engagement in physical activity.

Development of motor performance skills is fundamental to improving physical literacy in primary school K-6 PE (Lisa et al., 2016; Tompsett, Burkett, and McKean, 2014). It is important to note that the concept of physical literacy is becoming a big picture concept within the area of PE and motor performance (Young, O’Connor, and Alfrey, 2019). In Australia, the concept physical literacy is defined as ‘building the skills, knowledge and behaviours to lead active lives and includes the holistic learning that gives children and young people: physical skills and fitness, the attitudes and emotions that motivate you to be active, the social skills to be active with others, the knowledge and understanding of how, why and when you move’ (Sport Australia, 2019, p. 6). The recently updated primary NSW PDHPE Syllabus includes an explicit
focus on the value of physical literacy in developing the movement skills and concepts of students, in enabling participation in physical activities with confidence and competence (NESA, 2018).

Developments in the area of childhood physical literacy have also highlighted the importance of enhancing motor competence and related elements of physical literacy such as: self-confidence; providing children with the opportunity to develop physical fitness; and participating in a range of movement activities and games (Stodden, Langendorfer, and Roberton, 2009; Stodden et al., 2008). There is an increasing concern that without developing efficient motor performance skills, the body will be less likely to experience the required level of physical activity to optimally enhance elements of physical literacy (Active Healthy Kids Active Healthy Kids Australia, 2018; Beunen, 1989; Malina, 1973). In addition, previous research indicates that children with poor motor performance skills tend to be at risk of: poor neuromuscular function (Faigenbaum et al., 2014; Flanagan and Comyns, 2008; Flanagan, Ebben, and Jensen, 2008); lower physical fitness (Haga, 2009; Lloyd et al., 2014); reduced levels of physical activity (Lloyd et al., 2014; Wrotniak, Epstein, Dorn, Jones, and Kondilis, 2006); and are at higher risk of obesity (Bremer and Cairney, 2016; Cliff et al., 2012).

Given the impact of motor performance skill proficiency on engagement in physical activity and its associated benefits, there are potential implications for the PE curriculum. In Australia, the National Health and Physical Education Curriculum reinforced the importance of ensuring that children develop motor performance skills and engage in physical activity (Australian Curriculum Assessment and Reporting Authority, 2016). In addition, Australian schools provide all children with PE instruction from the start of primary school, which is continued through high school. In general, it is appropriate to consider that in Australia, PE
Curriculum is the primary vehicle driving the delivery of physical instruction and enhancement of motor performance skills.

Currently, the PE curriculum is designed to enhance movement skills resulting in improved MPS proficiency in primary school children (Dudley, Okely, Pearson, and Cotton, 2011). A meta-analysis of PE to effectively target motor performance skills, physical activity and enjoyment of physical activity by Dudley et al., (2011), supports the notion that the PE curriculum does focus on motor performance skill development and may positively influence skill development. In Australia, PE is a Key Learning Area (KLA) that provides an opportunity to develop children's ability to engage in a lifetime of movement (Barnett et al., 2016). As such, within the PE context, it is critical to examine innovative techniques and strategies that can better facilitate improved motor performance skills, which may also increase engagement in physical activity. An innovative strategy that has demonstrated some initial promise in achieving these outcomes is plyometrics (Konukman et al., 2018; Peitz, Behringer, and Granacher, 2018).

Plyometric training has been researched primarily within the exercise science field. It has been acknowledged as a safe and efficient method for youth to enhance neuromuscular function and develop specific motor abilities (Kohl and Cook, 2013; Lloyd, Radnor, De Ste Croix, Cronin, and Oliver, 2015; Michailidis et al., 2013; Ramirez-Campillo et al., 2013). Children have a higher degree of neuromuscular plasticity (Patterson and Caulfield, 2010), hence, more significant adaptations to sustained stimuli and enhanced development of motor performance skills may be achieved (Lloyd and Oliver, 2012; Okely, Booth, and Patterson, 2001; Pappa, Evaggelinou, and Karabourniotis, 2005).
Plyometrics is a form of exercise intended to link speed of movement to strength and to produce explosive strength which is commonly known as muscular power (Booth and Orr, 2016). Plyometric movements involve a rapid, explosive movement using an eccentric contraction followed immediately by an explosive concentric contraction, also referred to as the stretch-shortening cycle (Booth and Orr, 2016). Traditionally, plyometrics have been used to increase muscular power and speed of athletes involved in a variety of sports such as weightlifting, football, volleyball and athletics (Booth and Orr, 2016). Recently, this form of exercise has been used to improve motor performance skills of volleyball, basketball and soccer players while reducing the time engaged in sport-specific skill development within training (Cherni et al., 2019; Gjinovci, Idrizovic, Uljevic, and Sekulic, 2017; Meylan and Malatesta, 2009). More importantly, meta-analytic studies have suggested that plyometric exercise could enhance motor performance skills, although there is a need for research in children (Behringer et al., 2011; Harries, Lubans, and Callister, 2012; Johnson, Salzberg, and Stevenson, 2011; McKay and Henschke, 2012; Viru et al., 1998). The research to date on plyometric training and children has mostly been restricted to improving aspects of fitness or a limited range of sports skills. Furthermore, research within the primary school setting has tended to focus on improving aspects of fitness via the addition of plyometric training to the daily school programme, rather than incorporated into the physical education lesson. Currently, no research into the effect on motor performance skills has been conducted in the seven- and eight-year age group within the primary school PE setting. The seven and eight year old age group was identified as the most appropriate, since the PDHPE curriculum objectives suggest that this age group should attain motor performance skills proficiency by the end of Stage One of learning (NESA, 2018).
Recent meta-analytic studies have indicated that plyometric exercises in childhood may provide significant neuromuscular benefits (James, Montgomery, and Young 2002; McKay and Henschke, 2012). An enhanced neuromuscular function is important as it has been closely linked with motor performance skills (Diallo et al., 2001; Graf et al., 2004; Kotzamanidis, 2006; Lloyd et al., 2014; Robinson, Wadsworth, and Peoples, 2012; Saez-Saez de Villarreal, Requena, and Newton, 2010; Young, James, and Montgomery, 2002). By enriching motor performance skills in seven and eight-year-olds, they are more likely to develop higher levels of physical fitness, experience a reduction in neuromuscular deficits, and a higher chance of improving levels of motor competence (Hands, 2008; Lloyd and Oliver, 2012; Rink and Hall, 2008). Participation in plyometric activities could conceivably be an appropriate strategy and intervention for improving motor performance skills, which forms the basis of performing and learning various sports, physical activities, and movement skills commonly used each day.

There appears to be a limited number of primary school-based interventions focussed on seven and eight-year-old children to accelerate motor performance skill development (Lai et al., 2013). Plyometric exercise can theoretically improve a child’s jumping ability, muscular power production, speed of movement, and running speed. However, it is unclear whether a plyometric exercise-based program can be an effective way to improve motor performance skills in students who are seven to eight years of age. Furthermore, research is also necessary to determine whether seven and eight-year-old children in the school setting can participate in and improve their motor performance skills from engaging in plyometric activities over eight weeks. Current research has not yet examined frequent and regular participation in a 10 to 15 minute plyometric circuit as a PE strategy to specifically improve motor skills for children. Therefore, this primary school-based study was designed to address these aspects not yet seen in previous interventions.
1.2 Research Purpose

The purpose of this study was to create new knowledge and extend the understanding associated with the potential benefit of engaging children in a school-based plyometric program. Specifically, findings from this study can provide an enhanced understanding of whether plyometric based exercises can have a positive influence on student motor performance skills within the primary PE setting.

1.3 Research Questions

This research is guided by the following questions:

1. Does participation in a plyometric-based program influence the motor performance skills of students aged seven and eight years?

2. Does involvement in a plyometric-based program influence the muscular power in students aged seven and eight years?
   a. Does involvement in a plyometric-based program influence the upper body muscular power in students aged seven and eight years?
   b. Does involvement in a plyometric-based program influence the lower body muscular power in students aged seven and eight years?

3. What is the association between elements of muscular power and motor performance skills in the study participants?
1.4 Hypotheses

1. Students involved in the plyometric group will significantly increase their level of motor performance skill proficiency compared to the comparison group due to participation in the plyometric-based program.

2. Students involved in the plyometric group will significantly increase their upper body muscular power compared to the comparison group due to participation in the plyometric-based program.

3. Students involved in the plyometric group will significantly increase lower body power compared to the comparison group due to participation in the plyometric-based program.

4. Muscular power will be positively associated with motor performance skill proficiency.

1.5 Significance of the Research

The research within this thesis is significant for several reasons. Results could provide support for the infusion of plyometric training to enhance motor performance skills of seven and eight-year-old children within the PE setting. To date, there is an emerging understanding of the association between motor performance skills proficiency and development of student muscular power through the use of plyometric training.

Secondly, the present study aims to inform future practice and curriculum in PE by providing potential insight into how plyometric grounded exercises can meet the educational needs of the PE student. The research findings will add to the limited number of studies balancing the fundamental principles of paediatric exercise science with effective pedagogy in the Australian context to improve the level of motor performance skill proficiency.
One of the main objectives of PE is to enhance the learning of students (Baghurst, Tapps, and Kensinger, 2015). In the NSW PDHPE syllabus, the Stage statements encapsulate the knowledge, understanding and skills that are to be developed by students at each Stage of learning (NESA, 2018). Each Stage of learning can be focused within three domains - psychomotor, cognitive and affective (Hansen, 2008; Silverman and Mercier, 2015). It can be argued that in many New South Wales primary schools, ‘generalist’ teachers are more often concerned with students having fun in PE lessons than with the aims of the syllabus Stage statements (Lynch and Soukup, 2017; Morgan and Hansen, 2008). This is often at the expense of lesson structure, with activities conducted in a fragmented approach, often devoid of sequential development of movement activities required for enhanced movement performance and learning (Bruno and Faigenbaum, 2019; Kim, Kim, So, and Choi, 2017). Therefore, PE lessons have few longitudinal aims being associated with the syllabus objectives and may not be tailored to the children’s needs (Lucertini et al., 2013). According to Konukman et al. (2018) and Howard-Shaughnessy, Bush, and Cherry (2013), an identified instructional approach demonstrating promise in enhancing the psychomotor domain of learning and raising the quality of PE in primary schools is plyometrics.

The literature review of this thesis (see Chapter Two) suggests that forms of resistance training, such as plyometrics, are not widely used in primary school settings, despite their identified benefits (Howard-Shaughnessy et al., 2013). Advocates of plyometrics partially attribute this to myths associated with resistance training and children, such as stunted growth, and a lack of research (Faigenbaum and McFarland, 2016). This lack of research is evident in academic publications, with a relatively small number of investigations conducted regarding any type of resistance training in the primary school setting. One of the most supported benefits of
plyometrics is that they have the potential to enhance students’ sport-specific motor performance skills, yet the majority of studies supporting this claim are within a sporting environment and involving subjects 12 years and older (Booth and Orr, 2016). Furthermore, no studies have been conducted in an Australian primary school setting. Clearly, improving motor performance skills in PE, especially when plyometric training is administered, is yet to be adequately addressed.

The current study is invaluable in that it endeavours to address this topic by providing evidence from a substantial sample to determine the influence that a plyometric warmup can have on students’ motor performance skill in Australian primary schools.

The PDHPE K-6 Syllabus in New South Wales has a strong focus on students being motor performance skill proficient before applying them in games and sports contexts (NESA, 2018). For instance, one of the key points from the Stage One (e.g. students in Year 1 and 2) syllabus implies that students work towards performing motor performance skills and apply movement concepts to perform simple sequences (NESA, 2018). It can be argued that contemporary approaches to improving motor performance skills could facilitate the achievement of this and similar outcomes. This supports an impetus for investigating the effectiveness of approaches such as plyometric training which align with the educative aims of the PDHPE K-6 curriculum.

The literature review of this thesis highlights that within NSW primary schools, students’ level of motor performance skills proficiency is a concern (Hardy, Mihrshahi, Drayton, and Bauman, 2017). This concern is similar to the those raised in a recent report titled “Muscular Fitness – It’s Time For a Jump Start”, published by Active Healthy Kids Australia (Active Healthy Kids Australia, 2018), which reinforces this stance and explains that relationship of poor motor performance skill proficiency to low levels of muscular power. Furthermore, the report
argues that the inclusion of resistance training activities in PE lessons is essential to address poor motor performance skills. This assertion is supported abroad by key organisations; The British Association of Sport and Exercises Sciences (BASE), National Strength and Conditioning Association (NSCA), which have established position statements emphasising the potential positive impact of resistance training (e.g. plyometrics) on motor performance skills (Lloyd et al., 2016). However, research evidence to support the use of types of resistance training to develop motor performance skills in children aged seven and eight is not well established. In essence, the current study is further justified by the conception that it can interpose to the current body of evidence addressing this deficiency.

The noteworthiness of the present study is that research into children's’ motor performance skills and resistance training have been in isolation, and this study seeks to apply paediatric exercise science principles within PE lessons. Accordingly, the results of the current study will begin to address this gap in the research literature and postulate findings of the merits of resistance training, specifically, plyometric training within the primary PE setting. In conducting this research, it is foreseen that the results will lead to further research into similar pedagogical approaches to assist physical educators in achieving motor performance outcomes in the curriculum effectively. The significance of the current study is further reinforced by investigating how a small amount of time can be devoted to plyometrics in lessons with less time spent on movement skill instruction.

1.6 Overview of Research Design

This study utilised a quasi-experimental design involving students from pre-existing classes of Year Two students. The study aimed to determine the effect of using a plyometric
warmup (independent variable), in a primary school PE setting, on students’ motor performance skills and measures of muscular power (dependent variables). The study utilised a pre- post-test design to examine the plyometric warmup on students’ motor performance skills and measures of muscular power.

1.7 Overview of Methodology

The study involved Year Two students in two classes at one primary school in Sydney, New South Wales, Australia. Both classes received 16 lessons. The two classes of students aged between seven and eight years were recruited and randomly assigned to either the plyometric (experimental) or comparison (control) group. Randomisation was conducted at the class level. The lead researcher randomly assigned one class to the plyometric group and one class to the comparison setting before beginning the study. The treatment group consisted of 31 students (16 male, 15 female), who engaged in the plyometric activities at the start of their PE practical lesson, while the comparison group consisted of 30 students (15 male, 15 female) who attended their regular PE practical lessons. The study design and intervention are addressed in the Methodology Chapter. All lessons covered knowledge and understanding outcomes from the ‘Game and Sport’ strand and Moving Skill outcomes in the NSW PDHPE Syllabus (BOS NSW 2013).

1.8 Delimitations of the Study

- Year 2 students from a Catholic Primary School, aged seven years to eight years formed all the test population.
1.9 Limitations of the Study

- Testing of students was restricted to primary school hours to avoid minimising the number of students available for testing and thus variance amongst the subjects.
- The student’s physical activity levels and types outside the PE lesson were not controlled.
- The intervention addressed only the initial phase (eight weeks) of plyometric activities in primary school health and PE students aged seven to eight. Accordingly, the results of this research do not provide insight into long-term plyometric activity adaptations, nor may the findings apply to secondary school health and PE students.
Chapter Two – Literature Review

2.1 Introduction

Despite the well-known psychosocial and physiological benefits of participation in physical activity (Erickson et al., 2019; Prakash, Voss, Erickson, and Kramer, 2015), recent evidence consistently demonstrates that children and adolescent participation in physical activity is not optimal (Active Healthy Kids Australia, 2018; Bardid, Rudd, Lenoir, Polman, and Barnett, 2015; Guthold, Stevens, Riley, and Bull, 2020; New South Wales Audit Office, 2012; Okely and Baur, 2010). An integral element associated with the activity behaviours of children is their proficiency in motor performance skills (Barnett et al., 2009; Hume et al., 2008; Jaakkola, Yli-Piipari, Huotari, Watt, and Liukkonen, 2016; Lacourse, Turner, Randolph-Orr, Schandler, and Cohen, 2004; Robinson et al., 2012; Ungerleider, Doyon, and Karni, 2002; Wall, Xu, and Wang, 2002). ‘Motor performance skills’ is a universal term used in this thesis to reflect various terms previously used in the research literature (i.e. motor performance, fundamental movement/motor skill, and fundamental sports skills) to explain goal-directed human movement. An inadequate foundation in motor performance skills is possibly associated with a theoretical ‘proficiency barrier’ (Seefeldt, 1982), whereby low-motor performance may result in lower levels of health-enhancing physical activity and health-related fitness later in life (Stodden et al., 2009).

During childhood, motor performance skill development is an opportune time to make worthwhile improvements from appropriate training interventions (Chaouachi et al., 2014; Giblin, Collins, MacNamara, and Kiely, 2014). A relevant setting to accomplish this development is during primary school PE. PE has been identified as an ideal setting to assist children in developing their overall motor performance (e.g. running, jumping, throwing) and
physical activity behaviours (Hensch, 2005; Ito, 2004; MacNamara, Collins, and Giblin, 2015; Rosengren, Savelsbergh, and van der Kamp, 2003).

In Australia, the development of motor performance skills is an integral component of the Health and Physical Education K-6 curriculum (Australian Curriculum Assessment and Reporting Authority, 2018; NESA, 2018). Despite this, researchers have demonstrated low and decreasing levels of motor performance skill proficiency that is concomitant with the growing trends in children being overweight and obese (Cliff et al., 2012; Hardy, Barnett, Espinel, and Okely, 2013; Moliner-Urdiales et al., 2010; Ogden, Carroll, Curtin, Lamb, and Flegal, 2010; Okely and Booth, 2004; Robinson et al., 2012; Runhaar et al., 2010; Tester, Ackland, and Houghton, 2014). The decreasing physical activity levels may be due to many children missing out on adequate engagement in a variety of motor performance skill enhancing activities early in their primary school years (Barnett et al., 2016). PE programs can provide opportunities that engage students in meaningful activities that specifically enhance motor performance skills. An area of inquiry that has illustrated some promise in enhancing children’s motor performance skills is plyometric activities (Harries et al., 2012; Johnson et al., 2011).

Plyometric exercises are classified as a type of resistance training commonly used in competitive and elite sports to improve an individual’s overall performance through enhanced neuromuscular performance, muscular power, stretch-shortening cycle and rate of force production (Kubo, Kanehisa, Kawakami, and Fukanaga, 2001; Lloyd et al., 2013). Plyometric training has also been noted as a significant contributor to motor performance skills such as jumping (Hammami, Gaamouri, Suzuki, Shephard, and Chelly, 2020; Kotzamanidis, 2006; Morgan et al., 2013; Stodden, True, Langendorfer, and Gao, 2013). Meta-analytic studies have indicated that older children and adolescent participation in plyometrics training, improve
muscular power and motor performance skills in the sport setting (Behringer, Vom Heede, Yue, and Mester, 2010; Faigenbaum et al., 2009; Falk and Tenenbaum, 1996; McKay and Henschke, 2012; Payne, Morrow, Johnson, and Dalton, 1997). These benefits are due to physiological changes, such as improved stretch-shortening cycle, increased neuromuscular activation, improved rate of force development and coordination, rather than muscle hypertrophy (Guy and Micheli, 2001; Kraemer and Newton, 1994; Morgan et al., 2013; Naughton, Farpour-Lambert, Carlson, Bradney, and Van Praagh, 2000). These aforementioned physiological changes have also been associated with enhanced motor performance skill (Aagaard, Simonsen, Andersen, Magnusson, and Dyhre-Poulsen, 2002; Faigenbaum et al., 2009).

2.2 Overview of Motor Performance Skills

When reviewing motor performance skills research, it is imperative to explicitly define the features and characteristics of related terms such as, motor skills, motor performance skills, motor development, motor learning and motor abilities. The term motor development describes the transformation in movement behaviour from childhood to adulthood and the factors that lead to these changes (Clark and Whitall, 1989). More specifically, it refers to progressive, age-related biological developments whereby movement behaviour changes. Key factors affecting developmental changes in movement behaviours include experience, stage of maturation and aging.

Motor learning is a term used to describe physical adaptations that are relatively permanent as a result of practice, training and structured strategies rather than development due to maturation (Lloyd et al., 2015; Schmidt and Lee, 1988). Motor learning not only includes the mastery of new and unfamiliar skills, but also encompasses improvement, and relearning of
previously acquired motor skills (Cherni et al., 2019; Gjinovci et al., 2017; Meylan and Malatesta, 2009). Learning and skill development however, are symbiotic as the effectiveness of learning specific sport-related motor skills depends on the developmental status and the demands imposed on the biological system (Sigmundsson, Trana, Polman, and Haga, 2017).

Movement skill is defined as a structured and well-controlled series of intended body movements to achieve the desired result (Rudd et al., 2015). Movements of the body, head and limbs must be coordinated to result in the efficient performance of a movement skill effectively, such as illustrated in a forward roll. Cognitive and sensory processes influence an individual's choice of movements and how they are applied (van der Fels et al., 2015). For example, the bilateral movements and timed performances used in a dodge. Motor abilities also influence the way a person will perform and learn motor skills. The term motor ability describes the capacity of the individual to perform a variety of motor skills (Lämmle, Tittlbach, Oberger, Worth, and Bös, 2010; Magill and Anderson, 2007). For example, possessing adequate muscular power (speed-strength) to surmount an obstacle and maintain balance illustrates the concepts of using multiple movement skills to complete a task. A diverse range of critical motor abilities underlies the performance of a motor skill. In the past, motor abilities have been classified as general motor coordination (i.e. multi-limb and gross body coordination) balance, spatial orientation, strength, and power (Fleishman, Quaintance, and Broedling, 1984). More recently, motor abilities have been regarded as multidimensional, comprising of five general dimensions: flexibility; endurance; speed; strength and coordination with ten sub-dimensions (anaerobic endurance, aerobic endurance, muscular endurance, coordination under time pressure, maximum strength, action velocity, speed-strength, speed of response) (Lämmle et al., 2010). This multidimensional approach can be understood in the following example: throwing a javelin; the
individual performs specific components of that skill, for example, run-up, side steps, backswing, forward swing. The underlying motor abilities involved in the throwing of the javelin are; coordination under time pressure, multi-limb coordination, the speed of leg and arm movement, aiming and speed-strength (power).

Motor performance skills is a term used internationally in published literature. Examples such as motor skills (Barnett, Morgan, van Beurden, and Beard, 2008), fundamental movement skills (Gallahue and Ozmun, 2006), fundamental sports skills (Larsson and Quennerstedt, 2012), are used to describe movement skills that are essential for complex specific activities like sport-specialized skills that individuals may engage in (Behringer et al., 2011; Wickstrom, 1983). 'Motor performance skill proficiency' is the level of competency achieved via the learning, practice and development of core motor performance skills in combination with sufficient development of motor abilities required, such as power, speed and strength resulting in efficient and effective movement in a multitude of physical and sporting activities (Collins, Booth, Duncan, and Fawkner, 2019). These motor abilities are the building blocks for physical literacy, which if adequately adopted in childhood will possibly have a positive effect on motor performance skills proficiency later in life (Gallahue and Ozmun 2005).

Explosive power is considered an essential element for performing motor performance skills and everyday activities (Buonomano and Merzenich, 1998; Cotman and Berchtold, 2002; Cureton and Barry, 1961; Delaš, Miletić, and Miletić, 2008; Fransen et al., 2014; Kraemer et al., 2001; Rarick and Dobbins, 1975; Saez-Saez de Villarreal et al., 2010). Most motor performance skills require fast, explosive movements to be performed efficiently and effectively, for example; jumping, throwing, hopping, skipping and running. Children with adequate motor coordination, balance and muscular power are likely to accomplish complex movement skills with a high
degree of postural control and intensity (Barnett et al., 2016; Bremer and Cairney, 2016; Trecroci, Cavaggioni, Caccia, and Alberti, 2015). Even the tests of motor performance skills require some combination of power (strength and speed) and motor control. Jumping tasks require motor coordination and muscle power to project the body horizontally forward in the standing long jump or vertically in the vertical jump. Throwing tasks require motor coordination and power in propelling an object, most often in the form of a ball thrown for distance. Dashes or sprints are a test of running speed that requires power and coordination to move the body as rapidly as possible. Shuttle runs are used as an indicator of agility, which is the ability to alter the direction when moving rapidly. More recently, muscular power has been identified as being the most integrated physical quality in learning motor performance skills for seven and eight-year-olds and is highly correlated with motor performance in children (Delaš et al., 2008). Therefore, muscular power is a crucial motor quality associated with the efficient and effective execution of motor performance skills.

In education, some professionals perceive that a natural predisposition of children to move and be playful will then involuntarily translate toward the achievement of motor development and motor skills (Stodden et al., 2008). Based on this assumption, children will naturally develop proficiency in motor performance skills and the importance of specific skill learning, practice and stimuli to obtain proficiency may be ignored. In reality, appropriate learning, practice, instruction, encouragement and sufficient development of motor abilities such as power, speed and strength, are necessary to develop proficiency (Lubans, Morgan, Cliff, Barnett, and Okely, 2010). Furthermore, a child may require an environment that provides a quality learning environment with adequate opportunities to participate in physical activities with a purpose that develops and improves motor performance skills.
2.3 Overview of the Development of Motor Performance Skills in Childhood

Motor performance skills are the foundation for the development of sport-specific movements and skills, representing the building blocks for partaking in physical activity and sport (Kirk and Rhodes, 2011). In the same vein, children should be better equipped with motor performance skills as they advance through primary and junior high school. Moreover, motor performance skills are required for participation in physical activities such as sports and movement (Clark and Metcalfe, 2002; Stodden et al., 2008).

Traditionally, motor performance skills can be composed of space covering (rolling, looping, crawling, walking and running), surmounting obstacles (moving through a limited space, climbing over, landing and jumping of vertical, diagonal and horizontal obstacles), resistance overcoming (pushing, pulling, holding and carrying) and object control (throwing and catching, targeting and shooting) (Mrakovic, Metikos, and Findak, 1993). Lack of motor movement skill proficiency might be a significant barrier to physical activity participation (De Meester et al., 2018). Stodden et al. (2008, p. 291) proposed that ‘if children cannot proficiently run, jump, catch, throw, then they will have limited opportunities for engagement in physical activities later in their lives because they will not have the prerequisite skills to be active’. Therefore, motor performance skill level of proficiency is critical in the continuum of skill development (van der Fels et al., 2015).

In developmental biology, childhood is a crucial period for the early improvement of motor performance skills. During childhood, age-related sensitive ‘periods’ or ‘time windows’ exist which offer biological opportunities for significant and heightened corticomotor plasticity (Buonomano and Merzenich, 1998; Cotman and Berchtold, 2002; Roig, Ritterband-Rosenbaum, Lundbye-Jensen, and Nielsen, 2014). During the sensitive periods in early
childhood, the neural representation of the learning experiences are formed and then followed by consolidation (e.g. the formation of long-term memories and automatic motor responses) (Hensch, 2005).

Since children have rapidly developing brains and heightened neural plasticity, they possibly will have a greater capability to be trained and learn skills than youth who are more developed (Hensch, 2005). Based on motor skill learning, pre-puberty may provide an “ideal” developmental stage to implement strategies which train and develop lifelong motor performance skills in children (Gallahue and Ozmun, 2006; Lubans et al., 2010). Following adolescents, corticomotor plasticity decreases into adulthood (Abellaneda-Pérez et al., 2019; Freitas et al., 2011; Rogasch, Dartnall, Cirillo, Nordstrom, and Semmler, 2009). Hence children may benefit more from motor performance skill development throughout age-sensitive periods of childhood than adolescents and more so adults (Ito, 2004).

Levels of motor performance skills proficiency achieved in childhood set a strong foundation for participation in general and organised physical activities during adolescence and in adulthood (Barnett et al., 2009; Lloyd et al., 2014). Motor performance skill development is a precondition to the learning and development of specialised sports skills preadolescence (Lubans et al., 2010). There is some evidence that motor performance skill proficiency and physical activity levels in primary school children and adolescents are correlated (Barnett et al., 2016; O’Brien, Belton, and Issartel, 2016; Raudsepp and Päll, 2006; Wrotniak et al., 2006). This view is in agreement with Lopes et al. (2010) who argued that their data supported the notion that six-year-old children with average or low levels of motor performance, recorded low levels of physical activity five years later compared with children who attained higher levels of motor performance (Lopes, Rodrigues, Maia, and Malina, 2011). This association is mirrored in the
Developmental Model of Sports Participation (DMSP) (Côté, Lidor, and Hackfort, 2009). The DMSP proposes that during childhood, children need to take part in deliberate practice, deliberate play and exercises that help the learning of motor performance skills and improve their motor abilities, rather than those sport-specific activities focusing on early specialisation (Côté et al., 2009). Hence, their development of motor performance skills is of utmost importance for short and long term participation in physical activity (Cronin and Mandich, 2005; Dauer and Pangrazi, 1989).

Traditionally, deliberate practice includes activities that are intense and emphasise the use of cognitive processes (Ericsson, Krampe, and Tesch-Roemer, 1993). These types of activities involve a process, which begins with the identification of a problem, then selection of an appropriate strategy which is then enacted, followed by feedback to evaluate the strategy (Ford, Ward, Hodges, and Williams, 2009). However, in the development of skills to increase sports participation, deliberate practice does not fully explain the improvement in motor performance skills, and therefore some flexibility is needed in the type of activities an individual requires for increased participation. For example, in addition to overall physical fitness, young children may enhance motor performance skills through activities that are categorised as deliberate play (Côté et al., 2009). Deliberate play activities can be enjoyable and goal directed, but can require adequate skill proficiency for engagement (Côté and Erickson, 2015). Recent research suggests that participation in activities which play a functional role in the development of motor performance skills can be beneficial (Cupples, O’Connor, and Cobley, 2018). However, Memmert, Baker, and Bertsch (2010) suggest that deliberate practice and play, including activities that lead to specific physiological adaptations might be needed to perform movement skill, which are necessary to engage in sport.
Specialised sports skills incorporate a single or multiple application of motor performance skills, to execute specific sports tasks. For example, the volleyball spike, NFL throw, European handball shoulder pass, soccer throw-in, are all advanced forms of throwing (Walkley et al., 1993). Therefore, failure to develop motor performance skill proficiency in childhood may encumber the development of complex movement skills such as specialised sports skills and be a barrier to participation in sport. A notable example to illustrate this is a child who can throw a ball is more likely to engage in softball, European handball, baseball, or netball in which throwing is a vital skill. In a study set out to determine the level of association between motor performance skills and physical activity levels, Barnett et al. (2009) found that: catching, throwing, and kicking proficiency in childhood, predicted time spent in physical activity and organised activities during adolescence. This study also suggested that being proficient in catching, throwing, and kicking during childhood increased the likelihood of being active during adolescence. Seefeldt (1980) called this a hypothetical "proficiency barrier," inferring children require essential movement skills to participate competently and successfully in physical activities. Gallahue and Donnelly (2003) explained that children who fail to be proficient and meet the perilous threshold of motor performance skill competence are more likely to experience failure, resulting in physical activity levels decline. Mastering motor performance skills is a prerequisite to the initial learning of sports specific activities (Cardinal, Yan, and Cardinal, 2013; Loprinzi, Davis, and Fu, 2015) with the practice of skills being crucial to the learning (Gallahue and Ozmun, 2006; Loprinzi et al., 2015). Children that don’t sufficiently develop the basic movement patterns of these skills may not be able to participate effectively in physical activities and sport-related activities (Cardinal et al., 2013; Loprinzi et al., 2015).
Most children have opportunities to participate in physical activities both within and outside the school environment (Health and Welfare, 2019). Considering all the health benefits associated with physical activity are continually being promoted at school and in the media, a lifestyle which includes regular participation in physical activity should be a primary goal. However, children who participate in physical activity are more likely to discontinue if they lack the necessary motor performance skill ability (Jess, Collins, and Burwitz 1999). This dropout may be due to the disappointment associated with not engaging successfully in specific movement tasks (De Meester et al., 2018). Fisher et al. (2005) posit that children with lower motor performance skills are more likely to be physically inactive, while those that participate in extracurricular activities will have better motor performance skills.

Children do not need to be an expert in all movement skills. However, those who are unsuccessful in attaining competency in motor performance skills are more likely to experience problems in transitioning their lack of movement skills into specific environments and engaging in games, sports and other physical activities (Barnett et al., 2009; Cliff, Okely, Smith, and McKeen, 2009; Fisher et al., 2005). Research suggests that an environment which nurtures and supports physical activity patterns to evolve during childhood via the targeted development of motor performance skills proficiency are more inclined to continue some physical activity (Jaakkola et al., 2009; Janz, Dawson, and Mahoney, 2000; Lloyd et al., 2014; Lubans et al., 2010).
2.4 Motor Performance Skills - Childhood a Critical Time for the Development of Motor Performance Skills

Throughout childhood, there are critical periods during which children have heightened sensitivity to neuromuscular development and training (Viru et al., 1998). In particular, early childhood (three to eight years) is a 'critical window of opportunity' for motor performance skill development (Gallahue and Donnelly, 2003; Stodden et al., 2008). It is during this critical period that the nervous system undergoes accelerated development and provides the ideal opportunity to develop motor performance skills and associated motor abilities (Davids and Baker, 2007; Lloyd et al., 2015; Lloyd et al., 2013; Rosengren et al., 2003). During childhood, the central nervous system matures at an increasingly faster rate, hence it is imperative to ensure students are provided with a sufficient stimulus to develop motor performance skills (Gallahue and Ozmun, 2006; Lubans et al., 2010; Morgan, Kingston, and Sproule, 2005; Morgan et al., 2013).

Following adolescence, corticomotor plasticity and the rapid ability for learning dynamic interceptive actions tends to be reduced (Hands, 2008; Myer et al., 2015; Rogasch et al., 2009; Rosengren et al., 2003; Tang et al., 2019). By inference, children may be best-offered opportunities during childhood to engage in activities which provide adequate stimuli to develop the neuromuscular system such as during PE classes.

The literature supports the notion that the development of motor performance skills proficiency in childhood has the potential to elicit a higher level of participation in physical activities. A longitudinal study of motor performance skill proficiency by Lopes et al. (2011) reported that six-year-olds with higher levels of proficiency are more likely to be engaged in higher levels of physical activity five years later in life when compared with those with low motor coordination (Kjønniksen, Anderssen, and Wold, 2009; Lopes et al., 2011). Additionally,
in a ten-year longitudinal study which included 630 adolescents, the individuals who were involved in organised sports during childhood were more physically active during adulthood than those who commenced involvement in sports at a later age (Kjønniksen et al., 2009). It is plausible that the increased motor performance skill proficiency cultivated through childhood and youth facilitated the formation of healthy behaviours and practices that continue into adulthood (Faigenbaum et al., 2011; Kjønniksen et al., 2009; Myer et al., 2011). Levels of motor performance skills proficiency achieved set a solid basis for participation in physical activity, especially in adulthood (Barnett et al., 2009; Lloyd et al., 2014). All physical activity-related settings use motor performance skills of one type or another. Hence, their development is of utmost importance during this time of life (Cronin and Mandich, 2005; Dauer and Pangrazi, 1989).

2.5 Overview of Physical Education in Developing Motor Performance Skills

In Australia, primary schools have PE lessons, together with play during class breaks and sports time, to develop motor performance skills and encourage physical activity in the school curriculum (Dudley, Cotton, Peralta, and Winslade, 2018). PE classes can offer an opportunity for students to enhance their motor performance skills (Australian Curriculum Assessment and Reporting Authority, 2016; Morgan and Hansen, 2008). Currently, motor performance skills such as the vertical jump, balance, side gallop, overarm throw, catch, kick, hop and skip are taught to primary students to provide a strong base for more sport-specific and or recreational skills (Barnett et al., 2016; Keegan, Keegan, Daley, Ordway, and Edwards, 2013; NESA, 2018). In addition, informal opportunities exist for children within the school setting to inadvertently
practise motor performance skills, for example playing activities such as soccer, handball, chasings and various ball games during class breaks.

In early years of primary school PE programs, the initial focus is on helping children attain competency in motor performance skills and movement concepts that form the foundation for later development of specialised games, sport, fitness and dance activities (NESA, 2018). This focus on primary school PE programs has also been recommended to be an ideal setting to begin the early promotion of wellbeing, health and emphasises the importance of physical activity and developing movement skills (Bailey et al., 2009). In the Australian Curriculum: Health and PE Curriculum (Australian Curriculum Assessment and Reporting Authority, 2016) Year One and Two students are provided with the opportunities that support them in broadening the range and complexity of motor performance skills. This is reflected in the diversity of movement sequences and situations (Australian Curriculum Assessment and Reporting Authority, 2015). There is an expectation that all students in primary school have opportunities to develop the following motor performance skills: catching, jogging, running, striking, kicking, throwing, leaping, jumping, hopping, dodging, galloping, skipping, and bouncing. This focus area of developing motor performance skills provides the foundation for children to be competent and confident participants in a variety of physical activities such as sports, games, dance and physical recreation. Thus, PE instruction can be the vehicle to “help students develop the knowledge, attitudes, motor skills, behavioural skills, and confidence needs to adopt and maintain physically active lifestyles” (Collins, Koplan, and Marks, 2009, p. 82).

The opportunity during childhood for the development of motor performance skills within the PE setting provides children with access to skill instruction, practice and enhancement. The primary school PE setting is considered as one of the critical settings where
children learn important generalisable motor performance skills (McKenzie and Lounsbery, 2009). Lander, Barnett, Brown, and Telford (2015), recognise the importance of motor performance skills taught through the directed instruction of teaching professionals. Two Australian publications have also endorsed the importance of motor performance skills development: Sport 2030 (Department of Health, 2018); and The Healthiest Country by 2020 (Moodie, 2008). Both of these publications make a comparable case to increase time for PE during school time so that the development of movement skills can be more efficiently promoted, in order to improve the nation’s future health.

2.5.1 Advantages of Motor Performance Skill Proficiency for Primary School Students

It is universally recognised that motor performance skills proficiency is important to primary school student’s physical literacy (Australian Government Department of Health, 2018; New South Wales Audit Office, 2012; United Nations Educational Scientific and Cultural Organization, 2015). As a result, the NSW PDHPE K-6 Syllabus (NESA, 2018) emphasises that it is the responsibility of schools’ PE program to provide students with regular and frequent opportunities for developing motor performance skills. For many children, PE provides their only consistent period of motor performance skill development and participation in physical activity, and this increases the necessity for students to receive their entitlement of quality PE within school curricula (United Nations Educational Scientific and Cultural Organization, 2015). Numerous reports from the Australian Institute of Health Welfare (2018), and the United Nations Educational Scientific and Cultural Organization (2015) list the various health benefits associated with young people being physically literate. Benefits include positive musculoskeletal
development, enhanced psychological and physical wellbeing and increased physical activity in adulthood.

Motor performance skill proficiency benefits primary aged children’s participation in physical activity and it can also be of great value to them cognitively. A systematic study and meta-analysis by Wick et al. (2017) found that several studies have reported associations between motor performance skills and student attention span and that proficiency has been considered a significant contributor to physical, social and cognitive development (Battaglia, Alesi, Tabacchi, Palma, and Bellafiore, 2019; Lubans et al., 2010; Taunton, Mulvey, and Brian, 2018). Conversely, if primary school students lack motor performance skill proficiency, it may negatively impact on their wellbeing. There is evidence to suggest that a lack of motor performance skill proficiency has a strong relationship with obesity in children aged seven and eight (Morrison et al., 2012). The report by Australian Institute of Health Welfare (2017) suggests that this can be of particular detriment to primary aged students’ participation in games and sports and their social and mental wellbeing, as well as having catastrophic long-term effects, not only on the individual but also in the broader community. These findings are supported by the estimated annual direct cost of obesity in Australia of almost nine billion dollars in 2011-2012 (Australian Institute of Health Welfare, 2017).

2.6 Physical Education Pedagogy Approach to Motor Performance Skills

Primary schools have mandatory PE lessons to develop motor performance skills and promote participation in physical activity (NESA, 2018). Within teaching, activities are used to develop each child's capacity to function efficiently and effectively, and by this, children develop adequate motor performance skills (Dudley et al., 2018). In Australia, a reduction in physical
activity levels and increase in obesity levels places greater importance on teaching in PE, as it can serve as a way to facilitate the development of students’ knowledge, understanding, values, attitudes, motor performance skills, confidence, self-management and interpersonal skills needed to adopt a physically active lifestyle (Collins et al., 2009).

In Australia, children are provided with opportunities within the primary school setting, to discover their emerging movement capabilities and learn, practise and play (NESA, 2018). During the first three years of the primary level of PE, children build the foundation for motor performance skills, useful in physical activities (NESA, 2018). Research supports that structured instruction along with feedback and relevant movement experiences in PE classes is required to generate and develop required neural pathways in the body (Gomez-Pinilla and Hillman, 2013; Thomas, Dennis, Bandettini, and Johansen-Berg, 2012). During childhood, the PE environment needs to provide structured and well-designed lessons which are underpinned by sufficient empirical validation to adequately develop motor performance skills (Carson, 2001; Dudley et al., 2011; Giblin et al., 2014; MacNamara et al., 2015).

In education, assumptions can be made that motor performance skills will emerge automatically, and that correct, efficient technique will develop as a process of adaptive play while participating in various games (Smith, 2014). Conversely, many motor performance skills require opportunities for learning, frequent practise, application and development of the required motor abilities (e.g. strength, speed, power) to increase the likelihood of successful engagement in a diverse range of physical activities including sports (Dudley, Pearson, and Cotton, 2011). Research investigations confirm that instruction-based interventions focused on the explicit teaching of motor performance skills can facilitate adequate motor performance skill proficiency in children aged four to six years (Smith, 2014). Motor performance skills are required to
execute a variety of combined and complex movement skills, for this reason, deliberate practice and planning around biological development and maturation may be necessary for the development of motor performance skill proficiency.

A contemporary strategy used in school is developing motor performance skill proficiency by engaging in games with a focus on enhancing students’ understandings of how to play games and sports (Miller, 2015). Considering that there is not enough allocated time within the school setting for PE to be dedicated to playing one specific game, it would be challenging to develop motor performance skill proficiency through games alone. Hence, the efficient use of time allocated to PE in the primary school setting is deemed to be critical (Bailey, 2006; Dudley et al., 2011; Kirk, 2005; Morgan et al., 2005). A recent meta-analysis suggests that those teachers who implement explicit teaching strategies which target motor performance skills are more effective (Dudley et al., 2011). This finding is similar to the research by Rink and Hall (2008), which affirms the need for adequate PE programs to focus on the development of motor performance skill development directly. Providing meaningful PE teaching experiences which adds value to student achievement of multiple learning goals are essential may lead to an increased value the student attributes to PE classes (Beni, Fletcher, and Ni Chróinín, 2017).

In the PE curriculum, health-related and skill-related components of fitness are a focus area (NESA, 2018). This focus area addresses the impact of physical activity on health-related and skill-related components of fitness and provides an opportunity to engage in resistance training to enhance fitness. According to Faigenbaum, Lloyd, MacDonald, and Myer (2016), the fitness components of muscular power and muscular strength need to be promoted to support motor performance skill development and to enhance skill level. Investigations have shown that muscular power which is a skill-related component of fitness is necessary for motor performance
skill proficiency (Behringer et al., 2011; Comfort, Stewart, Bloom, and Clarkson, 2014; Teeple, Lohman, Misner, Boileau, and Massey, 1975) and that children can make notable enhancements in muscular power when given appropriate physical activity interventions. Hence an emphasis on muscular power when addressing fitness components may support the development of motor performance skills.

2.6.1 Synopsis of Teaching Physical Education Using Skill Theme Approach in NSW Primary Schools

According to Kirk (2014), the teaching of movement skills, physical activities and sports in PE has been based upon providing students with a range of opportunities in games and sports, with an emphasis on students becoming proficient in motor performance skills. Traditionally, Physical Educators have pursued curriculum through utilising a pedagogical approach known as the ‘skill themes approach’ (Pill, Penney, and Swabey, 2012). This approach uses strategies involving students developing mechanical proficiency in motor performance skills and functional sports skills. These strategies are based on the premise that skills need to be crafted before they are applied in practice and during a range of physical activity contexts (Gosset, 2018). The traditional skill theme approach follows a continuous three-part process consisting of a warm-up, practise of skills or drills, and then applied within a physical activity context (Roberts and Fairclough, 2011). This approach remains a common practice for teaching the acquisition of motor performance skills and concepts to enable students to engage proficiently in a range of sports and physical activities (Richards, Ivy, Wright, and Jerris, 2019). To this end, the skill themes approach is recognised as a best-practice model for introducing students to motor
performance skills in primary school PE (Gosset, 2018; Graham, Holt/Hale, and Parker, 2012; Lund and Tannehill, 2005; Richards et al., 2019).

In NSW primary schools, the ‘skill theme approach’ is reflected in PE teaching resources which are used by primary school teachers, for example, the “Live Life Well at School” resource (Bravo, Innes-Hughes, BJ McGill, and Rissel, 2016), and the “Get skilled: Get Active” booklet (New South Wales Department of Education Training, 2000). The ‘Live Life Well’ is an initiative implemented by NSW Government Health and in conjunction with Catholic Schools NSW (CSNSW), Association of Independent Schools of NSW and the NSW Department of Education. It provides professional support for teachers to improve their confidence in teaching motor performance skills and the K-6 PDHPE curriculum. These resources are presented on the NSW Department of Education curriculum support website (New South Wales Department of Education, 2019). This approach is also supported by the new PDHPE syllabus, which is to be implemented in 2020. The new PDHPE syllabus rationale implies that teaching and learning for the acquisition of movement skills are required before engagement in games and sports (NESA, 2018).

Evidence from the 2015 NSW ‘Schools Physical Activity and Nutrition Survey’ (SPANS) suggests that there has been minimal improvement in fundamental movement skills (FMS) since the decline from 2004 to 2010 (Hardy et al., 2017; Schranz et al., 2018). This report also indicates that a high prevalence of children are achieving low-level proficiency for most motor performance skills in primary school. The NSW SPANS (Hardy et al., 2017) revealed that just one-third (36%) of Year Six female students demonstrated low levels of mastery for locomotor skills (i.e. leap, run, side gallop, vertical jump), similarly, just under half (41%) of Year Six male students demonstrated low levels of mastery for locomotor skills. The Data also revealed that
25% of female and 54% of male students in Year Six demonstrated mastery in object-control skills (i.e. catch, kick, and over-arm throw) (Schranz et al., 2018). The new PDHPE curriculum achievement bands suggest that teaching and learning opportunities provide students in Year Five and Six, opportunities to “perform specialised movement skills and sequences in a variety of contexts to meet outcomes” (NESA, 2018, p. 21). In consideration of the aforementioned achievement bands in conjunction with the low levels of proficiency indicated in the 2015 NSW SPANS Report, it can be proposed that many primary students are not reaching movement skill competency and thus arguably not achieving a key component of the PE syllabus.

It can be inferred that despite the availability of resources such as Get skilled: Get Active and Live Life Well, there is scope for improvement in movement education concepts to enhance the skills being taught to achieve proficiency in motor performance skills effectively. This inference aligns with the 2018 Active Healthy Kids Australia Report (Schranz et al., 2018), in that this lack of achievement may in part be due to neglecting the development of physical capabilities such as neuromuscular performance and muscular power. As suggested by Konukman et al. (2018), the skill theme approach can utilise movement education concepts such as plyometric training within the PE lesson to enhance the development of motor performance skills.

### 2.6.2 Level of Motor Performance Skill Proficiency of Primary School Students

The Australian Government Department of Health (2018), recommends that young people should be proficient in motor performance skills. However, despite the apparent health benefits previously mentioned, there has been a steady decline in motor performance skill proficiency among Australian children (Schranz et al., 2018).
It is a widely held belief that schools and PE are an effective medium to provide students with opportunities to develop motor performance skills (Australian Sports Commission, 2016; McKenzie and Lounsbery, 2009; McLennan and Thompson, 2015; National Heart Foundation of Australia, 2019). For this reason, it is recommended that within Kindergarten to Year Two PE lessons, students engage in activities that develop motor performance skills (Lisa et al., 2016). However, various reports and studies suggest that in primary schools, this is rarely achieved (Hardy et al., 2013). Evidence suggests that many primary school students in NSW also do not meet the recommended motor performance skills proficiency (Hardy et al., 2017). Results found in the SPANS report (Hardy et al., 2017) from a large study that examined primary aged students’ motor performance skills in NSW, less than 50% of the Year K-2 achieved proficiency. As such, it can be deduced that overall, NSW primary school students struggle to achieve recommended levels of motor performance skills proficiency, which is consistent with the findings of Hardy et al. (2013), Lisa et al. (2016), O’ Brien, Belton, and Issartel (2016), Engel, Broderick, van Doorn, Hardy, and Parmenter (2018), who reviewed several studies worldwide that examined primary school students.

The previous discussion provides evidence to support a perception that in NSW primary schools, students may not receive sufficient opportunities to develop motor performance skills and that this contributes to the overall low levels of physical activity as documented previously. This is indicative of the necessity for researchers to examine new and innovative approaches that can improve students’ motor performance skills. The 2018 Active Healthy Kids Australia report has called for further research into improving the motor performance skills of Australian children when engaged in organised activities, such as PE lessons, thus providing further impetus for the current study (Active Healthy Kids Australia, 2018).
2.7 Relationship Between Motor Performance Skills and Muscular Power

Current research shows that youth engaging in explosive strength or muscular power training improves specific motor skills (Lubans et al., 2010). This improvement is similar to that observed in older adolescents and adults, whereby a higher level of motor performance is achieved through engagement in resistance power training (Daly et al., 2015; Harries et al., 2012). Young children participating in explosive strength training may also lead to the improved proficient performance of movement skills (Zwolski, Quatman-Yates, and Paterno, 2017).

Considering that muscular power has been identified as an important motor ability related to learning motor performance skills, improvement in muscular power may improve motor performance in children (Delaš et al., 2008). Therefore, it is entirely plausible that the development of muscular power may support improved motor performance skills. However, the current literature has not given attention to the nature or direction of this potential relationship.

Maturation, and the age at which the improvement in muscular power accelerates, need to be considered in determining the potential benefits for developing muscular power in children. A meta-analysis by Viru et al. (1998) revealed the specific chronological age periods characterised by an annual acceleration in rates of aerobic endurance, explosive speed strength and strength can be used to identify critical time frames for development. For both genders aged seven and eight, speed and muscular power had heightened acceleration (Myers, Beam, and Fakhoury, 2017; Pichardo, Oliver, Harrison, Maulder, and Lloyd, 2018; Viru et al., 1998). This finding suggests that the seven to eight years age group is a sensitive and optimal period for producing desirable changes in explosive strength. By inference, the seven and eight-year-old age group provides an opportunity to utilise strategies such as plyometrics that involve explicit teaching and practice of motor performance skills while also enhancing neuromuscular power (Freitas et
Within PE programs and lessons, correctly prescribed movement activities during periods of specific development will enable students to realise and accelerate more significant neural and architectural adaptations to the neuromuscular system. Together, these transformations can facilitate the improvement of motor abilities, such as neuromuscular power in children, resulting in the enhanced performance of motor skills, such as hopping, sprinting, throwing (Rumpf, Cronin, Pinder, Oliver, and Hughes, 2012) and jumping (Lloyd et al., 2013).

2.8 Plyometric-Based Program in Physical Education for Development Motor Performance Skills

It is worth reiterating that plyometrics refers to exercises and training activities that are intended to augment neuromuscular performance (Wilson, Murphy, and Giorgi, 1996). Plyometric training conditions the body through fast, explosive physical movements, which involve an initial rapid eccentric muscle contraction, followed by an explosive concentric muscle contraction, known as the stretch-shortening cycle (SSC) (Chu, 1998). When the stretch and shortening of a muscle is performed rapidly, the force produced during the concentric muscle contraction is significantly larger than the force that would have been produced if the muscle was not initially stretched rapidly, prior to the concentric contraction (Cliff et al., 2009; Sollerhed, Apitzsch, Rastam, and Ejlertsson, 2008). For example, a jump preceded by a downward countermovement will produce a more significant jump height than a jump performed from a static squat position.

There are adaptations from participating in plyometric activities that may enhance improved motor performance skills. One adaptation is that the nervous system is trained, enhancing the stimulus-response function, leading to a quicker response to stimuli, and improved
neuromuscular related skills (Blazevich, Gill, Bronks, and Newton, 2003; Brown, Mayhew, and Boleach, 1986; Ferrer-Caja and Weiss, 2000; Jaakkola et al., 2009; Rumpf et al., 2012; Sollerhed et al., 2008). These adapted characteristics are seen when a child in the school playground is running at maximum speed to catch a ball; the child side steps an obstacle or child to avoid a collision and catches the ball safely. The speed of the muscular exertion or reactive performance of the child to side-step to avoid a collision without losing their balance or sustaining a lower joint injury, is determined by neuromuscular coordination. Consequently, the child will move most successfully and powerfully within a range of speeds that the nervous system has been trained to allow.

Motor performance skills are the foundation for the development of sport-specific skills and movement patterns (Behringer et al., 2011) and support engagement in regular physical activity (Larsen, Kristensen, Junge, Rexen, and Wedderkopp, 2015). Other than the current study being conducted within this thesis, only one published study was found that specifically investigated the effects of a plyometric-based program intervention on motor performance skills. This lone study evaluated a 12-week plyometric program for boys (mean age: 9.9 years), who were identified as being overweight/obese (Nobre et al., 2017). The objective of the study was to improve lower body gross motor skills such as hopping, jumping and balancing. The study implemented an incremental lower body plyometric training program using school facilities; however, it was not part of the PE or school curriculum. Children were randomly assigned to one of two groups: plyometric training group and control group. The intervention consisted of plyometric training twice per week on non-consecutive days and was delivered by an instructor. Nobre and colleagues (2017) reported significant effects over time for children in the plyometric group. The finding revealed that balancing and hopping resulted in small effect size ($d = 0.29$ and
lateral jump and jumping from side-to-side showed a medium effect size ($d=0.8$), and the motor quotient effect size was large for the trained plyometric group ($d=1.02$). The results revealed a significant effect size ($d = 0.80$), while the control group showed only a small effect size ($d = 0.26$). Nobre et al. (2017) suggested that improvements were related to biomechanical parameters such as rate of force development, maximal isometric voluntary force, musculotendinous stiffness, contractile and elastic musculoskeletal properties.

While the investigation by Nobre et al. (2017) appear to have some similarities to the current study and supports the notion that plyometric activities to be potentially efficacious, the study is with limitations and differences to the research of this thesis. For example, the Nobre et al. (2017) study was conducted with a specific group of obese/overweight males and only included lower body gross motor skills. Furthermore, the intervention program was conducted outside any formal educational program (e.g. not associated with PE or school curriculum outcomes).

### 2.9 Advantages of a Plyometric-Based Program in Physical Education

The nature of PE is to provide opportunities for students to adopt a lifelong, physically active lifestyle, which is central to the ‘Personal Development Health and Physical Education’ PDHPE syllabus course objectives (NESA, 2018). The acquisition of motor performance skills, expertise, and physical fitness is a prelude to a lifelong participation in physical activity (Australian Curriculum Assessment and Reporting Authority, 2018; Gallahue and Ozmun, 2006). Developing a healthy, active lifestyle involves maintaining suitable levels of health-related physical fitness and physical activity. Associated benefits of a lifelong physically active lifestyle can include the reduced incidence of chronic diseases (Blair et al., 1995; Booth, Roberts, and...
Laye, 2012; Durstine, Gordon, Wang, and Luo, 2013), and the maintenance of necessary muscular strength, power, and endurance, which are functional limitations that have led to an increase in the likelihood of dependent care within the aged population sector (Brill, Macera, Davis, Blair, and Gordon, 2000; Hardy, Reinten-Reynolds, Espinel, Zask, and Okely, 2012; Strong et al., 2005).

In PE, the teaching and learning of the motor performance skill competencies such as kicking, jumping and throwing, begins in early childhood (Pate, Pratt, Blair, and et al., 1995). This early development of motor performance competencies promotes physical activity, increased neuromuscular development, and increased fitness level (Zwolski et al., 2017). Children who attain an adequate standard of proficiency in motor performance skills and continue to become more skilful during their years at school, have a greater range of physical activities to participate in and are more likely to be successful in physical activities requiring adequate motor performance skill level as adults (Dudley et al., 2011). These children are more likely to demonstrate higher levels of health-related physical activity and skill-related physical fitness (Clark 2005). However, to acquire high levels of motor performance skill competencies, children require greater strength and power outputs (Collins et al., 2019; Lloyd and Oliver, 2012; Young, 2006).

By engaging children in plyometric games or exercises which improve the anaerobic components of fitness, there may be a higher likelihood of enhancing motor performance skills. Plyometric exercises can improve biomechanical efficiency, body control, balance, neuromuscular control, propel an object, use of the limbs to produce an effective rate of force development and production (Cronin and Hansen, 2005; Lopes et al., 2011; Lopes, Stodden, Bianchi, Maia, and Rodrigues, 2012; Riddiford-Harland, Steele, and Baur, 2006; Wearing,
Hennig, Byrne, Steele, and Hills, 2006). Additional improvements include a higher level of skill and health-related fitness (Faigenbaum et al., 2009), running (Kotzamanidis, 2006), jumping (Kotzamanidis, 2006; Marques, Tillaar, Vescovi, and Gonzalez-Badillo, 2008), agility (Chaouachi, Othman, Hammami, Drinkwater, and Behm, 2014), muscular power (Marques et al., 2008; Pereira, Costa, Santos, Figueiredo, and João, 2015), and kicking distance (Rubley, Haase, Holcomb, Girouard, and Tandy, 2011), and muscular strength (Marques et al., 2008; Pereira et al., 2015). Plyometric activities incorporated in the PE setting may enhance the teaching and learning of motor performance skills.

2.10 Contribution of the Stretch-Shortening Cycle (SSC)

As children grow, they gradually become more efficient in their movements (Mian, Thom, Ardigo, Narici, and Minetti, 2006). They also build up more effective and adapted neuromuscular coordination from birth (Clark and Phillips, 1991; Thelen, 1985) and through childhood (Laffaye, Choukou, Benguigui, and Padulo, 2016; Temfemo, Hugues, Chardon, Mandengue, and Ahmaid, 2009). An important factor in accounting for efficiency in a child's motor performance skills is the stretch-shortening cycle (SSC) (Grigore, Courteix, and Patikas, 2014; Laffaye et al., 2016). Running, skipping, throwing a ball, hopping and jumping are all examples of activities requiring SSC, and are the types of activities in which children readily engage. The function and efficiency of SSC in force production has been researched comprehensively in adults, however, not in children aged seven and eight years old (Bosco et al., 1982; Chelly and Denis, 2001; Farley and Morgenroth, 1999; Grezios, Gissis, Sotiropoulos, Nikolaidis, and Souglis, 2006).
The SSC involves a successive and swift combination of eccentric and concentric muscle contractions (Padulo, Laffaye, and Chamari, 2013), with no pause between them. It is during the eccentric phase that high forces are generated, that augment the storage of elastic energy in the muscle-tendon complex, which is subsequently available for usage during the following concentric contraction (Komi, 2000). The initial eccentric ‘stretching’ of the muscle enables the concentric phase to exert more force than if the movement were initiated solely by the concentric phase (Komi, 2000).

During multi-joint movements, the SSC enables larger forces to be produced at any given rate during the concentric phase, in comparison to isolated concentric actions (Flanagan and Comyns, 2008; Komi, 1984). The variation in performance between SSC action and a purely concentric contraction can be observed by comparing the recorded jump heights achieved from a squat jump and a countermovement jump. For example, a child who is trying to jump for greatest height will prefer to do a countermovement jump which involves squatting down rapidly and then jumping up. In this example, the quadriceps and gastrocnemius undergo an eccentric contraction while squatting down which is followed by a rapid, forceful contraction in response to the lengthening of the muscle (Bosco et al., 1982; Linnamo et al., 2000). This response is a rapid, forceful concentric contraction of the quadriceps and gastrocnemius which is a voluntary shortening, regulated by the central nervous system via α motor neurons (Lieber and Bodine-Fowler, 1993; Webb and Trentham, 2010). Greater jump height is achieved performing 'countermovement jump' (CMJ) rather than a static squat jump due to greater power produced. This increased power production is a result of increased storage and restitution of elastic energy in the series’ elastic component (Asmussen and Bonde-Petersen, 1974; Komi, 2000) and smooth
generation and transition of muscle tension by regulating muscle stiffness (Asmussen and Bonde-Petersen, 1974; Bosco et al., 1982).

2.11 Stretch-Shortening Cycle Mechanistic Adaptations to Plyometric-Based Program

While few studies within the paediatric literature have examined mechanistic adaptations resulting from plyometric training, this area has been primarily investigated within the adult population. Within the adult population, the following has been assessed and found to have favourable outcomes: muscle fibre force and contraction velocity (Malisoux, Francaux, Nielens, and Theisen, 2006); excitability of soleus muscle rapid latency stretch reflexes (Voigt et al., 1998); and muscle activation strategies (Chimera, Swanik, Swanik, and Straub, 2004). The research of Malisoux et al. (2006) utilised an eight-week training programme and achieved significant increases in maximal muscle contraction velocity and peak force in type I (19% and 18%), type IIa (15% and 29%), and type IIb/IIx (16% and 22%) muscle fibres. There were also significant concomitant increases in absolute peak power for each muscle fibre type. In addition to the mechanistic adaptations, significant improvements were also revealed for squat and countermovement jump heights after the training intervention.

There are a limited number of studies that have focused on the underlying neuromuscular adaptations (Behrens, Mau-Moeller, and Bruhn, 2014; Behrens et al., 2016; Kubo et al., 2007; Kyröläinen et al., 2005). To date, only one study has determined the impact of plyometric training on voluntary muscle activation and force production during eccentric isometric, concentric contractions (Behrens et al., 2016). Most other studies have investigated the ability to activate a muscle voluntarily after a set period of plyometric training under isometric testing conditions (Behrens et al., 2014; Kubo et al., 2007). The research of Behrens et al. (2016)
utilised a six-week training programme and achieved maximum voluntary contractions during eccentric, isometric and concentric contraction. The muscular strength improvements were primarily due to an amplified neural activation of the quadriceps, more specifically, enhanced neural drive to the muscles. Therefore, plyometric training could be used to improve neuromuscular function during static and dynamic movements. Hence jumping, throwing, sprinting, skipping, hopping, and manoeuvring benefit from plyometric training due to improvements in the stretch-shortening cycle.

The optimal duration of training exposure to attain mechanistic SSC adaptations is currently unclear and appears to be highly specific to the training population. Chimera et al. (2004) reported the effects of two plyometric sessions per week, for six weeks, on female muscle activation strategies during a drop jump test. The results of the study revealed that a plyometric programme including drop jumps, wall touches, lateral cone jumps, split squat jumps and cone hops with a 180° turn, produced significant enhancements in the activation of the adductor muscles in the legs during the preliminary phase of drop jump performance. Additionally, a substantial increase in abductor-adductor co-activation during the preparatory phase was reported. An increased co-activation of quadriceps and hamstrings during the reactive phase was also reported. The study by Chimera et al. (2004) highlights the potential effects that plyometrics may have on functional adaptations to muscle activation strategies in the adult population, however, whether children can attain similar adaptations remains unknown.

Reactive strength index (RSI) is a measure of SSC ability (Komi, 2000) and has been used to quantify plyometric or SSC performance (Ebben and Petushek, 2010; Flanagan and Comyns, 2008). Young (1995, p. 89) defines RSI as "an individual’s ability to change quickly from an eccentric to concentric contraction and can be considered as a measure of"
explosiveness”. The RSI has functional importance in fast and forceful muscle contraction (Aagaard et al., 2002; Diallo et al., 2001; Faigenbaum et al., 2007; Markovic, Mirkov, Knezevic, and Jaric, 2013). Any increase in contractile RSI is of benefit, in that it allows for an increased level of muscle force in the initial phase of muscle contraction (Aagaard et al., 2002). Changes in RSI are often attributed to neural factors such as neural drive; neural activation; motor unit recruitment and synchronization; and firing frequency (Alkjaer, Meyland, Raffalt, Lundbye-Jensen, and Simonsen, 2013; Behrens et al., 2016; Oxfeldt, Overgaard, Hvid, and Dalgas, 2019). In regards to plyometric activities, the first adaptation mechanism of skeletal muscle is neural (Arazi, Mohammadi, and Asadi, 2014; Chaouachi et al., 2014; Markovic and Mikulic, 2010).

Of critical importance for SSC is the rate of a musculotendinous stretch to plyometric exercise (Bobbert, 1990; Bobbert, Gerritsen, Litjens, and Van Soest, 1996; Harman, Rosenstein, Frykman, and Rosenstein, 1990). The SSC stimulus provided by plyometric programs improves jumping ability (Diallo et al., 2001; Ford et al., 1983), agility (Meylan and Malatesta, 2009; Thomas, French, and Hayes, 2009), throwing (Pereira et al., 2015), kicking studies (Marques, Pereira, Reis, and van den Tillaar, 2013; Michailidis et al., 2013; Rubley et al., 2011), maximal and explosive strength (Michailidis et al., 2013; Saez-Saez de Villarreal et al., 2010) and consistent sport-specific performance (Sedano, Matheu, Redondo, and Cuadrado, 2011). Therefore, plyometric activity seems to be adequate to improve motor performance skills (Kotzamanidis, 2006; Meylan and Malatesta, 2009; Michailidis et al., 2013; Saez de Villarreal, Requena, and Cronin, 2012).
2.12 The Effects of Plyometric-Based Program on Motor Performance Skill Development

Plyometric activities have been associated with an increase in positive benefits for students related to motor performance. One significant benefit is improved explosive power in children (Clutch, 1983; de Villarreal et al., 2008; Diallo et al., 2001; Fatouros et al., 2000; Lloyd et al., 2013; Matavulj, Kukolj, Ugarkovic, Tihanyi, and Jaric, 2001; Myer et al., 2011; Rink and Hall, 2008). Explosive muscular power is reliant on the capacity of the muscular system to produce a large volume of force in a brief period and to continue to produce high force output as shortening velocity rises. Explosive muscular power is considered an essential element for performing motor performance skills and everyday activities successfully. For example, throwing and lifting (Buonomano and Merzenich, 1998; Cotman and Berchtold, 2002; Cureton and Barry, 1961; Delaš et al., 2008; Fransen et al., 2014; Kraemer et al., 2001; Rarick and Dobbins, 1975; Saez-Saez de Villarreal et al., 2010).

Participation in plyometric activities can result in an increased level of muscle force in the initial phase of a motor performance skill (Behrens et al., 2016; Bogdanis et al., 2019; Chimera et al., 2004). A decrease in the time over which an individual applies force and accelerates the body can also be seen (Dobbs et al., 2019). An increase in initial force in movements is beneficial for rapid bursts of muscular power (Cronin and Hansen, 2005; Maffiuletti et al., 2016). The rapid increase in force is required when quickly changing direction or accelerating during physical activities and sports. For example, when a student involved in a game of tag evades by accelerating quickly and changing direction, the increased explosiveness improves motor performance skill efficiency (Hands, 2008; Kjønniksen et al., 2009; Lubans et al., 2010; Myer et al., 2011).
Participation in regular plyometric exercise has a plethora of positive motor performance skills outcomes for adolescents and adults. Plyometric research studies in a variety of settings have led to the following positive outcomes; significantly enhanced vertical jumping (Kawamori et al., 2006; Ziv and Lidor, 2010), improved countermovement jumps (Granacher and Gollhofer, 2012; Granacher, Muehlbauer, Doerflinger, Strohmeier, and Gollhofer, 2011; McLellan, Lovell, and Gass, 2011; West et al., 2011; Ziv and Lidor, 2010), 10m sprinting (West et al., 2011; Ziv and Lidor, 2010), throwing velocity (Marques, Saavedra, Abrantes, and Aidar, 2011; Newton and McEvoy, 1994; Watkinson, 1997) and balance (Ziv and Lidor, 2010). Therefore, enhancement of these motor performance skills may provide the level of enhanced motor competence skill which is required for participation in active games and sports.

Research has shown that plyometrics employed as training or during warm-up can significantly improve fitness test performance (Miarka, Del Vecchio, and Franchini, 2011), sprinting, slalom dribbling and kicking performance (Gelen, 2010). Dynamic warm-ups incorporating plyometrics has shown to increase motor unit synchronisation, which significantly contributes to increased muscle power explosiveness (Potteiger et al., 1999). In recent systematic reviews that examined plyometric training and motor performance skills in youth, the authors have suggested that plyometric school-based interventions could be implemented to improve motor performance skills competency in children (Behringer et al., 2011; Behringer et al., 2010; Lubans et al., 2010; McKay and Henschke, 2012; Saez-Saez de Villarreal et al., 2010). It could also be suggested that participation in plyometrics activities should occur in primary school when children are at the optimal age to master them. The combined body of knowledge around plyometrics illustrates a need to understand the application with children and in the primary school setting.
Even thou plyometric training can improve muscular power and sporting performance in athletes, it also has the potential to improve children's motor performance skills. Explosive muscular power and rate of force production are motor abilities which influence motor performance skills (Behringer et al., 2011; Cureton and Barry, 1961; Harries et al., 2012; Lämmle et al., 2010). Moreover, explosive strength is a critical element required for effective engagement and performance in a diverse range of sports (Bergeron et al., 2015; Lloyd et al., 2014). Many studies have revealed statistically significant positive effects of plyometric interventions on the motor performance skills of youth; however, no studies involved children aged seven and eight (Buchheit, Mendez-Villanueva, Delhomel, Brughelli, and Ahmaidi, 2010; Diallo et al., 2001; Kotzamanidis, 2006; Marques et al., 2013; Meylan and Malatesta, 2009; Michailidis et al., 2013; Rubley et al., 2011; Thomas et al., 2009). A number of meta-analyses of plyometric programs for youth have indicated that plyometric activities have a considerably significant positive effect on jumping and sprinting ability and associated smaller effect on strengthening muscular power (Behringer et al., 2010; James et al., 2002; Johnson et al., 2011; McKay and Henschke, 2012).

In a range of settings, plyometric training interventions have been demonstrated to improve a varied range of motor performance skills in adults, in adolescents and older children (Bedoya, Miltenberger, and Lopez, 2015). As previously noted, one of the motor performance skills which has been improved by the plyometric program has been running. Running is an important motor performance skill required to cover space quickly, playing games, and participating in physical activity or sport. Plyometric training has been shown by Kotzamanidis (2006) to improve running significantly in prepubescent male students, more specifically, the 10-20m and 20-30m sprint velocity. This positive effect of plyometrics on motor performance skills
has been supported by recent research with 10-12-year-old children (Chaouachi et al., 2014). Both studies acknowledged that the control groups had little or no improvement in running.

Recently, research by Lloyd, et al. (2015) examined the effect of plyometrics on boys (average age 12) and found significant improvements in 10m acceleration and 20m sprint following a six-week plyometric training, while the control group showed no significant changes in performance. In another study with a similar intervention period of 6 weeks (Ramirez-Campillo et al., 2015) involving young 10-15-year-old soccer players, participants experienced similar results. However, in this study by Ramirez-Campillo et al. (2015), a portion of the experimental group's soccer training session was replaced by plyometrics training, in which significant improvements were attained. The significant improvement was attained in the 15-30m sprint and multiple five bound tests, which was significantly different from the control group (Ramirez-Campillo et al., 2015). A further three studies also confirmed statistically significant improvement in running and agility measures compared to the control groups (Meylan and Malatesta, 2009; Michailidis et al., 2013; Thomas et al., 2009).

Plyometric training has also been shown to enhance motor performance skills such as jumping and hopping. These two motor performance skills can be utilised in a wide variety of games, physical activities and sports. Plyometric training has been shown by Kotzamanidis (2006), to significantly improve vertical jump performance in prepubescent male students, more specifically, the squat jump. According to Kotzamanidis (2006), the enhancement in vertical jump height could be caused by un-matured neuromuscular system and more compliant elastic tissue within them than adults.

This positive effect of plyometrics on motor performance skills has been supported by more recent research with 10-12-year-old children (Chaouachi et al., 2014). In a study involving
10-12-year-old children, plyometrics training twice weekly over 12 weeks had a significant impact on countermovement jump and horizontal jump (Chaouachi et al., 2014). More recent research by Lloyd, et al. (2015), into boys with a mean age of 12 found that following six weeks of plyometric training, there were significant improvements in squat jumping and hopping, while the control group showed no significant changes in performance. Other research by Faigenbaum et al. (2009) into eight and eleven-year-old elementary school children found that a nine-week plyometric circuit training performed twice a week, significantly improved long jump performance from baseline results compared to the control group. In another study, Faigenbaum et al. (2007) found that vertical jump height increased significantly in the 12-15-year-old male participants over six weeks of plyometric training twice weekly. Faigenbaum et al. (2007) hypothesised that the findings in vertical jump height came from the lower body plyometric exercises. According to Kotzamanidis, (2006), the enhancement in vertical jump height could be caused by the un-matured neuromuscular system and more compliant elastic tissue within them compared to adults. In the studies noted above, the control groups had little to no improvement in jumping.

Some of the research into the effects of plyometrics on jumping and hopping performance have focused on athletes within the sporting setting. Most recent studies on the impact of plyometrics have been on older children and adolescent athletes who have been soccer players, resulting in significant improvement in jumping and hopping (Bedoya et al., 2015). Research by Buchheit et al. (2010) into the effect of plyometrics on youth soccer players have also noted moderate improvements in hopping and countermovement jumps when compared to repeated shuttle sprint training. Similar results in 10-15-year-olds countermovement jump were noted. In a study by Ramirez et al. (2015), the plyometric group attained significant improvement in
performance in the countermovement jump compared to the control group (Ramirez-Campillo et al., 2015). These results have also been mirrored in volleyball players.

Research into 14-year-old adolescent volleyball players has demonstrated that eight weeks of plyometric training to enhance volleyball performance led to an increase in vertical jump height for the experimental training group (20.1%) and no significant changes in the control group (3.2%) (Pereira et al., 2015). These findings were similar to the results of Marques et al. (2008), who also found a significant improvement of 11.2% in jump height after 12 weeks of plyometrics training in female volleyball players and no significant changes in the control group. This enhanced jumping ability is significant for volleyball since jump efficiency is one of the elements used in an interception and shot-blocking (Rousanoglou, Georgiadis, and Boudolos, 2008; Thissen-Milder and Mayhew, 1991).

Throwing is an important motor performance skill required for ball sports and games. Research into a variety of different population groups has demonstrated significant improvements in throwing performance. In another study by Faigenbaum et al. (2007), researchers investigated the combined effect of plyometrics over six weeks and resistance training on adolescents within the school setting. The training group that combined plyometrics and resistance training experienced a significantly higher gain in medicine ball throwing than the group that combined resistance training and static stretching. Most of the other studies into the effect of plyometrics on throwing have been conducted in the athletic population groups.

A study by Pereira et al. (2015) involving young female volleyball players, investigated the impact of eight weeks of plyometrics and volleyball training. One of the dependent variables was the medicine ball and volleyball ball throw. The plyometric group improved in medicine ball and volleyball ball throws by increases of 5.2% and 23.3% (respectively). These increases
demonstrate the potential benefits of including plyometrics into regular training. In a study involving young handball players, Chelly, Hermassi, Aouadi, and Shephard (2014) investigated if substituting part of the regular training session with an eight-week biweekly course of plyometric training would enhance ball throwing velocity. There were significant increases for running ($p<0.001$), throwing and velocity tests compared to the control group who participated in gameplay rather than plyometrics. These results accords with findings from research which utilised plyometric intervention with adolescent athletes such as; baseball players (Carter, Kaminski, Douex, Knight, and Richards, 2007) and handball players (Chelly et al., 2014). In these studies, which involved adolescent athletes, eight weeks of plyometric training significantly increased ($p<0.05$) throwing velocity when compared with the control group who only practiced throwing. It is evident that the inclusion and sometimes substitution of part of a practice session with plyometrics can improve explosive actions, such as throwing.

In many ball games, physical activities and sports, kicking is a fundamental skill (Bacvarevic et al., 2012). Plyometrics have also been shown to enhance kicking (Bedoya et al., 2015). Several studies thus far have linked ten weeks of plyometric training to improved kicking distance and velocity in soccer players (Rubley et al., 2011; Marques et al., 2013; Michailidis et al., 2013). The improvement may be accredited to the improved muscular power of the leg muscles as determined by a strong correlation with improvement in jump performance. In an additional study of plyometrics combined with soccer training in female players, it was shown that a 12-week plyometric program significantly increased ($p<0.05$) kick speed and muscular power in female soccer players and that these increases translated to improved kicking performance (Sedano Campo et al., 2009). A similar study into young adult males studied the effects of a 10-week plyometric training program on kicking speed in young elite soccer players.
The plyometric group also demonstrated significant increases \((p<0.05)\) in kicking with both left and right leg at eight and ten weeks respectively. Both studies revealed that a 10-12 week plyometric program may be a more effective training stimulus to improve kicking compared to a more standard soccer training program (Sedano et al., 2011).

In children, motor performance skills proficiency is strongly associated with muscular power or explosive strength (Lämmle et al., 2010). Muscular power has been identified as a significant predictor of motor performance skill proficiency in children (Cureton and Barry, 1961; Fransen et al., 2014; Lämmle et al., 2010; Rarick and Dobbins, 1975). In the 1960s, research into predictors of motor performance skills proficiency identified muscular power as a strong predictor of motor performance skill in the age group seven and eight years (Cureton and Barry, 1961; Rarick and Dobbins, 1975). This research has been supported over the years by similar studies (Fransen et al., 2014; Lämmle et al., 2010), and further supported by the recent inclusion of muscular power as a capability that develops physical literacy (Keegan et al., 2019). Muscular power is strongly linked to motor performance skills, therefore improvements in muscular power may have the potential to rapidly develop motor performance skills in children ages seven to eight (Lloyd et al., 2015; Viru et al., 1998). However, there is a need to address the dearth of research on resistance training interventions, such as plyometrics on seven and eight-year-old students’ motor performance skills and muscular power within the PE setting.

2.13 Overview of Plyometric-Based Program Parameters

For seven and eight-year-old children commencing plyometric-based program, a gradual progressive approach which initially does not involve excessive eccentric loads, but does involve activities that require low technical competency with minimal intensity, is optimal (Lloyd and
Other factors such as duration, volume and intensity can influence the effectiveness of plyometric training, and numerous investigations have used a variety of combinations of duration, volume and intensity parameters (Buckley, Brinkworth, and Abbott, 2003; Fatouros et al., 2000; Herrero, Izquierdo, Maffiuletti, and Garcia-Lopez, 2006; Martel, Harmer, Logan, and Parker, 2005; Saez-Saez de Villarreal et al., 2010; Wilson, Newton, Murphy, and Humphries, 1993). The optimal combination of duration, volume and intensity for most significant enhancement remain to be elucidated. In this study, the plyometric training was performed using the following parameters:

- Duration (total number of continuous weeks), eight 8 weeks;
- Volume (total repetitions per exercise), six to ten;
- Total number of exercises per session, six to ten;
- Sets (per station), one to two;
- Frequency (sessions per week), two;
- Recovery (inter-session hours), 72;
- Rest (between sets [seconds]), 30;
- Progression and Intensity, progressive increase in intensity.

These parameters are based on the recommendations and the guidelines for the paediatric population (Behm, Faigenbaum, Falk, and Klentrou, 2008; Konukman, Jenkins, Yilmaz, and Zorba, 2008; Lloyd and Oliver, 2014), past studies (Bobbert et al., 1996; Faigenbaum et al., 2009) and systematic reviews (Johnson et al., 2011; Malina, 1994).
2.13.1 The Safety and Efficacy Plyometrics-Based Program for Children

In the past, there were concerns about children and adolescents participating in plyometric activities. These concerns have formed from general misconceptions about the safety of resistance exercise and plyometric activities (Falk and Eliakim, 2003). A common misconception was that exercise which involved strength or power development would be inappropriate and unsafe for children and lead to structural injuries (Borms, 1986). In contrast, evidence-based research consistently indicates that involvement in a planned activity program conducted by a qualified trainer is safe and effective for children and adolescents (Davids and Baker, 2007; Faigenbaum and Myer, 2010; Faigenbaum, Myer, Naclerio, and Casas, 2011; Falk and Eliakim, 2003; Malina, 2006; Miller, Cheatham, and Patel, 2010). Another misconception was that children would not benefit from activities that improve muscular power because they lack adequate quantities of testosterone for muscle hypertrophy (Docherty, Wenger, Collis, and Quinney, 1987; Vrijens, 1978). However, over the last 30 years, much more information has become available that children can benefit from activities that improve muscular power as a result of neural adaptations, greater activation of muscle fibres, not hormonal changes (Granacher et al., 2011; Myer et al., 2011; Ozmun, Mikesky, and Surburg, 1994; Ramsay et al., 1990). A study involving strength and power training for seven-year-olds has highlighted the safety and the motor performance benefits associated with increased strength and power (Davids and Baker, 2007).

A further misconception was that strength and power training would damage growth plates, resulting in stunted growth in children and adolescents (Kato and Ishiko, 1976). Power and strength training have no adverse effects on growth height, growth plates, or the aerobic fitness ability of children (Faigenbaum et al., 2009; Ramsay et al., 1990). If the child is training
with suitable equipment (beginners - one kilogram medicine ball; advanced - three kilogram medicine ball), using the correct technique (as per instruction and demonstration) and in a strictly supervised setting (instructor/ teacher is positioned to view all students), displaying mature behaviour, then the risk of injury is very low and is even safer than playing soccer (Hamill, 1994; Malina, 2006; Sewall and Micheli, 1986).

There is no current research or clinical observations to suggest that plyometric exercise is unsafe. There are some plyometric studies involving children that demonstrate plyometrics to be safe (Cappa and Behm, 2013; Faigenbaum et al., 2009; Rink and Hall, 2008). As with other similar forms of training, well designed supervised plyometric exercises enhance movement biomechanics (Cotman and Berchtold, 2002; Timothy, Gregory, and Kevin, 2005) and reduce sports injuries in children and adolescents (Thomas et al., 2009). The following guidelines can enhance biomechanics and prevent injuries:

- Ensure children follow the instructed and demonstrated techniques (Faigenbaum and Myer, 2010; Howard-Shaughnessy et al., 2013);
- Use appropriate equipment, which is free of damage and appropriate, for example, no more than a one kilogram medicine ball with beginners (Chu, Faigenbaum, and Falkel, 2006; Faigenbaum and Myer, 2010);
- Ensure the floor and exercise area is clear of any hazards (Faigenbaum and Myer, 2010; Howard-Shaughnessy et al., 2013);
- Follow recommended paediatric guidelines for plyometric training structure (Faigenbaum and Myer, 2010);
- Ensure full supervision at all times (Faigenbaum and Myer, 2010; Howard-Shaughnessy et al., 2013).
Furthermore, there is academic acceptance of children and adolescents participating in resistance exercise by numerous medical and fitness organisations (Australian Strength and Conditioning Association, 2007; Behm et al., 2008; Faigenbaum et al., 2009; Faigenbaum and Myer, 2010; McCambridge and Stricker, 2008; Mountjoy et al., 2008; Stratton et al., 2004; Thompson, Gordon, Pescatello, and American College of Sports Medicine, 2010; Turner and Jeffreys, 2010).

### 2.14 Gaps in the Body of Knowledge Related to Physical Education

Only a limited number of published studies have investigated the effect of plyometric-based programs on physical performance in children with even less housed within a PE or school setting. From these identified studies, a study by Nobre et al. (2017) specifically investigated movement skills. This study was focused on evaluating change in lower body gross motor skills of male obese/overweight children, through the use of lower body plyometric exercises only. It is important to note that the study, as mentioned above, was conducted within a school setting but was not delivered by a PE teacher or connected with the school curriculum. A second study by Faigenbaum et al. (2009) assessed the change in lower body muscular power of nine-year-old students and found similarly positive results across a range of fitness-related measures. While this chapter illustrated the potential benefit of plyometric movements for children, there are a number of gaps that this thesis hoped to shed light upon. Firstly, previous research has not investigated the influence of plyometric activities on the entire body of children (i.e. upper and lower) within a holistic education-based program. Secondly, diverse groups of participants that include both male and female are limited. Thirdly, plyometric interventions have not been associated with PE school curricular elements which may be necessary for understanding future pedagogical practices and strategies.
2.15 Chapter Summary and Further Research

This literature review provides a theoretical and conceptual foundation for conducting the current study. The low level of proficiency in Australian children indicates the need to promote motor performance skills. This is a concerning situation which has been highlighted by this review, indicating that there is a need for research on innovative teaching approaches that could address this problem of low motor proficiency skills in young people. PE provides the setting to improve the motor performance abilities and skills of children (Buonomano and Merzenich, 1998; Lämmle et al., 2010; Rarick and Dobbins, 1975). A new innovative strategy which can capitalise on the consolidation of influences which contribute to enhanced motor skill performance is of vital importance for children whose motor capabilities, and neuromuscular system are highly amenable and “plastic”. A plyometric-based program is one strategy that could provide a remedy. It is supported from this review that research is needed into the effectiveness of plyometric-based programs within the school setting and with children aged seven and eight years.

The literature also highlights plyometric-based programs possibly being appropriate for children to improve factors which may influence motor performance proficiency and requiring further investigation. These factors include neuromuscular system, stretch-shortening cycle, and both upper and lower muscular power. On this basis, a plyometric-based program may enhance the associated elements of motor performance skill in children aged seven and eight. Therefore, embedding plyometrics into the Year Two PE program may be beneficial and could provide long term benefits during childhood and possibly into adulthood.

The following chapters will describe the methodologies, data analysis, results of the study, discussion of the main findings and a recount of the implications.
Chapter Three - Methodology

In Chapter Two, a review of the published literature was undertaken to examine the focal issues, and in doing so, questions were established for this research. The intent of Chapter Three is to explain and justify the research plan applied to examine the effect of a plyometric training program on the motor performance skills of seven and eight-year-old children within a PE setting.

This chapter will detail the study’s research methodology and design beginning with ethical considerations. Next, the research questions and hypotheses are identified. This is followed by an outline of the quantitative methods used to answer these questions and test the hypotheses. The research design will then be explained, and details about the pilot study and the intervention will be provided. Next, the population and sample are defined. Then an explanation of the testing and data collection procedures are provided. The data analysis is then explained, followed by the description of the variables and the rationale of the data analysis.

3.1 Ethical Considerations and Authorisation

The ethical considerations in the current study were reinforced by the principles to protect and respect (Thomas, Silverman, and Nelson, 2015). This study involved implementing an intervention and the gathering of data, which emphasised respect for the individual (Gopichandran et al., 2016).

There was an explicit attempt throughout the research to follow ethical guidelines (Thomas et al., 2015). The research was reported honestly, and ethical practices were followed whilst maintaining the confidentiality of students.
For this research study to take place, authorisation from the University of Wollongong (UOW) Human Research Ethics Committee (HREC) and Sydney Catholic Schools (SCS) was obtained. Additional consent was obtained from the school principal, classroom teachers of the two classes, and participants and their parents/carers due to all students being under the age of consent.

3.1.1 Approval from the University of Wollongong HREC

The UOW HREC provided approval (HE13/374) for this research study prior to data collection (See Appendix 3).

3.1.2 Approval from Sydney Catholic Schools

The SCS Director of Teaching and Learning was contacted regarding participation in the study and provided with information about the proposed research (See Appendix 4). Written approval was sought to approach the Principal of the primary school and for research approval within a Sydney Catholic School. Final approval was granted for the research to commence in a Sydney Catholic School (See Appendix 5).

3.1.3 Approval from the Principal of a Selected School

On receipt of approval from SCS, the principal was contacted. Initial contact involved providing an outline of the study and related requirements (see Appendix 6). This initial contact was followed by a meeting with the principal and assistant principal to outline the school’s involvement in the study, study protocol, guarantee of confidentiality and steps to protect the student’s well-being. Permission to conduct the study within the school was also granted by the
principal. The principal then nominated the names of two teachers who volunteered their classes to participate in the study.

3.1.4 Approval From the Teachers of the Participating Classes

Subsequently, a meeting with the two Year Two teachers who volunteered for their classes to be involved in the study occurred. In the meeting held with the teachers, the research study requirements were reviewed and discussed.

3.1.5 Parents/Carers and Students’ Consent

Before students consented to participate, an information presentation was held to inform parents/carers and children of the research project, activities, and testing involved. Additionally, parents and students received an information pack which contained information outlining the project and activities involved (See Appendix 7). Due to the participation of students under the age of 18, both parental/carer and student consent were obtained in writing before the collection of data and implementation of the plyometric activities (See Appendix 8). All students and parents/carers provided consent to participate in that group’s PE classes.

3.1.6 Research Data Storage

The collected research data were stored securely and safely following University of Wollongong guidelines. All data from the phases of research were stored in password-encrypted storage media. In addition, all consent forms and hard copies of recorded data are held in a secure, locked storage security safe.
3.1.7 Confidentiality

An essential element in human research is participant confidentiality. To maintain the confidentiality of the participating students, their identities were not included within the research data and report. The schools' name and the suburb were also kept confidential.

3.2 Research Questions and Hypotheses

The primary research questions (RQ) that guided this study are as follows:

RQ1 – Does participation in a plyometric-based program influence the motor performance skills of children aged seven and eight years?

RQ2 – Does involvement in a plyometric-based program influence the muscular power in students aged seven and eight years?

a. Does involvement in a plyometric-based program influence the upper body muscular power in students aged seven and eight years?

b. Does involvement in a plyometric-based program influence the lower body muscular power in students aged seven and eight years?

RQ3 – What is the association between elements of muscular power and motor performance skills?

In order to address these research questions, the following hypotheses were tested:

Hypothesis for RQ1 – Students involved in the plyometric group will significantly increase their level of motor performance skill proficiency compared to the comparison group due to participation in the plyometric-based program.
Hypothesis for RQ2 – Students involved in the plyometric group will significantly increase their upper body muscular power compared to the comparison group due to participation in the plyometric-based program.

Hypothesis for RQ3 – Students involved in the plyometric group will significantly increase their lower body muscular power compared to the comparison group due to participation in the plyometric-based program.

Hypothesis for RQ4 – Muscular power will be positively associated with motor performance skills proficiency.

3.3 Overview of Research Design

To examine the overall research aims and questions, this thesis followed a quasi-experimental design, which was used to determine the influence of an independent variable on a dependent variable (Page, 2012). The study aimed to determine the effect of using ‘plyometric exercises’ (independent variable), in a primary school PE setting, on the dependent variables of students’ motor performance skills, and upper and lower body muscular power.

To investigate the research questions, the study utilised a two-group pre – and post-test design which is one of the conventional methods used to determine the effectiveness of specific teaching and/or training model (Page, 2012; Thomas et al., 2015). All participants in both groups were tested before and following the intervention program, as the study was intentionally focused on the effect of in-class plyometrics exercises.

This study involved 61 students enrolled across two PE classes, from one primary school in South West Sydney, NSW, Australia. The primary school comprised of children between Kindergarten (aged five and six) and Year Six (aged 11 and 12) with over 800 students within the
entire school. There were four classes per Year level, each class consisting of approximately 30 students. The classes were heterogeneous and not graded according to academic and/or physical abilities. Across all year groups, PE was taught twice a week and provided 100 minutes of class time per week.

All students involved in the study (N = 61), completed a battery of assessments (explained in Section 3.3 of this chapter). Upon completion of the pre-tests, students participated in a 16-lesson unit (see Appendix 1). Each 50-minute lesson consisted of a warm-up (10–15 minutes), then the set lesson activities from the PE unit titled “Games and Sport: Ball Skills” (See Appendix 1). This unit was implemented as part of their regular scope and sequence of learning and taught by the same PE teacher. The main difference between units and classes was that the plyometric group participated in an eight week (16-lesson) plyometric training program as their warmup, while the comparison group participated in their regular warm-up at the beginning of each PE lesson. After the unit, post-test data were obtained, with students performing the same assessments as in the pre-test.

3.3.1 Randomisation procedure

Through the utilisation of intact PE classes, random assignment of the two groups: the plyometric group and the comparison group, was conducted at the class level, supporting this study’s classification as quasi-experimental (Handley, Lyles, McCulloch, and Cattamanchi, 2018). Random assignment of groups was conducted by an independent third party who was blind to the study, using a coin toss (Amonette, English, and Kraemer, 2016; Faulkner, Taylor, Ferrence, Munro, and Md, 2006; Moher et al., 2010)
3.4 Outcome Measures and Procedures

Study outcomes were measured pre-intervention (within one week prior to the commencement of the intervention) and post-intervention (within one week following completion of the intervention) by trained assessors. The testing measures included anthropometric (height and weight), FMS-Polygon, squat jump, reactive strength index (drop jumps 10cm, 20cm, 30cm) and medicine ball chest throw. Pre and post anthropometric measures were used in the calculation of lower body muscular power. The testing measures employed in this study have been shown to be valid and reliable, as noted in the following section.

3.4.1 Anthropometric measures and procedures

Anthropometric measures were collected to determine body weight, height and then calculate body mass index. These measures were taken prior to any testing for both pre and post-tests. All measures were collected using recommended procedures (Booth, Denney-Wilson, Okely, and Hardy, 2005; National Health and Medical Research Council, 2013) and were taken by trained assessors who were blinded to student group allocation. Measurements of height and weight are considered to have a low observer and measurement error when performed by trained assessors (Lobstein, Baur, and Uauy, 2004). Ulijaszek and Kerr (1999) also indicate that reliability are high for both weight (> .95) and height (> .90) assessments.

Student height was measured using a portable stadiometer (HART Sport and Leisure, Australia) and collected whilst standing without shoes. After students removed their shoes, they were positioned with their heels, buttocks, upper back and head against the stadiometer, and then measured. Height measured the vertical distance between the bottom of the feet and top of the head in centimetres.
Weight was measured using a calibrated portable Innerscan Body Composition Monitor (Tanita BC-541) and was recorded in kilograms to the nearest 0.1 (Booth et al., 2005; National Health and Medical Research Council, 2013). During the weight assessment, students removed their shoes and were instructed to stand with both feet completely on the scales. Two measurements were taken, with the final value being the average of the two and recorded by the trained assessors.

These measurements were also used to calculate lower body muscular power and to identify any significant changes in the physical characteristics of students which may influence performance during tests.

3.4.2. Motor Performance Skills Test and Procedure

In this study, the change in motor performance skills were measured using the Fundamental Movement Skills Polygon Test (FMS-Polygon) and measured by time (Bozanic, Miletic, and Zuvela, 2011). As this was a school-based intervention, there was no minimal clinical significance calculation conducted before engaging in the research. The main focus of the intervention and analysis was to examine a significant change in time between-groups at the post-test and any within-group change for both groups using repeated measures analysis of variance procedures.

The FMS-Polygon consists of 4 tasks: tossing and catching a volleyball against a wall six times consecutively; running 15 metres and clearing three soft hurdle obstacles; carrying and placing two 3kg medicine balls on a gymnastics vault and then 20 metre straight-line running measured using an electronic timing system (Just Run Timing System, Probotics Inc., Huntsville, Alabama, USA) (see Figure 1 and 2). The result of the test is the time to successfully complete all four tasks successively. Students are provided with four attempts to perform the test, the initial attempt is a trial, and the subsequent attempts are timed and recorded.
The FMS Polygon has been accepted as a valid and reliable instrument for assessing motor performance skills (throwing, catching, running, jumping, gross object control) of children (Bozanic et al., 2011; Culjak, Miletic, Kalinski, Kezic, and Zuvela, 2014; Faigenbaum, Lloyd, Oliver, and Medicine, 2019; Franjko, Žuvela, Kuna, and Kezić, 2013; Valentini, 2012; Vrbik et al., 2016; Zuvela, Kezic, and Krstulovic). This test has concurrent validity with the "Test of Gross Motor Development" (TGMD-2) (Culjak et al., 2014; Edwards et al., 2018; Faigenbaum et al., 2019; Zuvela, Kezic, and Krstulović, 2016; Zuvela, Kezic, and Miletic, 2011). Furthermore, the intraclass correlation coefficient (ICC) for the FMS-Polygon is very high (0.98) (Zuvela et al., 2011).

In this study, testing followed standardised test procedures as provided in the published paper titled "POLYGON - A New Fundamental Movement Skills Test for 8 Year Old Children: Construction and Validation" (Bozanic et al., 2011). Arrangements were made to accommodate the test in a safe environment for the students and to minimise administration time and distractions. The equipment for this test included the following; 12 markers, three sponge hurdles (height 50cm, width 100cm and depth 10cm), two 3kg medicine balls, gymnastics vault (height 110cm, width 150cm and depth 65cm), volleyball, and electronic timing system. The minimum dimension of the assessment area is 10 by 24 meters and a wall (see Figure 1).
Figure 1 3D Representation of the FMS-Polygon
Figure 2 Dimensions of the FMS-Polygon

Note. Measurements in centimeters
The test consisted of four tasks which were completed successively. The test began with the student standing on a starting line one meter from the wall with a volleyball in their hands. An outline of a square (60cm by 60cm) was marked on the wall 150cm high. On the researcher’s signal, the student begins the first task of tossing and catching a ball against the wall 6 times. Immediately after the first task, the student performs the second task by running across three 50cm high hurdles and then through two cones to the third task. The third task involves lifting and carrying two 3kg balls three meters, one at a time and placing them on a gymnastics vault. The fourth and final task is to run 20 meters until passing over the electronic timing mat. It is important to emphasise that the middle sponge hurdle must be moved aside before the run, which is the assistant’s task. The result of the FMS-Polygon test is the time needed to successfully complete the four aforementioned tasks (Zuvela et al., 2011). Using the electronic timing system, each student attempted to complete the tasks correctly in the fastest time. Students had four attempts to perform the test with 2 minutes rest between attempts. The initial attempt was a trial, and the three subsequent attempts were timed and recorded. An overall score was calculated by averaging the three trial times, which was presented in seconds.

3.4.3 Lower Body Muscular Measurements and Procedures

Lower body muscular power was measured using the squat jump, drop jumps, and calculated using the Sayers peak power equation.

Squat jump (SJ) performance was measured to assess lower-body muscular power. This test employed the Takei 5406 digital jump belt meter (Takei, 5406-Jump MD, Tokyo, Japan) instrument to quantify squat jump height. Jump belt mats have been shown to be a valid measure of vertical jump height (Buckthorpe, Morris, and Folland, 2012) and have a high test-retest reliability (ICC .94 p <
0.001) in children aged 6-12 years (Fernandez-Santos, Ruiz, Cohen, Gonzalez-Montesinos, and Castro-Piñero, 2015).

During the assessment, the digital vertical jump meter (Takei, 5406-Jump MD, Toyko, Japan) was attached tightly around the student’s waist. The student was then instructed to stand on the center of the rubber mat. The belt was connected to the rubber mat by a cord. Before proceeding with the squat jump, slack was removed from the cord. Students then placed their hands on their hips to eliminate arm swing during the jump take-off phase. The squat jump (SJ) involved the subject flexing the knee to a 90-degree angle position, holding the position for three seconds before completing an upward only (concentric) jump. During the flight phase, students were not allowed to bend their knees. This test required the students to jump vertically on two feet as high as they could, with the jump belt meter attached to their waists and then landing back to where they commenced the jump. The distance jumped vertically was recorded on a digital indicator. Each student was provided two trials and then three recorded attempts with two minutes rest between each attempt to see how high they could jump. The student’s best jump measured in centimetres (cm) was identified as the final recorded score.

Estimated peak leg power was calculated to provide a measure of the peak power capabilities of each student. Peak power was calculated using the Sayers equation (see below) that uses the jump height and body mass (kg) of each student, Peak Power = (60.7) × (jump height [cm]) + 45.3 × (body mass [kg]) – 2055 (Sayers, Harackiewicz, Harman, Frykman, and Rosenstein, 1999). The Sayers equation has been validated in adults who performed squat jump tests and has a reported difference of 2.7% compared to the peak leg power measured using a force plate (Sayers et al., 1999). To date, no prediction equation has been validated for the estimation of peak power generated for children performing the squat jump. However, the Sayers' prediction equation has been applied as a measure of the change in estimated peak power of children over time (Amonette et al., 2012; Lara-Sanchez,
Zagalaz, Berdejo-Del-Fresno, and Martinez-Lopez, 2011; Quagliarella, Sasanelli, Belgiovine, Moretti, and Moretti, 2011).

Students reactive strength index was assessed using the drop jump from 10cm, 20cm and 30cm heights and measured using an electronic contact mat (Just Jump: Probotics, Huntsville, AL, USA). Drop jumps using an electronic contact mat are a valid assessment of reactive strength index (Flanagan and Comyns, 2008; Rogan, Radlinger, Imhasly, Kneubuehler, and Hilfiker, 2015). In previous studies involving children (Bassa et al., 2012; Marina and Torrado, 2013; Quatman, Ford, Myer, and Hewett, 2006), intraclass correlations coefficients for the drop jump have been obtained, varying between .81 to .95.

During the assessment, students placed their hands on their hips to eliminate arm swing during the jump take-off phase of the jump mat. The students dropped from a box to the ground after an initial step forward. Immediately upon both feet contacting the Just Jump timing mat (Probotics Inc, Huntsville, AL, USA), the student jumped as high as possible. The timing mat measured and recorded flight and ground contact time in seconds. Initially, students were provided with two practice trials. The students then performed three trials from each specified height with a two-minute rest between each attempt. Reactive strength index was calculated by dividing jump height by ground contact time for all three applied drop jump heights (e.g. 10, 20 and 30cm) (Flanagan and Comyns, 2008). For example, if the student ground contact time with the timing mat is 0.2 seconds (sec) prior to the rebounding jump, and the jump height is 10cm, the RSI is 50 cm/sec. For this study, only the best trial score was used for analysis.
3.4.4 Upper Body Muscular Power Measurement and Procedure

The medicine ball chest throw was used to assess change in upper body muscular power from the start to the end of the study. The medicine ball chest throw has been shown to be a valid measure of upper body power (Davis et al., 2008; Hackett, Davies, Ibel, Cobley, and Sanders, 2018; Harris et al., 2011; Vossen, Kramer, Burke, and Vossen, 2000) and has high reliability (ICC .88) in children (Davis et al., 2008).

Before each medicine ball chest throw, the 1kg weighted ball was coated with magnesium carbonate (e.g. gymnastic chalk) resulting in a distinctive mark on the floor after the ball landed, allowing for precise measurement. Each student sat on the floor with their legs straight and feet pointing vertically and their back against a wall. A 90cm wide lane was marked out to guide the throw. When performing the medicine ball chest throw, the student placed their elbows against the wall. The student was then required to throw the ball as far as possible from their chest. A two-minute rest was provided after each of the three attempts. The distance of the medicine ball throw was measured using a measuring tape which was secured to the floor, to withstand the force of the ball landing on it. The measured distance was from the wall to the near edge of the mark on the floor made by the ball and recorded in centimetres. Each student had two trials and then three attempts with only the farthest distance used for further analysis.

3.5 Participants and Settings

3.5.1 Sample Size Calculations

Similar intervention studies were utilised for sample size calculations (Behringer et al., 2011; Johnson et al., 2011). Based on interaction effects between groups and time in a two-way ANOVA, a priori power analysis (GPower V3.1.9.2, Dusseldorf, Germany) was conducted to
estimate the minimum amount of students needed to achieve the desired power (Faul, Erdfelder, Lang, and Buchner, 2007). A priori power analysis using G*Power 3 (Faul et al., 2007) with a significance level of $p = 0.05$, a (conservatively estimated) medium to large effect size of $d = 0.50$, and the desired power of $(1-\beta) = 0.8$ (80% or greater chance of finding a statistically significant difference when there is one) revealed a sample size of $N = 34$ (17 in each group). This is extremely important as it increases the ability to detect small differences, as well as non-significant effects with the level of confidence desired (Faul, Erdfelder, Lang, and Buchner, 2007). A convenience sample of 61 was decided upon to account for class sizes and potential attrition. In this study, the sample size was larger than previous studies involving plyometric interventions with children (Behringer et al., 2011; Johnson et al., 2011).

### 3.5.2 Selection of Research Site

Primary school students were chosen as participants because motor performance skills proficiency is generally low among school-age children in NSW (Hardy et al., 2017). The utilisation of plyometric training within the primary school setting was due to its capacity to be an effective, practical and quality pedagogical approach (Konukman et al., 2018). Moreover, if students are exposed to plyometric exercises at an early age in primary schools, this may assist in the development of motor performance skills and strengthen their ability later in life to participate in physical activity (Pesce, Faigenbaum, Crova, Marchetti, and Bellucci, 2012; Robinson et al., 2015). Year Two students were also selected as their neuromuscular system is going through rapid development which has also been acknowledged as a critical period for learning motor performance skills (Malina, 1994; Viru et al., 1998).
This study utilised a purposeful sample that was inclusive of participants from diverse demographics and socioeconomic status backgrounds, from South West Sydney. The selection of the school was based on willingness to engage with the study, resources, indoor area availability for wet weather conditions and the pre-established relationship between the researcher and the school.

Before contacting a primary school, the lead researcher obtained permission from the University of Wollongong Human Research Ethics Committee and Sydney Catholic Schools (SCS) Education Application Process. Next, the researcher made initial contact with three Principals of SCS primary schools located in the south-west region of Sydney. A formal meeting was held with one school, and the Principal and Assistant Principal were present. In the meeting, the details of the whole study were discussed, and the principal was issued a formal letter describing the proposed study. All documentation relating to the approval of the study to be conducted are provided in Appendix 3 to 6.

3.5.3 Selection of Participants

Participants in this study consisted of two Year Two classes (n=61, aged between seven and eight years). The students belonged to one of two classes, and each class was randomly assigned to the Plyometric group (treatment) or the Comparison group (control). The assignment of the class to plyometric or comparison groups was determined by an independent third party using a coin toss before beginning pre-testing.

In this study, students were required to submit parental consent forms before their involvement. A physical activity readiness questionnaire was also required to be completed
before participation to assess if students had any health or fitness related conditions that could affect their involvement in the study (See Appendix 9).

3.5.4 Selection and Training of PE Teacher

At the chosen primary school, prior to the study, the PE lessons were taught by the generalist classroom teacher or by external providers of PE. While the facilitator of the PE curriculum units may vary at the school, traditionally each class received similar content and instruction as per the schools’ PE teaching programs. Since this study included plyometric activities, a PE teacher with experience in plyometric training was utilised to implement the intervention and the teaching unit for this study. Therefore, both the comparison and the plyometric group had the same PE teacher.

The PE teacher in this study had strength and conditioning coaching qualifications. Further to this, the PE teacher attended a one-day workshop and training course on plyometrics and how to implement all lessons within the teaching unit. The training day was facilitated by the researcher, who is an experienced PE teacher, Level Two Strength and Conditioning Coach and has a Master’s degree qualification in Exercise Science. Each lesson in the teaching unit was broken down, explained and demonstrated, with the PE teacher having the opportunity to participate and observe exemplary teaching practice utilising the plyometric exercises. Moreover, the PE teacher was given the teaching unit containing the PE activities, description of the plyometric exercises along with a copy of the plyometric station cards to assist with their implementation of the program.
3.5.5 Research Assistants Recruitment

Three research assistants were recruited and trained in collecting pre- and post-test data. These assistants comprised of three exercise scientists who volunteered for this project. All assistants had exercise physiology testing experience with children. Research assistants were blind to treatment conditions at baseline and post-test assessments.

3.5.5.1 Research Assistant Training and Reliability

Three research assistants administered the pre-and post-tests. To ensure the reliability and validity of the data, assistants attended training. The training was conducted over two weeks and consisted of;

1. A workshop to explain the protocols and procedures for each outcome measure.
2. Providing a hard copy of the test instructions, test scripts and testing protocols (see Appendix 10-13).
3. One day to learn and apply the testing assessment techniques.
4. One day of learning and practising correct reporting administration techniques.

For involvement in the research, each research assistant was required to deliver the tests accurately, detect technical violations and measure performance on ten successive attempts (See Appendix 10-13). Inter-observer reliabilities were assessed to ensure an adequate level of reliability. Two observers independently and simultaneously observed the delivery of the tests, detection of technical violations and measurement of performance. Inter-observer reliability was calculated using the following equation: [agreements/(agreement + disagreements)] x 100 (Thomas et al., 2015). The interobserver reliability scores across the battery of assessments were
100% agreement, which is higher than the recommended 85% threshold required to establish reliability (Thomas et al., 2015).

3.6 Intervention Development and Pilot Testing

This section will outline the theoretical framework that positions the plyometric intervention and offers a foundation that justifies and directs the structure of the eight week plyometric training utilised in this study. The process to determine the suitability of the plyometric training program for students aged seven and eight years of age is also described here, providing a rationale for the final design of the plyometric intervention used in this study.

The specific plyometric principles used in the pilot testing were:

- **Volume** - six to ten repetitions per set and 12 to 14 sets in total per session.
- **Recovery** - plyometric sessions separated by a minimum of 48 hours and at least 30 seconds rest between sets during the session.
- **Frequency** - two plyometric sessions per week.
- **Progression and Intensity** - employed a progressive increase in intensity. Progression was in the form of basic to complex plyometric movements, taking into consideration the experience of the individual and their age, and performed with moderate to fast repetition velocity (sets completed within 20 seconds).
- **Safety** - correct form was demonstrated for the plyometric exercises, and observation of technique was performed, and the technique was corrected when necessary.

These principles were derived from the body of literature on plyometric interventions (Faigenbaum and Chu, 2017; Faigenbaum et al., 2007; Faigenbaum et al., 2009; Faigenbaum et al., 2009; McCambridge and Stricker, 2008).
Two pilot tests were conducted to determine the feasibility, usability, and practicality of the data collection measures and proposed intervention. Aspects of focus within the pilot testing were the proposed tests, identifying and modifying deficiencies or limitations, and determining the exact dimensions of all equipment that would be suitable for children seven and eight years of age. Each pilot testing period involved students aged seven and eight years old (i.e. ten students) at the same Catholic Primary School. These students only participated in one pilot test period, and none of the children in the pilot test were involved in the main study.

Implementation of the pilot testing occurred over a time frame of five weeks. The first and fifth week of each pilot test was used to assess the feasibility and usability of the data and battery of assessments. During weeks two through to four, participants were involved in all the activities within the plyometric intervention as outlined in Appendix 14. The intent of having all students complete the variety of plyometric activities was to assess the suitability of activities and the associated instruction.

3.6.1 Pilot Testing Results

The first pilot test investigated the feasibility and uniformity of pre and post-intervention measurements (i.e. static squat jump, medicine ball chest throw, drops jumps, and FMS-Polygon). The methods and tests for assessing the dependent variables proved to be transparent for participants, as demonstrated by their ability to follow the instructions and perform the tests according to the prescribed protocols.

After the first pilot testing, it was determined through input from the Year Two primary students, teachers and researcher, that two aspects of the plyometric warmup intervention required improvements and modifications. For each plyometric activity, an A3 poster (297 x 420
mm) that provided (a) the name of the specific activity and (b) illustration of how to perform the activity, was included. The poster served as a cue and reminder of what the participant was required to do. Also, some names of the plyometric activities were changed to assist the students in understanding what movements were required. Feedback from the students assisted with these name changes. For example, an activity titled 'Split Squat Jumps' was renamed to 'Take Your Marks and Jump'. These changes to the accessibility of the program were to improve the students' ability to recognise the required plyometric activity to perform.

In the second pilot test, it was evident that students understood the plyometric activities and instructions, as they followed instructions and performed the plyometric activities as aligned with the protocols. The ability to conduct the data collection during times of wet weather posed an issue on one occasion for both groups. During wet weather, water flowed across the concrete surface where the data collection was scheduled to occur. An indoor facility was made available to address this issue. This indoor facility was available for PE during wet weather, which occurred only twice for both classes on the same days. In summary, the pilot testing revealed that it was feasible to implement the plyometric program with boys and girls aged seven and eight.

### 3.6.2 Plyometric Warm-up

The plyometric activities in this study utilised the stretch-shortening cycle, for example, hopping on one leg over marking cones. Since plyometric activities are a form of resistance training, body weight and or medicine balls were utilised as the resistance force (e.g. load), to impose loads on the upper extremities, and trunk. The load used in this study mirrored recommendations by Chu et al. (2006) and Faigenbaum and Mediate (2008).
The specific warmup consisted of a circuit of plyometric stations in which students worked in pairs or individually. The plyometric stations involved exercises that have been previously used with children (Chaouachi et al., 2014; Faigenbaum et al., 2007; Faigenbaum et al., 2009; Faigenbaum et al., 2014; Nobre et al., 2017) and the structure of the program met the suggested training guidelines for children: training repetitions of 6-10 (Lloyd, Meyers, and Oliver, 2011; Lloyd and Oliver, 2014; Malina, 1994), at least 30 seconds rest between each exercise (Moreno, Brown, Coburn, and Judelson, 2014; Rousanoglou et al., 2008; Thissen-Milder and Mayhew, 1991), frequency of two sessions per week, and 72 hours recovery between sessions (Lloyd et al., 2011; Lloyd and Oliver, 2014; Malina, 1994; Moreno et al., 2014). Each warmup session ended with one set of a plyometric exercise in a relay format which involved students performing the plyometric exercise as quickly as possible before commencement of the next student (Konukman et al., 2008; Miller, Herniman, Ricard, Cheatham, and Michael, 2006; Monsef et al., 2012).

A progressive plyometric framework was used in this study to allow a progressive adaptation and strengthening of muscles and tendons to the volume and intensity of work, with the intent of preventing injury and overtraining (Bompa and Buzzichelli, 2018; Faigenbaum et al., 2007). The plyometric framework required planned changes over the eight weeks in acute training variables such as; exercise choice, number of repetitions per set, number of sets, and rest between sets in order to maximise training adaptations (Miller, Berry, Bullard, and Gilders, 2002; Miller et al., 2006). The framework used in this study was based on findings from previous investigations involving children and youth engaging in plyometric training (Faigenbaum et al., 2007; Nobre et al., 2017), and is consistent with previous recommendations for progressively decreasing volume and increasing plyometric intensity to provide appropriate exercise stimulus.
The progressive plyometric intervention was divided into three phases (periods), with the first and second phase lasting three weeks in duration and the last phase being two weeks.

Each of the three phases in the plyometric program built upon the preceding phase with planned, systemic variations in volume, intensity, and exercises in order to apply overload and allow adaptations to occur (Ebben et al., 2010; Myer et al., 2005). The first phase was low intensity and high volume with two sets of 10 repetitions performed for each exercise. The exercises in phase one were lower intensity exercises (e.g. straight jumping, double-leg) to introduce the students to these types of activities safely. The second phase was designed to increase the intensity of the circuit while the repetitions decreased; for example, two sets of eight repetitions performed for each exercise. The exercises in phase two required higher intensity (e.g. Hurdle hops on one leg). Finally, the third phase exercises involved performing two sets of six to eight repetitions with higher intensity, for example, progressing from the zig-zag double-leg jump drill to the zig-zag single leg jump drill.

The plyometric group performed eight different plyometric activities in each session (see Appendix 13). For plyometric exercises involving the use of a medicine ball, students were instructed with a lightweight rubber ball weighing 200 grams before performing them with a weighted 1-kilogram medicine ball. Medicine ball activities in weeks seven and eight utilised a 2 kg ball.

A qualified PE teacher implemented the plyometric warmup and PE teaching program. During each lesson, a fidelity checklist and logbook was used to monitor implementation for adherence and quality (see Appendix 15 and 16).
3.6.3 Comparison Group Warm-up

Participants in the comparison group participated in a range of warm-up activities, consisting of walking, brisk walking and side steps, followed by dynamic stretches (see Appendix 17). The comparison group warmups did not include any ‘plyometric exercises’ or ‘plyometric training’ as per the warmup protocol and replicated the regular PE class warmup prior to the study. Students were observed during each lesson to monitor adherence to the comparison group warmup (see Appendix 18 and 19). This style and format of warm-up was performed at the start of each lesson and then followed by the set lesson for the PE unit titled “Games and Sport: Ball Skills”.

3.7 Data Collection Procedures

This section describes the data collection procedures utilised to conduct the study. Data collection consisted of procedures designed to collect pertinent data to answer the research questions of this thesis (Abildgaard, Saksvik, and Nielsen, 2016). These procedures included subject preparation and familiarisation, administration of data collection, the fidelity of implementation. The data collection approaches need to align with the clearly defined goals and the study design. The data collection methods used in this study were valid, reliable and had been previously used in research to measure the change in children aged seven and eight.

3.7.1 Subject Preparation and Familiarisation

All students were screened for health-wellbeing status and related risk factors using a physical activity readiness questionnaire prior to involvement in the research (see Appendix 8). Each student was provided with; a comprehensive description of the purpose of the tests; an outline of testing
procedures and the potential risks associated with participation in the study (Appendix 6). To participate, students and their legal guardian were both required to sign an informed consent form prior to participation (Appendix 7). Students were asked to refrain from partaking in any physical activity in the previous 24 hours in order to avoid or minimise acute exercise effects on physical performance.

Before any data collection, students completed two familiarisation sessions before the testing day. During the sessions, the students were familiarised with the squat jump, drop jump, medicine ball throw and FMS polygon to minimise learning effects. The familiarisation sessions focused on correct techniques and procedures for each test and allowed practice attempts until correct techniques were mastered. The testing procedures were also explained to students before the initial testing session to ensure participants had an adequate understanding of performing the tests correctly. At both familiarisation sessions, students’ questions were answered.

3.7.2 Administration of Data Collection Assessments

Collection of data for both the pre- and post-tests were conducted over two days. The detailed testing procedures are outlined in Appendices 9-12. The testing order for each individual remained the same for all testing occasions to maintain consistency of testing fatigue and administration of students.

On the first day of testing, students completed the FMS-Polygon, followed by the medicine ball throw. Two days after the initial day of testing, height, weight, lower body muscular power and reactive strength index/stretch-shortening cycle were assessed in the order as listed.
3.7.3 Fidelity of Implementation

Fidelity of implementation (also referred to: treatment integrity, treatment fidelity, intervention fidelity and adherence to protocol) is a central component of any research study (Bellg et al., 2004; Breitenstein et al., 2010; Carroll, et al. 2007; Resnick et al., 2005; Santacroce, Maccarelli and Grey, 2004; Sidani and Braden, 2011). Recent research literature within the curriculum setting provides the following key components of fidelity implementation; the content of the intervention; the process of the intervention; the quantity of the intervention; the quality of the intervention, and adherence by the subjects (Loflin, 2015; McKenzie and van der Mars, 2015; Stylianou, Kloeppe, Kulina, and van der Mars, 2016). Fidelity of implementation was assessed in this study to ensure that the research interventions were delivered as planned and thus any treatment effects observed (or not observed) were due to the intervention and not alterations in research study execution. Attention was given to the study design, conceptual design of the intervention, training of all research assistants and measuring the consistency with which the intervention was delivered and received by the students (Bova et al., 2017).

Conceptual alignment and direct observation were applied to assess the fidelity of implementation. Direct observation was chosen over video recording based on feedback obtained from parents and teachers during pilot tests in which they indicated that an observer would be the most acceptable and least intrusive. Every lesson, the PE teacher (i.e. plyometric checklist and comparison group warmup checklist) and both groups (i.e. plyometric logbook, the comparison group warmup logbook and PE lesson checklist) were each observed (Century, Rudnick, and Freeman, 2010; Gersten et al., 2005; O'Donnell, 2008). To ensure that the warmup was delivered as intended each lesson, the researcher and the classroom teacher both observed the PE teacher and a sample of students participating. According to the minimum value provided in the
literature, ten percent of the sample was required for direct observation (Chaffin et al., 2004; Hewitt, Edwards, Ashworth, and Pill, 2016; Loflin, 2015; McKenzie and van der Mars, 2015; Stylianou, Kloeppe!, Kul!, and van der Mars, 2016). In each class observed in the present study, four students were randomly selected each day and observed throughout the warm-up. The researcher and the classroom teacher observed and recorded data using the checklists and logbooks.

3.7.3.1 Conceptual Alignment

The plyometric training program adhered to the American College of Sports Medicine (ACSM) plyometric training for children and adolescent guidelines and was conceptually aligned with previous research investigating the effect of plyometrics on children (Faigenbaum et al., 2007; Faigenbaum et al., 2009; Johnson et al., 2011). The duration of the plyometric program was eight weeks, which is in line with that previously used in research with children that has demonstrated training effects (Faigenbaum et al., 2009; Johnson et al., 2011). During the training, all subjects were under direct supervision and instructed on how to perform each exercise.

3.7.3.2 Direct Observation

Fidelity data were collected using direct observation checklists completed during monitoring of PE lessons. The checklists related to plyometric warmup, comparison group warmup, and PE lesson content and structure. In addition, student attendance was monitored each lesson, and students were expected to attend a minimum of 13 sessions (80%) over the eight
weeks, without missing two consecutive sessions (Gonzalez-Aguero et al., 2012; Negra et al., 2016).

The researcher assessed whether the warmups for both groups were delivered as intended using the following; plyometric checklist (see Appendix 14), treatment logbook (see Appendix 15) and comparison group checklist (see Appendix 17) and comparison group warmup logbook (see Appendix 18).

### 3.7.3.3 Plyometric Checklist and Logbook

A plyometric checklist was utilised to document PE teacher adherence in delivering the plyometric intervention. In addition, a plyometric logbook was used to determine if the activities performed by the students mirrored the set activities and prescribed training variables required to attain benefits from the intervention (Johnson et al., 2011; Lloyd and Oliver, 2014). The researcher and the classroom teacher used the plyometric checklist and logbook to record adherence to the defined plyometric intervention protocol for each session. The observed and assessed variables were; plyometric exercises performed correctly, movements included an eccentric contraction followed by a rapid concentric contraction; students completed two sets per station; the required number of repetitions completed were within 20 seconds; 30 seconds’ rest was taken between sets; session exercises were completed, and the session medicine ball specifications were correct. The elements in the checklist and logbook were checked, then summed to give a score. These recordings were then used to determine if the plyometric warmup were implemented as designed. From the assessment of each warmup, both the researcher and the classroom teacher agreed that each warmup was implemented as required and included
prescribed activities as outlined. Plyometric warmup fidelity of implementation (>90%) was found to be adequate (Hastie and Casey, 2014).

3.7.3.4 Comparison Group Checklist

For the comparison group warmup, the checklist allowed for collection of data on three variables: initial general warming up activities, dynamic warmup stretches, and adherence to no plyometric exercise or training. The researcher and the classroom teacher used the comparison checklist and logbook to record adherence to the defined comparison group warmup for each session. Adherence to the prescribed warmup was coded as “yes” or “no,” depending on whether the PE teacher delivered the set activities during the warmup. These recordings were then used to determine if the comparison warmup were implemented as designed. From the assessment of each warmup, both the researcher and the classroom teacher agreed that each warmup was implemented as prescribed. Fidelity of implementation was established (100%) for all sessions.

3.7.3.5 Physical Education Lesson Checklist

Teacher fidelity checklist was used to collect data for each implemented PE lesson of the unit, “Games and Sport: Ball Skills” for both groups. The checklist included all items for the lessons (see Appendix 1). These items related to lesson structure (introduction, drills, lesson focus, game), management (e.g. forming groups/teams), equipment (e.g. used and easily accessible), and lesson content (e.g. the lesson comes from the school unit program). The researcher and the general classroom teacher both observed the PE lessons simultaneously and recorded data (Kloeppler, Kulina, Stylianou, and van der Mars, 2013). These recordings were then used to determine if the lessons were reflective of the unit lesson. From the assessment of
the PE lessons, each unit lesson was implemented as required, and both the researcher and classroom teacher agreed that the unit taught was reflective of the content and strategies outlined in the unit.

3.7.4 Fidelity of Implementation Inter-observer reliability

Inter-observer reliability was assessed using 50% of the observations with the direct observation checklists and 50% of observations with the treatment log. On these occasions, two observers simultaneously observed the warm-ups, PE lessons and independently collected data using the observation checklists and logbooks. Inter-observer reliability percentages were calculated by dividing the number of agreements by the total number of observations and then multiplying this by 100. Inter-observer reliability was above 90% for the checklists and 100% for the plyometric logbook.

As a critical aspect of ensuring consistency in testing, inter-observer reliabilities were conducted. Inter-observer reliabilities were calculated using the following equation:
\[
\left[ \frac{\text{agreements}}{\text{agreement} + \text{disagreements}} \right] \times 100
\]
which is based on the recommendations of Thomas, Silverman, and Nelson (2015).

Two research assistants and the lead researcher conducted the inter-observer reliabilities. Initially, the research assistants received two hours of training from the lead researcher on how to accurately measure the performance of all data collection assessments. Each of the assistants also received the protocols for each assessment (see Appendices 9-12). Following the training, the assessors practiced scoring performances not associated with the current research for a further 2 hours.
On data collection days, the two assistants and the lead researcher independently evaluated the following: anthropometric, FMS-Polygon, Squat jump test, reactive strength index and medicine ball chest throw. For each assessment, the three individuals stood one metre apart, rated performance, and were instructed not to communicate results to each other. Inter-observer agreement was calculated for 56 per cent of the student’s performance of each test. Reliabilities of above 90 per cent agreement were obtained, which were higher than the recommended 85% threshold needed to establish reliability (Thomas et al., 2015).

3.8 Data and Statistical Analysis

Statistical analysis followed data collection for each variable under investigation. The analysis was conducted to establish meaning and answer the research questions. Students data were excluded from analysis if their attendance was less than thirteen sessions (80%) or two consecutive lessons were missed (Gonzalez-Aguero et al., 2012; Negra et al., 2016). All students met the required threshold; hence all student data were included for statistical analysis to answer each research question. A detailed description of the statistical procedures conducted are presented below.

3.8.1 Analysis to Examine Research Questions

Analysing quantitative data in this thesis required establishing meaning from data that was collected from the 61 students who participated in both pre- and post-tests. The procedure was sequential with a prearranged step-by-step method. All data were entered into Microsoft Excel by the lead researcher and double-checked for accuracy. The data were then exported from Microsoft Excel into the ‘Statistical Package for the Social Sciences’, SPSS 24 (SPSS Inc,
As previously reported in this chapter (Section 3.7), treatment fidelity data were analysed throughout the study to ensure the intervention was conducted in an appropriate manner.

Data analysis involved a chronological approach that included multiple steps as follows:

1. Calculation of study variables;
2. Descriptive analysis of group characteristics and study variables (illustrate the overall background of participants);
3. Reliabilities of study measures (establish the appropriateness of each measure);
4. Data Screening and Repeated Measures ANOVA (examination of significant between and within-group changes);
5. Post Hoc Analysis (examine the location of the significant ANOVA calculations);
6. Correlational analysis (examine relationships between variables).

**3.8.2 Calculation of Study Variables**

The calculation of study variables for use within this thesis focused on processing the raw data from each study measure and calculating each into the study variables used for further analysis. The process for calculating each study variable followed the guidelines and procedures outlined in Section 3.4. As such, study variables were calculated for:

- Motor performance skills proficiency;
- Upper body muscular power;
- Lower body muscular power;
- Peak power;
- Reactive strength index.
3.8.3 Descriptive Analysis of Group Characteristics and Study Variables

Descriptive statistics included calculations of means and standard deviations for all pre- and post-test study variables (i.e. motor performance skills proficiency; upper body muscular power; lower body muscular power; peak power; reactive strength index), and the group characteristics which included age, height, weight and gender.

3.8.4 Reliabilities of study measures

Twelve students (six boys and six girls) were randomly selected as part of the assessment for test-retest reliability of each data collection measure. A sample of students were chosen rather than all students due to school time and curriculum constraints. Cronbach alpha tests were used to examine the reliability of the study measures. Cronbach alpha scores were calculated for all pre- and post-test study variables of FMS-Polygon, medicine ball chest throw, squat jump, drop jump RSI 10cm, drop jump RSI 20cm and drop jump RSI 30cm. A threshold of .80 was identified as being appropriately reliable based on the recommendations of Thomas et al. (2015). Paired sample t-tests were used to compare the differences between dependent variable scores in test and retest sessions.

3.8.5 Data Screening and Repeated Measures ANOVA

To examine the first two research questions, a repeated measure analysis of variance (RM ANOVA) was conducted to examine any significance between and within-group differences for each study variable. Before conducting a RM ANOVA, all data were screened for assumptions that a RM ANOVA would be an appropriate analysis. The specific assumption tests were to (a) the examination of outliers, (b) Shapiro Wilk tests of normality and (c) Brown-Forsythe test of
homogeneity of variance. The examination of outliers was performed to identify and remove any data that were unrepresentative scores and may abnormally influence the results if included. Shapiro Wilks test was used to test the null hypothesis that sample data were drawn from a normally distributed population. Lastly, the Brown-Forsythe test was used to verify if the data is normally distributed.

A (2 x 2) (Group x Time) repeated-measures ANOVAs was used to evaluate the effects of the intervention for each variable as a function of group (comparison and plyometric) and time (pre- and post-intervention). The between-subject independent variable was the intervention groups with two levels: the comparison group and the plyometric group. The within-subject independent variable was the time with two levels: pre- and post-intervention. Due to conducting multiple RM ANOVAs, the original significance was set at $p < .05$, except where Bonferroni correction was employed in which case an alpha level of 0.05 was divided by the number of calculations performed.

3.8.6 Post Hoc Analysis

When a significant RM ANOVA was returned, the location of this difference (e.g. between groups) was examined using a Bonferonni pairwise comparison. Bonferroni correction Alpha was set at $p \leq 0.05$ for FMS-Polygon and medicine ball chest throw. For all other measures, the Bonferroni correction Alpha was adjusted and set at $p \leq 0.01$ due to multiple measures for the lower body muscular power domain. As part of the initial analysis using SPSS, a pairwise comparison provided insight to examine where the significant differences are located (i.e. within and/or between groups).
3.8.7 Correlational analysis

Correlation analysis in the form of the Pearson product-moment coefficients were performed to establish the strength of the relationships between motor performance skill proficiency and muscular power variables. Pearson’s product-moment correlation coefficients were performed to assess the associations (both strength and direction) between variables of differences for all outcome measures. Correlational indices were set at small (0.1-0.3), moderate (0.3-0.5), large (0.5-0.7), and very large (0.7-0.9) using the guidelines of Hopkins, Marshall, Batterham, and Hanin (2009).

3.9 Conclusion

The present study explored the effect of plyometric activities on motor performance skills of children aged seven and eight years. The study achieved this by using a quasi-experimental design, which included pre- post-tests to explore three research questions of this study. The quantitative research design provided numerical data which indicated the effect of using plyometrics exercises when teaching Year Two primary school students. The data collection methods measured the students’ motor performance skill proficiency, upper and lower body muscular power. It is evident throughout this chapter that the methodology is logically coherent and aligned with the aims of the current study, conducted ethically and ensures the validity of the results.
Chapter Four - Results

4.1 Introduction

The purpose of this chapter is to provide the results of the study with reference to the study aim. Specifically, results are presented to determine if performing plyometrics in the warmup of the PE lesson would lead to greater improvement in motor performance skills and upper and lower body muscular power, compared to the absence of plyometrics exercises in the warmup. 61 students completed the study in either the plyometric ($n = 31$; 14 girls and 17 boys) or comparison group ($n = 30$; 15 boys and 15 girls). No injuries were recorded for the plyometric and the comparison group. Student attendance for the PE lessons was in the acceptable range ($\geq 13$ lessons), with attendance data revealing a mean of 15.48 lessons (out of a total of 16 PE lessons). All students attended the pre- and post-tests days.

The results of the data analysis are presented in the following order:

1. Group characteristics and study variables;
2. Descriptive statistics;
3. Reliabilities of study measures;
4. Data Screening, Repeated Measures ANOVA and Post Hoc Analysis;
5. Correlational analysis.

4.2 Group Characteristics and Study Variables

Students’ physical characteristics (means ± standard deviations) are displayed in Table 1 below. At baseline, both groups had similar characteristics based on the results of initial t-tests, with no significant differences between the plyometric and comparison group in terms of age ($p$
= 0.93), weight ($p = 0.33$), height ($p = 0.25$) or BMI ($p = 0.60$) being evident. While not directly related to the thesis research questions, t-tests were employed to assess whether student physical characteristics differed pre- and post-intervention. There were no significant differences over the ten-week research study for height, body weight and BMI as displayed in Table 2.

Table 1 Participants Physical Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Plyometric Group</th>
<th>Comparison Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>7.35 ± 0.49</td>
<td>7.37 ± 0.49</td>
</tr>
<tr>
<td>Body height (cm)</td>
<td>128.13 ± 6.13</td>
<td>126.30 ± 6.23</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>30.26 ± 5.91</td>
<td>28.80 ± 5.21</td>
</tr>
<tr>
<td>Body mass index (kg m$^{-2}$)</td>
<td>18.43 ± 3.42</td>
<td>18.03 ± 2.61</td>
</tr>
</tbody>
</table>

Note: Values are Mean ± Standard Deviation

Table 2 Pre- and Post-Test Subject Physical Characteristics (comparison of means)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pre-test Mean ± SD</th>
<th>Post-test Mean ± SD</th>
<th>t-Value</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>127.2 ± 6.2</td>
<td>128.6 ± 6.1</td>
<td>1.19</td>
<td>120</td>
<td>.24</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>29.6 ± 5.6</td>
<td>30.6 ± 5.6</td>
<td>0.97</td>
<td>120</td>
<td>.33</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>18.2 ± 3.0</td>
<td>18.5 ± 3.1</td>
<td>0.54</td>
<td>120</td>
<td>.58</td>
</tr>
</tbody>
</table>

4.3 Descriptive Statistics

Descriptive statistics (means ± standard deviations) and the differences between pre- and post-testing dependent variable results are presented as relative changes (%) for each group in Table 1. Results of data analysis are presented to examine each dependent variable.
<table>
<thead>
<tr>
<th></th>
<th>Plyometric Group (n = 31)</th>
<th>Comparison group (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-</td>
<td>Post-</td>
</tr>
<tr>
<td>FMS-Polygon (s)</td>
<td>34.40±3.72</td>
<td>29.96±3.29</td>
</tr>
<tr>
<td>Squat Jump Height (cm)</td>
<td>23.45±5.18</td>
<td>26.61±4.36</td>
</tr>
<tr>
<td>Estimated Peak Power (W)</td>
<td>376.23±281.73</td>
<td>505.14±276.20</td>
</tr>
<tr>
<td>Medicine Ball Chest Throw (cm)</td>
<td>209.63±23.93</td>
<td>223.74±23.23</td>
</tr>
<tr>
<td>Drop Jump 10 cm (RSI)</td>
<td>40.62±12.98</td>
<td>48.44±11.75</td>
</tr>
<tr>
<td>Drop Jump 20 cm (RSI)</td>
<td>39.79±13.89</td>
<td>46.49±14.104</td>
</tr>
<tr>
<td>Drop Jump 30 cm (RSI)</td>
<td>38.60±13.53</td>
<td>44.38±12.75</td>
</tr>
</tbody>
</table>

*Note.* % is the percentage of change from pre to post-test measurements.
4.4 Intra-session and Inter-session Reliability

4.4.1 Intra-session Reliability

Intra-session reliabilities were calculated for all pre- and post-test dependent variables using Cronbach’s alpha. The overall values for all dependent variables ranged between 0.83 to 0.99, indicating that all measures were reliable based on the .80 threshold suggested by Thomas et al. (2015). Table 4 provides the alpha scores for all study variables.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS-Polygon</td>
<td>.977</td>
<td>.991</td>
</tr>
<tr>
<td>Medicine ball chest throw</td>
<td>.955</td>
<td>.928</td>
</tr>
<tr>
<td>Squat jump</td>
<td>.982</td>
<td>.985</td>
</tr>
<tr>
<td>Drop jump RSI 10cm</td>
<td>.936</td>
<td>.851</td>
</tr>
<tr>
<td>Drop jump RSI 20cm</td>
<td>.922</td>
<td>.899</td>
</tr>
<tr>
<td>Drop jump RSI 30cm</td>
<td>.916</td>
<td>.895</td>
</tr>
</tbody>
</table>

4.4.2 Intersession Reliability

Intraclass correlation was used to determine the intersession reliability. The ICC for all six tests exceeded 0.8 (Table 5), with those between 0.8 and 0.9 considered ‘good’ and those exceeding 0.9 as ‘excellent’ reliability (Koo, et al. 2016). The paired t-tests showed non-significant differences between the means of the two sessions across all measurements.
### Table 5 Test Re-Test Reliability Intraclass Correlation Coefficients (ICC)

<table>
<thead>
<tr>
<th>Test</th>
<th>Test-retest reliability (ICC), 95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS-Polygon</td>
<td>.979, .928 to .994</td>
</tr>
<tr>
<td>Squat jump</td>
<td>.996, .985 to .999</td>
</tr>
<tr>
<td>Medicine ball chest throw</td>
<td>.879, .579 to .965</td>
</tr>
<tr>
<td>Drop jump RSI 10cm</td>
<td>.853, .569 to .955</td>
</tr>
<tr>
<td>Drop jump RSI 20cm</td>
<td>.846, .464 to .956</td>
</tr>
<tr>
<td>Drop jump RSI 30cm</td>
<td>.802, .311 to .943</td>
</tr>
</tbody>
</table>

#### 4.5 Fidelity of Implementation - Inter-observer Agreement and Treatment Integrity

Inter-observer agreement was assessed during 56% of the pre-test and post-test assessments and was 95% for the anthropometric measurements (91-100%), 95% for the medicine ball chest throw (91%-100%), 100% for squat jump, 100% for the drop jumps and 100% for FMS-Polygon.

Inter-observer reliability percentages were calculated for treatment integrity by dividing the number of agreements by the total number of observations and then multiplying this by 100. Inter-observer reliabilities were; 92% for the plyometric checklist, 100% for the plyometric logbook, 100% for comparison group warmup checklist, and the PE lesson checklist was 100%.

The key elements of the warmups were adhered to by the teacher and performed by the students, as described in Section 3.6 and outlined in Appendix 14 and 17.

#### 4.6 Data Screening, Repeated Measures ANOVA and Post Hoc Analysis

Assumptions of normality and homogeneity were assessed. Tables 6 and 7 display the Shapiro-Wilks test for normality and indicated that all data for each dependent variable were statistically appropriate for use in further analysis. In order to determine whether the plyometric and comparison groups were statistically different at the outset of the study, the Brown-Forsythe assumption of homogeneity of variance test was employed. The assumption was met for all
included data, as displayed in Table 8, indicating that the randomization procedure was appropriate in distributing the variability homogenously between the two groups \((p > 0.05)\).

Results of the repeated measures ANOVA are presented to examine research question one and two. To evaluate the effect sizes (ES), partial eta-squared values \((\eta^2)\) were presented (small ES: \(>.02\); medium ES: \(>.13\); large ES: \(>.26\)) (Cohen, 1988). Where required, the Bonferroni’s post hoc pairwise analysis was used to highlight significant differences between the two groups. The level of significance was set at \(p < 0.05\). Results of the Bonferroni’s post hoc pairwise analysis are presented for research question one and two.

**Table 6** *Shapiro-Wilk Test of Normality for Pre-Test Dependent Variables Data*

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Shapiro-Wilk Statistic (s-w)</th>
<th>df</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS-Polygon</td>
<td>.987</td>
<td>61</td>
<td>.776</td>
</tr>
<tr>
<td>Medicine ball throw</td>
<td>.982</td>
<td>61</td>
<td>.493</td>
</tr>
<tr>
<td>Squat jump height</td>
<td>.989</td>
<td>61</td>
<td>.870</td>
</tr>
<tr>
<td>Drop jump 10cm (RSI)</td>
<td>.987</td>
<td>61</td>
<td>.749</td>
</tr>
<tr>
<td>Drop jump 20cm (RSI)</td>
<td>.979</td>
<td>61</td>
<td>.369</td>
</tr>
<tr>
<td>Drop jump 30cm (RSI)</td>
<td>.979</td>
<td>61</td>
<td>.395</td>
</tr>
</tbody>
</table>

*Note.* Values above 0.05 confirm normality (Ghasemi and Zahediasl, 2012)

**Table 7** *Shapiro-Wilk test of Normality for Post-Test Dependent Variables Data*

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Shapiro-Wilk Statistic (s-w)</th>
<th>df</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS Polygon</td>
<td>.965</td>
<td>61</td>
<td>.074</td>
</tr>
<tr>
<td>Medicine ball throw</td>
<td>.988</td>
<td>61</td>
<td>.805</td>
</tr>
<tr>
<td>Squat jump height</td>
<td>.978</td>
<td>61</td>
<td>.344</td>
</tr>
<tr>
<td>Drop jump 10cm (RSI)</td>
<td>.967</td>
<td>61</td>
<td>.095</td>
</tr>
<tr>
<td>Drop jump 20cm (RSI)</td>
<td>.983</td>
<td>61</td>
<td>.581</td>
</tr>
<tr>
<td>Drop jump 30cm (RSI)</td>
<td>.977</td>
<td>61</td>
<td>.318</td>
</tr>
</tbody>
</table>

*Note.* Values above 0.05 confirm normality (Ghasemi and Zahediasl, 2012)
Table 8 Brown-Forsythe Assumption of Homogeneity of Variance Test

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Statistica</th>
<th>df/2</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMS Polygon</td>
<td>0.154</td>
<td>54.79</td>
<td>.697</td>
</tr>
<tr>
<td>Medicine ball throw</td>
<td>0.143</td>
<td>49.63</td>
<td>.707</td>
</tr>
<tr>
<td>Squat jump height</td>
<td>0.407</td>
<td>58.90</td>
<td>.526</td>
</tr>
<tr>
<td>Drop jump 10cm (RSI)</td>
<td>1.530</td>
<td>58.8</td>
<td>.221</td>
</tr>
<tr>
<td>Drop jump 20cm (RSI)</td>
<td>1.724</td>
<td>57.93</td>
<td>.194</td>
</tr>
<tr>
<td>Drop jump 30cm (RSI)</td>
<td>2.033</td>
<td>57.85</td>
<td>.159</td>
</tr>
</tbody>
</table>

Note. a Asymptotically F distributed

4.6.1 Research Question One

Research question one investigated how time spent participating in plyometric warmup affected motor performance skills. Repeated measures analysis of variance (ANOVA) revealed a significant interaction effect (Wilks' Λ = .401, $F(1, 59) = 88.065, p < .05, \eta^2 = .599$) for the FMS Polygon test. Pre-and post-test means for motor skill performance are illustrated in Figure 3. Follow-up pairwise comparisons indicated that significant improvement for the plyometric group in the motor performance skills was identified at the post-test time point (FMS-Polygon) ($p \leq .01$) with students in the plyometric group demonstrating lower scores compared to the comparison group. Pairwise comparison results are displayed in Table 9.
**Figure 3**  *FMS-Polygon Mean for the Treatment by Time Interaction between Comparison and Plyometric groups*

![Graph showing FMS-Polygon Mean for the Treatment by Time Interaction between Comparison and Plyometric groups](image)

**Table 9**  *Follow-up Pairwise Comparisons for FMS-Polygon (motor performance skills)*

<table>
<thead>
<tr>
<th>Treatment (I)</th>
<th>Treatment (J)</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plyometric Pre-test</td>
<td>Plyometric Post-test</td>
<td>4.44</td>
<td>0.37</td>
<td>0.00*</td>
<td>3.69</td>
<td>5.20</td>
</tr>
<tr>
<td></td>
<td>Comparison Pre-test</td>
<td>0.64</td>
<td>1.32</td>
<td>0.62</td>
<td>-1.99</td>
<td>3.29</td>
</tr>
<tr>
<td>Comparison Post-test</td>
<td>Comparison Pre-test</td>
<td>-0.193</td>
<td>0.33</td>
<td>0.56</td>
<td>-0.86</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>Plyometric Post-test</td>
<td>5.24</td>
<td>1.26</td>
<td>0.01*</td>
<td>2.71</td>
<td>7.77</td>
</tr>
</tbody>
</table>

*Note. * Significant at $p \leq 0.01$
4.6.2 Research Question Two

Research question two investigated how time spent participating in the plyometric warmup affected lower and upper body muscular power. Repeated measures ANOVA revealed a significant interaction effect (Wilks' $\Lambda = .585, F(1, 59) = 41.81, p < .01, \eta^2 = .415$) for the squat jump test. Pre and post-test means for squat jump height performance are illustrated in Figure 4. Follow-up pairwise comparisons indicated significant improvement for the plyometric group in lower body muscular power at the post-test time point (squat jump) ($p < .01$) with students in the plyometric group demonstrating higher squat jump scores compared to the comparison group. Pairwise comparison results are displayed in Table 10.

**Figure 4 Squat Jump Height Mean for the Treatment by Time Interaction between Comparison and Plyometric groups**
### Table 10 Follow-up Pairwise Comparisons for Squat Jump (lower body muscular power)

<table>
<thead>
<tr>
<th>Treatment (I)</th>
<th>Treatment (J)</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plyometric Pre-test</td>
<td>Plyometric Post-test</td>
<td>-3.16</td>
<td>0.44</td>
<td>0.00*</td>
<td>-4.05</td>
<td>-2.27</td>
</tr>
<tr>
<td></td>
<td>Comparison Pre-test</td>
<td>0.84</td>
<td>1.33</td>
<td>0.53</td>
<td>-1.81</td>
<td>3.51</td>
</tr>
<tr>
<td>Comparison Post-test</td>
<td>Comparison Pre-test</td>
<td>0.53</td>
<td>0.37</td>
<td>0.16</td>
<td>-0.022</td>
<td>1.29</td>
</tr>
<tr>
<td></td>
<td>Plyometric Post-test</td>
<td>-2.84</td>
<td>1.10</td>
<td>0.01*</td>
<td>-5.04</td>
<td>-0.65</td>
</tr>
</tbody>
</table>

*Note. * Significant at $p \leq 0.01$

Repeated measures ANOVA revealed a significant effect in estimated lower body peak power production ($\text{Wilks'} \Lambda = .582, F (1, 59) = 42.350, p < .05, \eta^2 = .418$) using the Sayers formula. Pre-and post-test means for estimated peak power production are illustrated in Figure 5. Follow-up pairwise comparisons indicated significant improvement for the plyometric group in estimated peak power production at the post-test time point (Estimated Peak Power) ($p < 0.01$) with students in the plyometric group demonstrating higher scores compared to the comparison group. Pairwise comparison results are displayed in Table 11.
Figure 5 Estimated Peak Power Mean for the Treatment by Time Interaction Between Comparison and Plyometric Group

![Graph showing estimated peak power mean for the treatment by time interaction between comparison and plyometric group.]

Table 11 Follow-up Pairwise Comparisons for Peak Power

<table>
<thead>
<tr>
<th>Treatment (I)</th>
<th>Treatment (J)</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plyometric Pre-test</td>
<td>Plyometric Post-test</td>
<td>-215.71</td>
<td>26.81</td>
<td>0.00*</td>
<td>-270.45 -160.97</td>
</tr>
<tr>
<td></td>
<td>Comparison Pre-test</td>
<td>-12.73</td>
<td>96.11</td>
<td>0.89</td>
<td>-205.05 179.59</td>
</tr>
<tr>
<td>Comparison Post-test</td>
<td>Comparison Pre-test</td>
<td>-2.66</td>
<td>24.31</td>
<td>0.91</td>
<td>-52.38 47.06</td>
</tr>
<tr>
<td></td>
<td>Plyometric Post-test</td>
<td>-225.78</td>
<td>84.43</td>
<td>0.01*</td>
<td>-394.73 -56.83</td>
</tr>
</tbody>
</table>

Note. * Significant at $p \leq 0.01$
Repeated measures ANOVA revealed a significant interaction effect (Wilks' $\Lambda = .789$, $F(1, 59) = 15.806, p < .05, \eta^2 = .211$) for the medicine ball chest throw test (upper body muscular power). Pre-and post-test means for medicine ball chest throws are illustrated in Figure 6. Follow-up pairwise comparisons indicated significant improvement for the plyometric group in upper body muscular power at the post-test time point (upper body muscular power) ($p < 0.01$) with students in the intervention group demonstrating higher scores compared to the comparison group. Pairwise comparison results are displayed in Table 12.

**Figure 6** Medicine Ball Chest Throw Mean for the Treatment by Time Interaction Between Comparison and Plyometric Group
Table 12 Follow-up Pairwise Comparisons for Medicine Ball Throw

<table>
<thead>
<tr>
<th>Treatment (I)</th>
<th>Treatment (J)</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plyometric Pre-test</td>
<td>Plyometric Post-test</td>
<td>-14.10</td>
<td>2.27</td>
<td>0.00*</td>
<td>-18.73</td>
<td>-9.47</td>
<td></td>
</tr>
<tr>
<td>Comparison Pre-test</td>
<td></td>
<td>-3.01</td>
<td>7.91</td>
<td>0.71</td>
<td>-18.84</td>
<td>12.81</td>
<td></td>
</tr>
<tr>
<td>Comparison Post-test</td>
<td>Comparison Pre-test</td>
<td>-1.57</td>
<td>3.25</td>
<td>0.63</td>
<td>-8.21</td>
<td>5.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plyometric Post-test</td>
<td>-15.54</td>
<td>7.16</td>
<td>0.03*</td>
<td>-29.87</td>
<td>-1.22</td>
<td></td>
</tr>
</tbody>
</table>

Note. *Significant at p ≤ 0.05

Repeated measures ANOVA revealed a significant interaction effect (Wilks' Λ = .791, F (1, 59) = 15.592, p < .05, η² = .209) for the 10cm drop jump, 20cm drop jump (Wilks' Λ = .840, F (1, 59) = 11.246, p < .05, η² = .160), and 30cm drop jump tests (Wilks' Λ = .846, F (1, 59) = 10.726, p < .05, η² = .154). Pre- and post-test means for drop jump RSI’s are illustrated in Figures 7 - 9. Follow-up pairwise comparisons indicated significant improvement for the plyometric group in reactive strength index at the post-test time point (10cm DJ, 20cm DJ, 30cm DJ) (p < 0.01). There was no difference between students in the plyometric group compared to the comparison group for reactive strength at the post-test time point. Pairwise comparison results are displayed in Tables 13 - 15.
Figure 7 Drop Jump (10cm) RSI Mean for the Treatment by Time Interaction Between Comparison and Plyometric Group

Figure 8 Drop Jump (20cm) RSI Mean for the Treatment by Time Interaction Between Comparison and Plyometric Group
Figure 9  *Drop Jump (30cm) RSI Mean for the Treatment by Time Interaction Between Comparison and Plyometric Groups* 

![Graph showing the mean RSI for drop jumps between comparison and plyometric groups over time.](image)

Table 13  *Follow-up Pairwise Comparisons for Drop Jump 10cm*

<table>
<thead>
<tr>
<th>Treatment (I)</th>
<th>Treatment (J)</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plyometric Pre-test</td>
<td>Plyometric Post-test</td>
<td>-8.95</td>
<td>1.46</td>
<td>0.00*</td>
<td>-11.93</td>
<td>-5.98</td>
</tr>
<tr>
<td></td>
<td>Comparison Pre-test</td>
<td>4.08</td>
<td>3.30</td>
<td>0.22</td>
<td>-2.52</td>
<td>10.68</td>
</tr>
<tr>
<td>Comparison Post-test</td>
<td>Comparison Pre-test</td>
<td>-0.73</td>
<td>1.99</td>
<td>0.72</td>
<td>-4.80</td>
<td>3.33</td>
</tr>
<tr>
<td></td>
<td>Plyometric Post-test</td>
<td>-4.14</td>
<td>2.97</td>
<td>0.17</td>
<td>-10.09</td>
<td>1.81</td>
</tr>
</tbody>
</table>

*Note. Significant at p ≤ 0.01*
Table 14 Follow-up Pairwise Comparisons for Drop Jump 20cm

<table>
<thead>
<tr>
<th>Treatment (I)</th>
<th>Treatment (J)</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plyometric Pre-test</td>
<td>Plyometric Post-test</td>
<td>-6.97</td>
<td>1.60</td>
<td>0.00*</td>
<td>-10.22</td>
<td>-3.71</td>
</tr>
<tr>
<td></td>
<td>Comparison Pre-test</td>
<td>4.34</td>
<td>3.31</td>
<td>0.19</td>
<td>-2.29</td>
<td>10.97</td>
</tr>
<tr>
<td>Comparison Post-test</td>
<td>Comparison Pre-test</td>
<td>-0.50</td>
<td>1.55</td>
<td>0.75</td>
<td>-3.68</td>
<td>2.68</td>
</tr>
<tr>
<td></td>
<td>Plyometric Post-test</td>
<td>-2.13</td>
<td>3.23</td>
<td>0.51</td>
<td>-8.59</td>
<td>4.34</td>
</tr>
</tbody>
</table>

Note. * Significant at p ≤0.01

Table 15 Follow-up Pairwise Comparisons for Drop Jump 30cm

<table>
<thead>
<tr>
<th>Treatment (I)</th>
<th>Treatment (J)</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plyometric Pre-test</td>
<td>Plyometric Post-test</td>
<td>-6.59</td>
<td>1.34</td>
<td>0.00*</td>
<td>-9.33</td>
<td>-3.85</td>
</tr>
<tr>
<td></td>
<td>Comparison Pre-test</td>
<td>4.93</td>
<td>3.245</td>
<td>0.16</td>
<td>-1.97</td>
<td>11.83</td>
</tr>
<tr>
<td>Comparison Post-test</td>
<td>Comparison Pre-test</td>
<td>-0.07</td>
<td>1.53</td>
<td>0.96</td>
<td>-3.21</td>
<td>3.07</td>
</tr>
<tr>
<td></td>
<td>Plyometric Post-test</td>
<td>-1.59</td>
<td>2.93</td>
<td>0.59</td>
<td>-7.45</td>
<td>4.27</td>
</tr>
</tbody>
</table>

Note. * Significant at p ≤0.01
4.6.3 Research Question Three

Research question three investigated the association between the measures of muscular power and motor performance skills. Pearson product-moment correlations were used to examine the relationship between dependent variables measured within this study. Strength of Pearson correlations was evaluated as small (0.1-0.3), moderate (0.3-0.5), large (0.5-0.7), and very large (0.7-0.9) using the guidelines of Hopkins et al. (2009).

Pre-test (baseline) correlations are provided in Table 16. Examining the data, there were some significant findings. Strong positive associations were indicated between motor performance skill proficiency and upper body muscular power $r(61) = -0.529, p < .01$. Moderate positive association between motor performance skill proficiency and lower body muscular power $r(61) = -0.374, p < .01$. Moderate, positive association were evident between motor performance skill proficiency and estimated peak power $r(61) = -0.366, p < .01$, and 30cm RSI, $r(61) = -0.346, p > 0.1$. Small positive relationship between squat jump height and drop jump 30cm $r(61) = 0.271; p < .05$ were also indicated.

**Table 16 Pearson Product-Moment Correlations Between Results Obtained at Baseline Testing**

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. FMS-polygon (s)</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Squat jump (cm)</td>
<td>-.37**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. MBCT (cm)</td>
<td>-.53**</td>
<td>.42**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Estimated Peak power (W)</td>
<td>-.37**</td>
<td>.74**</td>
<td>.60**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Drop Jump 10cm (RSI)</td>
<td>-.11</td>
<td>.19</td>
<td>-.15</td>
<td>-.20</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Drop Jump 20cm (RSI)</td>
<td>-.10</td>
<td>.24</td>
<td>-.13</td>
<td>-.136</td>
<td>.83**</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>7. Drop Jump 30cm (RSI)</td>
<td>.04</td>
<td>.27*</td>
<td>-.20</td>
<td>-.13</td>
<td>.74**</td>
<td>.86**</td>
<td>-</td>
</tr>
</tbody>
</table>

*Note.* ** indicates statistical significance of p < 0.01 (two-tailed); * indicates statistical significance of p < 0.05 (two-tailed)
In terms of post-test results, Pearson correlation analysis revealed a significant correlation between FMS-Polygon performance and squat jump, medicine ball throw, estimated peak power and 10cm drop jump for both pre and post-test performance (See Table 17). Large positive associations were indicated between post-test motor performance skill proficiency and upper body muscular power \( r (61) = -.55, p < .01 \). There were moderate positive association between post-test motor performance skill proficiency and lower body muscular power \( r (61) = -.40, p < .01 \), and estimated peak power \( r (61) = -.35, p < .01 \). Small, positive association between motor performance skill proficiency and 10cm RSI, \( r (61) = -.27, p > 0.5 \). The post-test results also revealed a moderate positive relationship between squat jump height and drop jump 10cm \( r = 0.378, p < 0.01 \), drop jump 20cm \( r = 0.395, p < 0.01 \) and drop jump 30cm \( r = 0.373, p < 0.01 \).

### 4.7 Summary of Results

Data from 61 primary school students were analysed to examine the research study questions investigating the potential efficacy of using plyometrics activities in the PE warmup to improve motor performance skills and associated muscular power improvements. Results were reported for each research question in this study. A summary of the results obtained is provided in Table 18.

---

**Table 17 Pearson Product-Moment Correlations Between Results Obtained at Post-Testing**

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. FMS-polygon (s)</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Squat jump (cm)</td>
<td>-.40**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. MBCT (cm)</td>
<td>-.55**</td>
<td>.50**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Estimated Peak power (W)</td>
<td>-.35**</td>
<td>.68**</td>
<td>.58**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Drop Jump 10cm (RSI)</td>
<td>-.27*</td>
<td>.45**</td>
<td>.16</td>
<td>.01</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Drop Jump 20cm (RSI)</td>
<td>-.11</td>
<td>.42**</td>
<td>.09</td>
<td>.01</td>
<td>.81**</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>7. Drop Jump 30cm (RSI)</td>
<td>.07</td>
<td>.34**</td>
<td>.04</td>
<td>-.08</td>
<td>.78**</td>
<td>.92**</td>
<td>-</td>
</tr>
</tbody>
</table>

*Note.* ** indicates statistical significance of \( p < 0.01 \) (two-tailed); * indicates statistical significance of \( p < 0.05 \) (two-tailed)
### Table 18  A Summary of Results

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does participation in plyometric activities influence the motor performance</td>
<td>• Participation in plyometrics during the warmup of each lesson</td>
</tr>
<tr>
<td>skills of children aged seven and eight years?</td>
<td>significantly improved seven and eight-year-old students’ motor</td>
</tr>
<tr>
<td></td>
<td>performance skills.</td>
</tr>
<tr>
<td>2. Does involvement in a plyometric-based program influence the muscular power</td>
<td>• Participation in plyometrics during the warmup of each lesson</td>
</tr>
<tr>
<td>in students aged seven and eight years?</td>
<td>significantly improved seven and eight-year-old students’ muscular</td>
</tr>
<tr>
<td></td>
<td>power.</td>
</tr>
<tr>
<td>a. Does involvement in a plyometric-based program influence the upper body</td>
<td>• Participation in plyometrics during the warmup of each lesson</td>
</tr>
<tr>
<td>muscular power in students aged seven and eight years?</td>
<td>significantly improved seven and eight-year-old students’ upper</td>
</tr>
<tr>
<td></td>
<td>body muscular power.</td>
</tr>
<tr>
<td>b. Does involvement in a plyometric-based program influence the lower body</td>
<td>• Participation in plyometrics during the warmup of each lesson</td>
</tr>
<tr>
<td>muscular power in students aged seven and eight years?</td>
<td>significantly improved seven and eight-year-old students’ lower</td>
</tr>
<tr>
<td></td>
<td>body muscular power.</td>
</tr>
<tr>
<td>3. What is the association between elements of muscular power and motor</td>
<td>• Upper and lower body muscular power were significantly related to</td>
</tr>
<tr>
<td>performance skills?</td>
<td>students’ motor performance skill ability.</td>
</tr>
</tbody>
</table>
Chapter Five - Discussion

5.1 Introduction

The findings from the present study are promising and infer the potential efficacy of including plyometric exercises in primary school PE lessons. The plyometric exercises infused into the warmup were designed to improve the body’s capacity to perform motor performance skills and increase whole-body muscular power, which is associated with motor performance skills proficiency (Behringer et al., 2011; Cureton and Barry, 1961; Harries et al., 2012). The results suggest that the changes that the plyometric group underwent were likely influenced by the addition of the plyometric exercises. The discussion will follow the structured format outlined in the Consort Statement (Schulz, Altman, Moher, and the, 2010).

This chapter will include the following:

- Summary of the key findings in the context of the three research questions;
- Comparison of the findings with other similar studies;
- Explanation of the findings in relation to current literature.

Recommendations will also be provided in this chapter to inform future primary school-based PE interventions, which target improving motor performance skills. The information presented in this chapter could also be used by other researchers to assist in the development of interventions and programmes designed to improve motor performance skills.
5.2 RQ1: Does participation in a plyometric-based program influence the motor performance skills of children aged seven and eight years?

The first research question examined the effect of a plyometric warmup on motor performance skills. It was hypothesised that participants in the plyometric group would show a significant increase in their level of motor performance compared to the comparison group.

5.2.1 Key Findings

The findings from this study were able to support the first research hypothesis and provide insight into the associated research question. Significant improvements were reported for motor performance skills for the plyometric group compared with the comparison group at post-intervention. Therefore, students who participated in the plyometric exercises during the warm-up phase of the PE lesson were found to have accelerated the improvement of their motor performance skills compared to students who participated in the comparison group warmup.

5.3 RQ2: Does involvement in a plyometric-based program influence the muscular power in students aged seven and eight years?

The second research question examined the effects of plyometric warmup on:

a. Upper body muscular power;

b. Lower body muscular power.

It was hypothesised that students in the plyometric group would show a significant increase in both their upper and lower body muscular power compared to the comparison group.
5.3.1 Key Findings

The findings from this study were supportive of the second research hypothesis. Significant improvements were reported for upper and lower body muscular power for the plyometric group compared with the comparison group at post-intervention. Moreover, reactive strength index, which is a measure of the function of muscles to switch from eccentric to a concentric contraction, enabling increased power, improved significantly within-group for the plyometric group. However, the increase in the reactive strength index was not significant when compared with the comparison group. Overall, these measures demonstrated a significant improvement for the plyometric group with limited change in the comparison group. Therefore, based upon the result of this research, it seems that incorporation of a plyometric program into PE lessons could prove effective in improving skill-related components of fitness such as muscular power.

5.4 RQ3: What is the association between the elements of muscular power and motor performance skills?

The third research question examined the association between the measures of muscular power and motor performance skills. It was hypothesised that motor performance skills would be associated with measures of muscular power.

5.4.1 Key Findings

The findings from this study support the third research hypothesis. A significant association was found between baseline and post-test measures of motor performance skills with upper and lower body muscular power. Furthermore, the marked improvement for FMS-Polygon
during the study in the plyometric group was correlated significantly with the changes for medicine ball chest throw, returning a moderate correlation between improvements in these two capacities. This suggests that muscular power could be a major factor influencing motor performance skill proficiency, in seven to eight year-old children.

5.5 Comparison with Other Studies

The findings from this study support the notion that participation in plyometric exercises at the commencement of a PE lesson can result in substantial improvement in children’s motor performance and measures of muscular power. Moreover, this study indicated a significant correlation between motor performance skills and elements of muscular power in seven and eight-year-old children. Some aspects of the findings observed in the current study mirror those of previous studies that have examined the effect of plyometric training on; movement performance in children nine years of age (Arabatzi, 2018; Góes Nobre et al., 2016), upper body muscular power in youth (Fernandez-Fernandez, Saez de Villarreal, Sanz-Rivas, and Moya, 2016; Pereira et al., 2015), lower body muscular power in children aged nine years (Faigenbaum et al., 2009; Kotzamanidis, 2006) and reactive strength index in youth (Lloyd, Radnor, De Ste Croix, Cronin, and Oliver, 2015; Markovic, Jukie, Milanovic, and Metikos, 2007). However, research studies involving children or athletes aged under nine years is limited. This is notwithstanding the fact that children aged five to nine years are in a window indicated as a favourable period of power development (Lloyd and Oliver, 2012; Papaiaakovou et al., 2009; Viru et al., 1998). With this in mind, in this section, key findings are compared to similar studies which are either school-based or within athletic populations. Furthermore, due to the dearth of
research and the interrelationship between the studied variables, this section provides a consolidated comparison from a holistic perspective.

5.5.1 The Effect of a Plyometric Based Program on Motor Performance Skills of Children Aged Seven and Eight

The findings of the current study are consistent with the findings of other studies investigating the change in specific motor performance and sporting skills following plyometric based programs delivered to older children and youth. Two studies, to date, applied a plyometric-based program within schools and found significant improvement in specific motor performance skills following the intervention. The first was a 12-week program that utilised lower body plyometric exercises, delivered by an instructor outside of the PE curriculum (Nobre et al., 2017). The plyometric program resulted in significant change over time for lower body gross motor skills. The second was a study by Chaouachi et al. (2014) whom reported improvements in motor performance skills test (e.g. 30m sprint, agility, star excursion and stork balance), with medium to large effect size (d=0.34 to 1.25) compared to the control group, following an eight-week lower body plyometric program delivered three times a week. In comparison with the current study, the research conducted by Nobre et al. (2017) and Chaouachi et al. (2014) had similar findings, however, the program and the participants differed and are worth noting. For example, the current study utilised a younger and gender-inclusive cohort and examined a lower and upper body plyometric program. The studies by Nobre et al. (2017) and Choaoouchi et al. (2014) were a group of male children with an average age of 9 years and older. In addition, these programs were not aligned with the school curriculum, which is worth identifying.
Plyometric training in the current study induced significant improvement in motor performance skills, whereas the standard PE lessons without the plyometric warmup, did not contribute to changes in this variable. Although there appears a dearth of studies that directly compare the effects of PE lessons and plyometric training in children, the results are comparable to the results of studies in sports. By way of example, a study by Fernandez-Fernandez et al. (2016) implemented an eight week upper and lower body plyometric program into tennis training to increase motor performance skills in young male tennis players aged 12 to 13. Consistent with the current study, the intervention was delivered twice a week for eight weeks and was a substitute for part of the tennis training, which mirrors the current study in which the warmup section of the PE lesson was incorporated with plyometric-based activities. Fernandez-Fernandez et al. (2016) found significant improvement in the motor performance skills of the plyometric group over the duration of the study. These performance skills included short sprints, agility testing, serve velocity and accuracy. These results and study design have similarities to the current study, which provide support for allocating 10 to 15 minutes of class time to plyometric training to improve motor performance skills. It is reasonable to conclude from the current study, and those described by (Cherni et al., 2019; Gjinovci et al., 2017; Meylan and Malatesta, 2009), that short bouts of plyometric training are an effective method to accelerate motor performance skills development when confronted with reduced PE. curriculum time. Of note in the current study, the comparison group experienced little or no improvement in all measured variables.

The current study builds on the research by Nobre et al. (2017), Chaouachi et al. (2014) and Fernandez-Fernandez et al. (2016) demonstrating that an upper and lower body plyometric-based program, as a component of a PE lesson, can improve overall motor performance skill proficiency in both female and male students between the ages of seven and eight. Their
intervention and the one examined in the current study share some similarities. Both programs provided plyometrics twice weekly on non-consecutive days, with the objective to improve the ability to perform movement skills. Furthermore, the current study posits that PE infused with plyometric training may accelerate student’s achievement of movement skills and fitness-related educational outcomes.

5.5.2 Lower Body Muscular Power

The current study produced significant improvement in lower body muscular power, which corroborates the findings of Kotzamanidis (2006) and Faigenbaum et al. (2007). Whilst there was evidence of these the aforementioned studies and significant improvement in older children, it was not known whether similar results would be observed in seven and eight-year-old PE students. Kotzamanidis (2006) implemented plyometric training to improve running and jumping performance in children aged 10 and 11 and demonstrated significant improvements in the plyometric group for the squat jump, and no significant changes were observed in the control group. Unlike the current study, plyometric training was a substitute for regular PE lessons. Between baseline and post-testing, Faigenbaum et al. (2007) investigated the effects of a PE based plyometric program on the fitness performance of children (mean age: 9 years). Akin to the current study, the plyometrics was performed at the beginning of the PE lesson in place of the regular warm-up. Findings showed that the plyometric group significantly improved lower body muscular power as measured by the standing long jump, compared with the control group (Faigenbaum et al., 2007). In accordance with the current study, the plyometric group significantly improved, and no statistically meaningful changes were observed in the control group. Faigenbaum et al. (2007) speculated that the changes in motor unit activation and motor
unit coordination, and rate of force production could explain, at least in part, the resulting improvements. The speculation for the changes, as suggested by Faigenbaum et al. (2007) is interesting in light of the current study in which the correlational analysis suggested a weak association between 30cm drop jump and reactive strength and the variables such as motor performance skills and jumping. Furthermore, as the squat jump was a static jump in both the current study and as that of Faigenbaum et al. (2007), meaning it is devoid of an eccentric contraction, we can speculate that its improvement may have contributed to the enhanced concentric contraction as measured in the current study. This may lead to enhanced ability to jump, kick, and throw when in a game situation when there is insufficient time for a counter movement to develop maximum power.

To the author’s knowledge, there have been no published papers investigating the change in reactive strength index following any plyometric training in children aged seven to eight years of age. As such, there is little data on the training load applicable to seven and eight-year-old children that might be effective in changing objectively measured reactive strength index. With so few investigations of the effect of plyometrics and training load on reactive strength index in children, there is limited evidence to inform the findings in this study. McGuigan, Cormack, and Gill (2013) suggested a change in the reactive strength index reveals that plyometric training in young children can improve the function of the stretch-shortening cycle, a mechanism for improved muscular power.

One study by Lloyd and colleagues (2015), examined the effects of a six-week combined plyometric and resistance training program. Unlike the current study, the intervention was delivered to male children (average age 12.7 years) and focused on lower body exercises in addition to the usual PE classes. Lloyd et al. (2015) established that the plyometric group
improved reactive strength index, while the control group exhibited no change (Lloyd et al., 2015), which is similar to the current study and comparable to the findings in the study by Markovic et al. (2007).

For the current study, inferential statistics showed that for reactive strength index, comparable performance changes between pre- and post-test were trivial for the groups. However, upon visual inspection of Figures 7-9, and comparison of baseline performances, magnitude-based inferences suggest that in response to the plyometric program, the plyometric group had improvements in reactive strength index that were likely greater than the comparison group. Lloyd and colleagues (2015) suggest that the high neural demand of plyometric training may lead to an improvement in RSI, however, in the current study, the training demand may not have been sufficient to improve this measure quite enough to result in significant differences between the groups. It seems that unlike the study by Lloyd et al. (2015), the current study included both upper body and lower body plyometric exercises rather than only lower body, which may be responsible to some extent for the differences between groups in this study.

It is also probable that student’s improvement in reactive strength influenced squat jump performance. For instance, observing the pre- and post-test Pearson correlations (see Table 16 and 17), there appears a strengthening in the relationship between squat jump and drop jumps (10cm, 20cm, 30cm). Considering that the results of previous plyometric studies have identified an association between reactive strength and both jumping capacities and agility in athletes from different sports, the strengthening of the relationship in this study is not surprising (Makaruk, Winchester, Sadowski, Czaplicki, and Sacewicz, 2011; Váczi, Tollár, Meszler, Juhász, and Karsai, 2013; Voisin and Scohier, 2019). Although correlation does not infer causation, the trends
in the data support a link between reactive strength index and squat jump performance. Interestingly, no significant difference was observed between groups reactive strength index.

### 5.5.3 Upper Body Muscular Power

Upper body power is an essential capability for performing the skills required for ball sports and games (Tsoukos et al., 2019). Most of the studies examining the effect of plyometrics on upper body muscular power have been conducted within the athletic population (Gjinovci et al., 2017; Singla, Hussain, and Moiz, 2017; Turgut, Cinar-Medeni, Colakoglu, and Baltaci, 2019). It appears that the current study is the first to measure the effect of plyometric training on upper body muscular power in primary school students. Two relevant studies for comparison are that of Pereira et al. (2015) and Carter et al. (2007). Pereira et al. (2015) investigated the impact of eight-weeks of plyometrics and volleyball training in young female volleyball players. The players trained twice a week, however, akin to the current study, the plyometric group had a portion of the usual set program replaced with the plyometric training. The plyometric group significantly improved upper body power as determined by a medicine ball and volleyball ball throw and likewise, in the current study, the plyometric group achieved significant improvement in upper body muscular power and no significant changes in upper body power were observed in their control group. Pereira and colleagues (2015) proposed that the improved performance resulted from greater neural activation, better synchronization of body segments, increased coordination levels, and increased muscular power. A further study by Carter et al. (2007) investigated the effect of a twice weekly plyometric program on baseball players upper body muscular power. In contrast to the current study, the plyometric training program only involved the performance of upper body plyometric exercises. The players in the control group completed
their regular off-season strength training with no plyometric activities. The plyometric group demonstrated significant increases in upper body muscular power (throwing velocity) compared to the control group over the duration of the intervention (Carter et al., 2007). Similar to the current study, the control group demonstrated no significant changes. Carter et al. (2007) suggest that the results are likely due to adaptations in the elastic properties of the muscle, resulting in improved muscle efficiency. A possible explanation for the plyometric group experiencing improved upper body power in the current study might be that the students were provided adequate training stimulus in the PE setting during the heightened window for optimal adaptations (Viru et al., 1998). Hence, this increased muscular power may have resulted in improved synchronization of muscle activity as exhibited in the current study by enhanced motor performance skills.

It is also a possibility that the significant improvement in the medicine ball chest throw by the plyometric group in the current study was also partly due to adaptations in the neuromuscular system resulting from the upper body plyometrics. Kubo, Ishigaki, and Ikebukuro (2017) suggest that plyometric training can result in increased extensibility of tendon structures and active muscle stiffness, leading to improved muscular power as exhibited in the current study. To the best of our knowledge, this is the first study to examine whole-body plyometric training-induced changes in both upper and lower body muscular power in primary school-aged students. Furthermore, from the results of the current study, it appears that primary students aged seven and eight develop their upper body neuromuscular performance within eight weeks by participating in a suitably designed plyometrics program. It is therefore reasonable to conclude that improvement in the FMS-Polygon performance, which was strongly associated upper and lower body muscular power, was likely a result of students’ neuromuscular property changes.
5.5.4 Association Between Motor Performance Skills and Muscular Power

The results from the current study also indicated significant correlations between motor performance skills and measures of muscular power in seven and eight-year-old children. In accordance with the present results, previous studies have demonstrated that muscular power is strongly associated with motor performance skills (Delaš et al., 2008; Rarick and Dobbins, 1975). These positive results are also supported through both meta-analysis and systematic reviews (Behringer et al., 2011; Harries et al., 2012; Lämmle et al., 2010) suggesting that modes of muscular power development may improve motor performance skills.

Researchers Rarick and Dobbins (1975) investigated predictive components in the motor performance of children aged six to nine years. Children were assessed on 60 measures of physical growth, muscular power, fine and gross motor coordination. The data analysis demonstrated that a strong relationship existed between muscular power and performance of motor skills. A more recent study by Delaš et al. (2008) investigated the influence of motor factors on fundamental movement skills of children seven years of age. The impact of various factors of motor abilities on the performance of motor performance skills was examined during four measuring points (pre and post gymnastic treatment). A factorial analysis isolated explosive strength (muscular power) as the most substantial associated integrated capability in learning motor performance skills. Together, these results suggest that there is an association between muscular power and motor performance skill proficiency.

5.5 Possible Mechanisms and Explanations

The results achieved by the plyometric group indicate that the plyometric training (see Section 4.6) was influential in developing seven and eight-year-old children’s motor performance
skills and measures of muscular power over eight weeks, and is in line with the findings of previous work using plyometric activities. Although the mechanisms responsible for the observed improvement is not entirely understood, motor performance skill proficiency was strongly associated with levels of muscular power. These results are encouraging, and there are several possible mechanisms and explanations which will be addressed in this section.

In this study, results indicated that in comparison with standard PE lessons, the inclusion of plyometric training seems to be a sufficient stimulus for improving motor performance skills. Furthermore, this stimulus for improvement was supported as limited positive changes in any test variables were detected in the comparison group, signifying the potential value of plyometric training for improving motor performance skills of primary school students aged seven and eight. Although the mechanisms responsible for this improvement in this study are not entirely understood or directly measured within this thesis, the change could likely be due to various neural or neuromuscular adaptations as exhibited by enhanced measures of muscular power. The neuromuscular system is essential for performing motor performance skills. Neuromuscular performance is governed by an effective and efficient interaction between both the nervous and muscular system. In children, the neuromuscular system is highly adaptable due to the heightened level of plasticity (Yue, Clark, Li, and Vaillancourt, 2017). Neuromuscular adaptations as a consequence of plyometric training include changes in motor unit recruitment, firing, and coordination, which are known factors that are vital for optimal movement, and are likely to play a key role in reported motor performance skill proficiency improvements (Behrens et al., 2014; Behrens et al., 2016; Collins et al., 2019). Research also supports the suggestion that plyometric training imparts both neuromuscular adaptations and muscular power adaptations, both of which have been identified as essential components of motor performance skill
development (Behringer et al., 2011; Malina et al., 2004; Ramirez-Campillo et al., 2018). Furthermore, there is supporting evidence from systematic reviews that plyometric training improves motor performance skills in children via enhanced neuromuscular development (Behringer et al., 2011; Collins et al., 2019; Johnson et al., 2011; Peitz et al., 2018). This is a logical inference considering the ability of the neuromuscular pathways to develop and adapt, leading to children being better able to move their bodies in different ways, both from a dynamic and static perspective.

The present study was the first to analyse the effects of an eight-week plyometric-based program on muscular power and associated reactive strength index in seven and eight-year-old children in the PE setting. The results achieved by the plyometric group indicates that the plyometric training (see Section 4.6.2) was influential in developing seven and eight-year-old children’s muscular power over eight weeks and the findings are comparable with the studies discussed earlier. Even though inferential statistics indicated that the plyometric group did not show enhanced response compared with the comparison group for reactive strength index, an inspection of the interaction (Group X Time) data showed an increase of up to sixteen percent at post-test compared to the pre-test. For the current study, significant small to medium effect sizes for squat jump ($\eta^2 = 0.415$), medicine ball chest throw ($\eta^2 = .211$), 10cm drop jump ($\eta^2 = .209$), 20cm drop jump ($\eta^2 = .160$), and 30cm drop jump ($\eta^2 = .154$) were achieved for between groups over time. These results can contribute to the body of knowledge as this study demonstrated that plyometric training could improve muscular power and reactive strength index in both boys and girls aged seven to eight within the PE setting. The minimal change in the comparison group may be attributed to the quality of PE lessons, which involved the development of fundamental skills via traditional PE games and sports activities. These observations indicate that the PE
programs that integrate plyometric training may be more effective than ‘standalone’ programs for enhancing fitness components of children such as muscular power. The findings regarding muscular power corroborate the ideas in the “2014 International Consensus on Youth Resistance Training – Position Statement” (Lloyd et al., 2014), which proposes that children can enhance their muscular power by regular participation in a resistance training program (Lloyd et al., 2014). Participation in the plyometric training in the current study resulted in significantly greater gains in selected measures of muscular power than the comparison group, which is consistent with other reports that noted significant gains in upper body strength and motor performance in children after structured resistance training (Lillegard, Brown, Wilson, Henderson, and Lewis, 1997). As no student was injured during the current study, these encouraging findings indicate that muscular power can be safely enhanced when plyometric training is infused into primary school PE within curricular time. Moreover, these findings are in agreement with recommendations to incorporate resistance training during primary school-based PE so all students can be targeted (Lofgren, Daly, Nilsson, Dencker, and Karlsson, 2013).

The significant improvements in muscular power in this study indicate the positive influence that plyometrics had on the students. Contrary to previous beliefs (Granacher, Puta, Gabriel, Behm, and Arampatzis, 2018), plyometric training seems to be an appropriate stimulus for improving muscular power in primary school students aged seven and eight. It can be argued that students’ improvements in muscular power were associated with various neuromuscular adaptations and improved stretch-shortening cycle, as exhibited by strengthening in the association between the variables RSI and squat jump performance, over the duration of the study. This suggestion corroborates the ideas of Behrens et al. (2016) and Radnor et al. (2018), who indicated that improvements are due to adaptations to structural and neural changes, such as
effective neuromuscular function of the Musculo-tendon unit (efficient and effective interaction between both muscular and neural systems). More recent research supports this suggestion of plyometric training imparting neuromuscular adaptations and improved reactive strength index resulting in enhanced muscular power (Moran et al., 2017; Ramirez-Campillo et al., 2018). Furthermore, there is supporting evidence from systematic reviews that plyometric training improves muscular power in children via enhanced neuromuscular development (Behringer et al., 2011; Johnson et al., 2011; Peitz et al., 2018).

The effect of plyometric training on muscle adaptations could possibly provide an explanation for the improvement in motor performance skills and muscular power within this study. Studies have examined the effect of plyometric training on muscle adaptations in adults, resulting in noteworthy intensifications in peak force and maximal muscular contraction velocity in Types I, IIa and IIb/IIx muscle fibres (Behrens et al., 2014; Hirayama et al., 2017; Malisoux et al., 2006). These studies demonstrated the likely effects of plyometric training on mechanistic adaptations and muscle activation programs in adults, nevertheless, investigation and experimentation of whether the equivalent adaptations can hold true for children need to be explored. Hence, it may be that the increase in SSC function resulting from plyometric training in the current study is a result of the following adaptations; enhanced activation of motor units, increased contraction velocity, pre-activation and a larger reliance on the brief latency stretch reflex, culminating in an enhanced response from SSC function (Saez Saez de Villarreal et al., 2009; Markovic and Mikulic, 2010). It appears that when PE lessons incorporate principles of plyometric training, it can induce positive effects on SSC and both upper and lower body muscular power. Thus, SSC stimulation could be crucial for the augmentation of motor performance skills.
This study revealed that the comparison group’s motor performance skills and muscular power did not change. As the eight weeks of PE lessons had minimal effect on motor performance skills or muscular power measures, the present findings suggest that the standard PE curriculum may benefit from plyometrics training in developing improvements in these areas. The results from this study suggest that the PE lessons alone may not have been able to achieve an appropriate ‘training load’ to elicit further improvements in motor performance skills (Behringer et al., 2011; Faigenbaum et al., 2014; Faigenbaum et al., 2014; Tveter and Holm, 2010). This is important to note, since training loads and skill-building exercises are thought to be influential during the developmental periods in which children experience a high level of neuromuscular plasticity (Myer et al., 2015; Myer et al., 2013). This has implications from a student physical fitness perspective, and for plyometric training being an important pedagogical method for accelerating improvements in MPS and muscular power.

Weekly participation in PE lessons with the inclusion of plyometric exercises during the warmup phases can make an important contribution to the improvement of motor performance skills of primary aged students. Indeed, effective use of time in PE lessons is important to develop proficiency in movement skills (Bailey, 2006; Barnett et al., 2016). Moreover, it seems in the current study that regular PE classes were insufficient to attain significant improvement in motor performance skills and physical capacities of primary school children over an eight week period. An implication of this is the possibility that pedagogical elements could be aligned with teaching and learning activities that use plyometric principles. This would also be in line with pedagogical assumptions that the perception of experiencing training and development of physical capabilities also supports motivation and acquisition of knowledge (Bukowsky, Faigenbaum, and Myer, 2014; Culpan, Draper, and Stevens, 2011).
The results of the current study seem to suggest that muscular power and motor performance skills proficiency were strongly related. Therefore, it seems that plyometric training may provide practical benefits as a strategy for developing motor performance skills. Muscular power is required for the execution of movements to manipulate body mass (e.g. jumping) or an implement or projectile (e.g. ball) (Bourdin et al., 2010; Vanezis and Lees, 2005). The constant within these examples, which may be a limiting factor of performance, is the individual’s muscular power. Previous research has suggested that children require adequate muscular power to perform many motor performance skills which are ballistic in nature, such as running, kicking, hopping, and skipping (Stodden et al., 2013). It has been suggested that children engaged in resistance training such as plyometrics, show training-induced gains in muscular power and skills such as running, throwing and jumping (Behringer et al., 2011). Furthermore, it is noteworthy that the results of the current study indicate that the development of upper body muscular power is significantly related to the development of motor performance skill. Albeit speculative, this finding may suggest that the increased upper body muscular power may have improved motor performance skills via enhanced upper body stability, improved rate of force production, and better synchronization of upper body segments (Collins et al., 2019; Faigenbaum et al., 2014).

As alluded to previously, the FMS-Polygon performance improvement was closely aligned with the degree of improvement in the medicine ball throw. It appears that increased muscular power exhibited in the medicine ball throw performance over the course of the intervention aligned with the improvement in the FMS-Polygon test. Although the physiological mechanisms underpinning such results were not within the scope of this investigation, several adaptations could be put forward including; plyometric exercises resulting in increased
stimulation and activation of motor units, higher neural firing frequency and greater generation of force (Pienaar and Coetzee, 2012) (Pereira et al., 2015). While the improved upper body muscular power is directly dependent on the rate of force generation, the improvement in motor performance skills proficiency are a likely consequence of such adaptations. As such, it appears that plyometric training significantly improved throwing abilities, which may have in turn been transferred to FMS- Polygon results. The low correlation between changes in jump measures and polygon-performance, however, is likely related to jumping-capacities not being highly challenged in the FMS-polygon. Therefore, in contrast to medicine ball throw, significant improvements in jumping performances were not directly translated to changes in FMS-polygon.

As previously discussed, it would appear that motor performance skills and muscular power are associated. This is a positive finding in this cohort, as it indicates that other forms of resistance training could be effective in developing muscular power, and therefore useful in enhancing students’ motor performance skills. A further important finding is that a small proportion of the lesson time (the warmup) was utilised for plyometric training, yet it was still shown to be effective. In addition, a novel aspect of the current research was that it examined the relationship between motor performance skill and upper and lower body muscular power in children aged 7 and 8 years, utilising a plyometric intervention embedded in the PE lessons. These findings provide supporting evidence for the safe and effective implementation of plyometrics into the PE curriculum.

In the current study, the medium to large effects reported for children’s motor performance skills and the measures of muscular power in the plyometric group may be attributable to the high level of physiological sensitivity of the children to plyometric exercises, and the related training load. Viru et al. (1998), Borms (1986), and Vrijens (1978) suggest that
critical periods of heightened sensitivity to training adaptations exist during childhood. Recent research also provides support that children can improve SSC function and measures of muscular power as a result of power training such as plyometrics (Bogdanis et al., 2019; Radnor et al., 2018). Between the ages of six and ten, children’s central nervous system has a high level of plasticity and are more sensitive to stimuli which influences the development of motor performance skills (Barnett et al., 2016; Stodden et al., 2008; Viru et al., 1998). In essence, children are more able to adapt and develop to their environment when compared with older adults. Such stimuli include physical training and neuromuscular development training such as plyometrics (Ford et al., 2011; Lloyd et al., 2011; Meylan, Cronin, Oliver, Hopkins, and Contreras, 2014; Viru et al., 1998; Williams et al., 2008). Due to this high level of sensitivity, researchers have suggested childhood as the ideal opportunity to introduce plyometrics to enhance the development of motor performance skills (Behringer et al., 2010; Faigenbaum et al., 2016; Faigenbaum et al., 2014; Lloyd et al., 2011; Viru et al., 1998). Moreover, from the findings of the current study, it is plausible to suggest that plyometrics provided greater stimuli for the development of motor performance skills in seven and eight-year-old children than PE alone.

Although the mechanisms responsible for the association between motor performance skills and muscular power are not entirely understood, there are a number of factors that may contribute to a child’s level of proficiency. The analogy “you can’t shoot a cannon from a canoe” emphasises the importance of lower body muscular power for the development of motor performance skills, especially postural control, throwing and change of direction. Several studies have shown that lower body muscular power enhances postural control, throwing (velocity and distance) and change of direction (Granacher and Gollhofer, 2012; Granacher et al., 2016; Suchomel, Nimphius, and Stone, 2016). In the current study, the squat jump and estimated peak
power were both moderately related to medicine ball chest throw and FMS-Polygon. This finding might be related to the increased trunk and lower body neuromuscular performance that moves the body proficiently, which is necessary for motor performance skills. Interestingly, the lower body provides a base for most of the tasks in FMS-Polygon, TGMD-2 and Peabody Developmental Motor Scales - Second Edition (PDMS-2) and assists the kinematic chain for upper body movements. Previous research has also suggested that children require adequate muscular power to perform many motor performance skills which are ballistic such as running, kicking, hopping and skipping (Stodden et al., 2013). Furthermore, the findings of the current study suggest that the development of upper muscular power is closely related to motor performance skill.

5.6 Chapter Conclusion

The findings of the current study support, in part, the research discussed in this chapter, and other research focusing on the effect of plyometric training on aspects of motor performance skills in older children, youth and young adults (Faigenbaum et al., 2007; Kotzamanidis, 2006; Ramirez-Campillo et al., 2014; Sankey, Jones, and Bampouras, 2008; Thomas et al., 2009; Voisin and Scohier, 2019). In addition, the results of the current research extend the findings of the studies mentioned above by demonstrating a positive effect in seven and eight year old students, that can be achieved by incorporating a plyometric program into the warmup phase of the PE lesson, and only 15 minutes are required. The implications of these findings include:

- Plyometric exercise is suitable for seven and eight-year-old primary school students to accelerate the improvement of their motor performance skills
- Plyometrics exercises should be considered when planning PE units targeting the development of motor performance skills.

- Plyometric exercises should be considered when planning PE units targeting the development of components of fitness, such as muscular power.

5.7 Limitations of the Study

The study included a number of areas that limit the generalisability of these findings. The limitations include:

1. Only one school engaged. Therefore, caution should be used in drawing conclusions regarding how well suited the program design may be for primary schools in general.

2. The research addressed only plyometric training in seven and eight-year-old children. Thus, the results from this investigation are only applicable to students of this age, and they do not provide insight into long-term training adaptations.

3. The study did not include a no-PE comparison group in the school setting. This was due to PE being a compulsory subject in NSW, and therefore it was not possible within the scope of this study to include a no-PE group.
Chapter Six - Conclusion

6.1 Summary and Implications for Practice

This research was undertaken to examine PE lessons infused with plyometric training on the following dependent variables; motor performance skills, upper body muscular power and lower body muscular power of students aged seven and eight. The work developed in this study contributes to historical and contemporary theories and research findings in the areas of motor development, PE and paediatric exercise. Evidence testing the three hypotheses of this study has been provided and explanations for the results have been discussed, adding to the body of work endeavouring to enhance the development of motor performance skills in PE.

The findings of this study have important implications for pedagogical practice that could improve student learning outcomes. Evidence from this research indicates that PE lessons which include plyometric training were influential in improving the motor performance skills of students aged seven and eight years. As the study utilised a larger sample (N= 61) than other similar studies, the results can, to a degree, be generalised to seven and eight-year-old NSW Primary School Stage One students. The findings of this investigation show that significant improvements in students’ motor performance skills and muscular power can be achieved simultaneously in a short period of eight weeks within PE lessons. The implications of this are that if improvements can be achieved in eight weeks, it is possible that students could make even further progress if plyometric training were used regularly in PE lessons throughout the year.

From the current study, it is also interesting to note the improvements in students’ motor performance skills may be transferred to a range of physical activities and sports. Many physical activities and sports (e.g. softball, netball, rugby league and basketball) require students to
perform a range of motor performance skills. Students' improvement in motor performance skills likely learnt in the unit of this study could be transferred to some, if not all sports, a notion that closely aligns with skill acquisition literature (Lämmle et al., 2010). Moreover, plyometric training embedded into the warmup phase of the PE lesson would potentially reduce the time required for students to learn how to perform specific skills required for games and modified activities, as they have already developed the capabilities required to perform the skills.

The results of this study support the idea of exposing students to plyometrics early in primary school. Early exposure can result in accelerated development of motor performance skills at an earlier age. It can be suggested from this work that enhanced motor performance skills at an earlier age may result in students acquiring the level of proficiency appropriate for secondary PE, where more specialised sports skills are taught (NESA, 2018). Furthermore, based on the notion that seven and eight years of age is a critical period for the attainment of motor performance skill proficiency, plyometric training could be utilised as a strategy to achieve the K-6 PDHPE syllabus objectives such as moving with confidence and competence within and across physical activities (NESA, 2018). As such, the study results are important for PE practitioners, as they provide support for the use of plyometrics in achieving a range of overarching objectives and outcomes. In practice, there is scope for this approach to gain more traction in Australian primary schools.

In the current study, the ability of students to develop motor performance skills and muscular power as a result of engaging in plyometric training has significant implications for teaching practice. This study showed that the plyometric group improved in the post-test measures, likely as a result of the alternative plyometric warmup activities. The findings also support the importance of incorporating teaching strategies that develop the underlying
capabilities of motor performance skills in PE (i.e. muscular power). The implications of this for teaching practices are twofold. Firstly, by engaging students in plyometric training during the warm-up phase of the lesson rather than increasing class time or changing teaching pedagogy, schools can provide their students with an opportunity and stimulus to develop motor performance skills during the warmup, while retaining valuable class time. Secondly, teachers may implement in-class upper and lower body plyometric exercises as a strategy to enhance skill-related fitness such as muscular power and also performance (i.e. jumping, throwing) in children aged 7 and 8 years. These two implications are currently supported by the NSW K-6 PDHPE Syllabus which recommends providing students with teaching and learning activities “that focuses on active participation in a broad range of movement contexts to develop movement skill and enhance performance” (NESA, 2018, p. 26) and also providing Year Two students with the opportunities to “participate in new and unfamiliar physical activities to develop fitness and health” (NESA, 2018, p. 54). Therefore, the use of plyometric training could be an important consideration in unit and lesson planning. Incorporation of plyometric training into PE is exemplified in a review by Konukman et al. (2018) and also supported by Faigenbaum et al. (2011) who suggest developmentally appropriate PE practices such as plyometrics may improve motor performance skills and promote being physically active. Plyometric training may benefit PE teachers by increasing their repertoire of strategies to meet the NSW PDHPE Syllabus objectives of developing students’ capabilities and potential for participation as best practice for lifelong participation in physical activity (NESA, 2018).

The notion of value-adding to the education of students without significantly creating a time issue may also relate to the lifelong physical activity standpoint. Specifically, the development of motor performance skills underpins the concept of physical literacy and
engagement in lifelong physical activity (Lundvall, 2015; Tompsett et al., 2014). Fundamentally, through engaging in plyometric training, which is embedded into regular PE lessons, students may be better able to develop motor performance skills that could apply to a range of physical activities and sports, thus furthering their potential to participate in physical activities and sports more comfortably throughout their lives. Therefore, teachers may consider using plyometrics to achieve curriculum goals.

Over the lifespan of an individual, choice of physical activity may change, however, the muscular power capability related to motor performance skills remains important. An individual’s overall performance of general sports skills (e.g. throwing, sprinting, jumping, kicking and change of direction), and specific sport skills performance, relies on muscular power to some degree (Suchomel et al., 2016). Based on the results of the current study, it can be inferred that when muscular power is developed, students may enjoy greater success in performing required motor performance skills. Furthermore, the results also provide grounds for potential research into whether increased time devoted to the development of muscular power via plyometric training can further improve motor performance skills.

The current study has shown that when a capability such as muscular power, which underlies the development of motor performance skills is enhanced using plyometric exercises in-class, student motor performance skills will improve significantly. As such, findings from the current study support the suggestions of the ‘2018 Active Healthy Kids Australia’ report on physical activity for Australian children and young people (e.g. increase children’s engagement in activities that enhance muscular power to improve fundamental movement skills) (AHKA 2018). The results from this study provide evidence that plyometrics can be a valuable teaching model from an in-class PE standpoint, a benefit that prior to this study was only supported by
presumptions. There now would appear a justification for primary school PE programs and teaching units to consider adopting muscular fitness activities such as plyometrics.

Plyometric training is recommended for improving stretch-shortening cycle muscle function as measured by the reactive strength index in adolescents and adults (Vetrovsky, Steffl, Stastny, and Tufano, 2019). This study adds to the body of knowledge of the changes to the stretch-shortening cycle resulting from children participating in plyometric training. The plyometric group improved reactive strength index substantially from pre-post-test, although there was no significant difference between groups observed, a trend towards significance was noted. It may be speculated that plyometric training embedded in PE, might be an efficient means for developing the stretch-shortening muscle function, which plays a vital role in sprinting, change of direction and hopping actions. Plyometric training employed in the current study was shown to be particularly beneficial to students and likely played an important role in the improvements in student motor performance skills. The implications could extend further than primary school PE settings and have utility for the teaching of games and sports in high schools, as well as for curriculum development. For instance, if students commence secondary school with proficiency in motor performance skills, the PE teacher could potentially focus more on advanced strategies and skills, that provide opportunities to achieve Stage Statements from the Syllabus (NESA, 2018). It can also be argued that the significant influence plyometric exercise had on motor performance skills in the current study was the product of the emphasis placed on student neuromuscular and power capabilities in relation to underlying predictors of performance common to games and sports. It is recommended that this capability be developed explicitly within the PE lessons in their own right, becoming another key lesson feature, and facilitating participation, engagement and demonstration of movement skills as per the NSW
PDHPE K-6 Syllabus. Also, the results of the current study provide reasons to investigate whether other forms such as muscular power training, using resistance training principles, are advantageous in school settings.

Overall, the findings of the current study suggest that the delivery of plyometric training with age-appropriate training and instruction has the potential to be a safe and justifiable primary school-based PE intervention which also aligns with the NSW PDHPE curriculum. The study also indicates that plyometric training delivered by a qualified PDHPE teacher, can lead to significant student improvement in motor performance skills and components of skill-related fitness such as power, whilst also being a safe and time-efficient method for students to learn within the meaningful context of primary school PE. One of the significant findings to emerge from this study is that 10-15 minutes of plyometric training performed twice weekly over a period of eight weeks, results in significantly greater increases in motor performance skills and components of skill-related fitness measure and muscular power, than increases normally achieved with traditional PE. Interventions such as plyometric training may be an important component of primary student PE programs because the synergistic association between motor performance skill and muscular power may strengthen over time, and help achieve the curriculum objectives of motor performance skill proficiency and lifetime engagement of physical activity. The positive findings from the present study can be used to inform the design and implementation of future interventions which are needed to assess the long-term effects of plyometric training on PE outcomes in primary students.
6.2 Directions for Future Research

The results of the current study have provided a foundation for future research. Further research could be to investigate whether the plyometric exercises used in the current study have a similar influence on motor performance skills in students of different age groups. The same research could be conducted with students in later stages in primary school. Alternatively, the effect of plyometric exercises within PE in secondary school could be assessed. This additional research would assist in further promoting and validating plyometric training within the education setting, as it would contribute to a complete picture of the age-appropriateness of plyometrics to improve students’ motor performance skills within the PE setting.

The current study has also demonstrated that there is a benefit to using training exercises and teaching students to perform exercises with an educative purpose and strengths-based approach in mind, as opposed to focusing on engagement and participation. Consequently, plyometric training may provide inherent educational value to students. Focusing on capabilities required for motor performance skills seems to have the capacity to allow students to link what they are presently learning about to their previous experiences in games and sports contexts (Barnett et al., 2016; Stodden, Gao, Goodway, and Langendorfer, 2014). Providing professional development with this in mind may deliver better outcomes due to the potential to improve content knowledge and pedagogical knowledge concurrently. In addition, it may be beneficial in providing access to plyometric training for all teachers and could reduce the difficulty of implementation. In essence, teachers may require opportunities to learn the main plyometric concepts and how to deliver the activities safely. It can be suggested that this would be a beneficial area for investigation because plyometrics have repeatedly demonstrated the capacity to promote muscular fitness and develop motor performance skills in athletic populations.
Although inferred links were made between motor performance skills and students’ muscular power, the current study did not directly investigate other specific aspects of muscular fitness such as endurance and strength. As such, a further area of study that could stem from the current research would be to assess these outcomes in PE classes utilising plyometrics explicitly. This would have the benefit of providing a clear picture of plyometric advantages within other aspects of muscular fitness (e.g. strength and endurance). Furthermore, a study of this nature could be linked to one that examines the potential benefits of plyometric induced motor performance skills benefits to contribute to lifelong physical activity. One way in which this could be achieved would be a longitudinal study investigating whether students’ participation in physical activities outside of school leads to increased engagement in physical activity, after participation in a plyometric training PE unit. This would indicate if the learning outcomes from the teaching unit translate into participation outside of school and if it has, the potential to facilitate students’ participation in these sports across their lifespans.

Students in this study had an opportunity to learn and perform plyometric exercises while improving their muscular power in a supportive PE environment that was engaging. Although it did not compare performance between students with low and high motor performance skill proficiency, plyometric training may be particularly beneficial for students with low muscular power or reduced motor performance skill proficiency. Considering that students with low muscular power or motor performance skill proficiency may be less likely to engage in physical activity (Schranz et al., 2018), these students are most likely to benefit from involvement in developmentally appropriate resistance training type of exercise (Fransen et al., 2014; Haga, 2009; Hands, 2008).
Considering the study findings, the identified study limitations (see Section 5.7), and the implications as mentioned previously in this chapter, the following key recommendations are made:

- The study design included a comparison group which was also engaged in PE lessons. There is, however, some uncertainty concerning the representativeness of changes in motor performance skills and muscular power in the comparison group compared to students who abstain from PE lessons. As such, inclusion of a true no-treatment comparison group may have eliminated potential bias that may have impacted on the conclusions regarding the effect of plyometric training on motor performance skills and muscular power of students aged seven and eight. Future research evaluating the short-term effects of similar movement programs may need to consider potential forms of comparative groups.

- To understand more clearly the effects of the intervention program in this study, along with the long-term benefits, future studies should consider the addition of secondary post-intervention tests in the study assessment protocol to assess long term impact.

- As improvements in motor performance skills were evident following the PE intervention in this study, the findings from this study suggest that teachers seeking to improve motor performance skills in students aged seven and eight should consider using the described pedagogical approach.

- As improvements in motor performance skills and muscular power progressed from week one to week eight of the study, future studies should consider and investigate the following modifications that may assist in further improvements:
(i) providing the plyometric training over a longer duration (e.g. two school terms) to allow skill development and to become more established (ii) providing a reduced quantity of traditional PE content over eight weeks and increasing the duration of plyometric training within the lesson, and (iii) providing complementary PE lessons which only involve plyometric training.

6.3 Conclusion Summary

From the current research, several valuable conclusions can be drawn. The principle purpose of this study was to investigate the influence that a plyometric warmup could have on motor performance skills of children aged seven and eight in a primary school setting. One of the primary findings from this study was that using plyometrics training in the PE lessons warmup can facilitate more significant development of motor performance skills than standard PE lessons alone in primary students aged seven and eight. This finding provides evidence that plyometrics should be considered as an element of effective pedagogy for developing motor performance skills in primary school PE students aged seven and eight years. Although further research is needed, this finding provides strong evidence that plyometrics have the potential to assist teachers in addressing one of the main objectives of PE: the provision of quality and enriching learning experiences in the area to assist in the adoption of lifelong physical activity (NESA, 2018).

The current findings are significant on several levels, not only for PE teachers and those interested in developing muscular power in young athletes but also for advocates and researchers of childhood paediatrics. In essence, the current study provides further empirical evidence that from a student learning perspective, plyometric training can be effective in actual school settings
in both improving motor performance skills and muscular power. The results of the current study affirm the findings of earlier plyometric research while addressing the problem that much of the evidence in this area has been from research investigating older children, or in the athletic setting. Moreover, the current study highlights that claims made in previous research (Attene et al., 2015; Barber-Westin, Hermeto, and Noyes, 2010; Bishop, Smith, Smith, and Rigby, 2009) are applicable in the teaching and learning landscape. Additionally, the results partially fill the void that exists in the literature regarding the effectiveness of plyometric training in Australian primary schools.

Another purpose of the current study was to investigate the association between muscular power and motor performance skills with Year Two students. In summary, the findings show that both upper and lower body muscular power is associated with motor performance skill performance. Primarily, the results inform us that providing students with opportunities to develop muscular power as directed by the syllabus (NESA, 2018), may provide increased motor performance skills proficiency.

The reactive strength index findings of the current research are significant because, like the motor performance skills results, they address an oversight in the literature. Prior to the current study, there had been little research that had examined the effect of plyometrics on RSI of seven and eight-year-old students who have participated in plyometric training. Thus, the evidence this study affords researchers and teachers should be of worth, as it is original and provides insight into the levels of RSI that can be achieved in PE lessons. These results are also valuable because RSI is a measure of the stretch-shortening cycle which is one of the adaptations of plyometrics, leading to increased muscular power. Ultimately, the current study indicates that using plyometrics in PE could improve muscular power by enhancing the stretch-shortening
Furthermore, the plyometric group results suggest that the plyometric training could assist educators in achieving a principal aim of primary PE, which is providing a range of opportunities to promote the development of motor performance skills in order to benefit students’ health and wellbeing (NESA, 2018).

Although further research is needed, the current study provides support that employing plyometric training could have the potential to assist educators in accelerating the development of motor performance skills in primary school PE. It is anticipated that the results of the current research will stimulate debate and lead to further investigation to validate the abovementioned claim, in addition to encouraging researchers to direct their efforts towards fulfilling the potential of the approach and supporting its implementation. Moreover, it is anticipated that the findings of the current study will encourage educators to consider the use of plyometrics in primary school PE, as it provides evidence of the substantial learning benefits the approach can afford students.

Although improvement of medicine-ball-throwing capacity was the lowest of all other studied variables, it seems that improvement of this capacity should be considered as crucial for progress in overall motor functioning of children aged seven and eight. Therefore, further experimental studies should specifically investigate modifications of the applied plyometric program in order to achieve superior effects in throwing capacities. Possible modifications may consist of: (i) higher frequency of throwing-oriented exercises, and (ii) inclusion of different forms of ‘assisted’ upper-body exercises (i.e. partner-assisted push-ups, rubber band exercises, push-ups on trampolines).

While skill development drills and practise within a game-like environment are often part of PE curriculum, the thesis findings indicate that PE infused with plyometric training can
enhance motor performance skill proficiency and muscular power in young primary students. Hence, PE curriculum infused with explosive strength exercises such as plyometrics can engage students in ways that develop their movement performance skills and muscular fitness while still being sufficiently oriented toward improvement of motor skills.

The study’s findings reinforce the potential that PE curricular have in improving motor performance skills in children. Collectively, the findings suggest that plyometric training as employed in the present study, may be a safe and valid PE pedagogical strategy to aid in the development of motor performance skills.


Australian Curriculum Assessment and Reporting Authority. (2015). *Health and Physical Education: Sequence of content F-10 Strand: Personal, social and community health.*


Childhood. Procedia - Social and Behavioral Sciences, 117, 60-66. doi:http://dx.doi.org/10.1016/j.sbspro.2014.02.179


National Heart Foundation of Australia. (2019). *Blueprint for an active Australia: National Heart Foundation of Australia.*


New South Wales Audit Office. (2012). *Physical Activity in Government Primary Schools: Audit Office of NSW.*


explosive strength, and kicking speed in female soccer players. *Journal Strength Conditioning Research, 23*(6), 1714-1722.


Smith, W. (2014). Fundamental movement skills and fundamental games skills are complementary pairs and should be taught in complementary ways at all stages of skill development. *Sport, Education and Society, 1*-12. doi:10.1080/13573322.2014.927757


Games and Sport: Ball Games

**Outcomes and Indicators**

Knowledge and Understanding

GSS1.8 Performs fundamental movement skills in minor games

Skills

MOS1.4 Demonstrates maturing performance of basic movement and compositional skills in a variety of predictable situations

Values

V1 Willingly participates in regular physical activity

**Unit Evaluation**

Were the students actively engaged in the learning experiences?
Were the learning experiences appropriate for the stage of learner?
Were there adequate resources available to students?
Did the learning experiences closely link to the stated outcomes?
Did the student assessment tasks cater for varying student-learning styles?
Did the students achieve the stated outcomes?

**Resources**

Witches hats, balls of various sizes, hoops, bean bags

**Assessment task:** A checklist of skills that are to be taught with a code to fill in.
<table>
<thead>
<tr>
<th>Lesson</th>
<th>Activities</th>
<th>Tick if Completed</th>
</tr>
</thead>
</table>
| 1-3    | **Dribbling with Feet**  
- Organise the children into rows of about 5 or 6 children. Give each row a soccer and place a witches hat about 10 metres in front of the row (See Diagram)  
[Diagram]
- Children  
- Teacher demonstrates how to dribble using the outside of the right foot. Children dribble to the witches hat and back.  
- Repeat for Left Foot and inside of foot. (Emphasise it is not a race and it is important do the skill correctly).  
- When all skills have been practiced get children to have a relay race using their new dribbling skills.  
- Play knockout dribble. Children are given a ball each and placed inside a large square. They have to dribble their own ball around while at the same time try to knock out everyone else's ball by kicking them out of the square. Once you ball goes outside the square you are out of the game. The winner is the last one with their ball.  
- Play 'Dribble Relay'. | |
| 4-6    | **Bouncing Dribbling**  
- Children begin in lines of even length. Teacher demonstrates how to dribble, emphasising a strong wrist and a firm push of the ball, not a slap. Children take turns dribbling the ball from one place to another.  
- When done with their preferred hands get them to repeat with their non-preferred hand.  
- Practice dribbling on the spot and swapping hands.  
- Practice dribbling in various positions in relation to their body  
  - In front of  
  - To the left  
  - To the right  
  - From side to side  
  - At different heights  
  - Around the body  
  - A specified number of times  
- Have three relay games where they dribble up with their right and back with their left hand. | |
7-9 **Catching and Throwing**
- Teacher demonstrates how to throw and catch a chest pass using a netball.
  - **Throw:** Fingers spread slightly, both hands behind the ball and pushing with both hands evenly. Explain that it is used for throwing over short distances.
  - **Catch:** Fingers spread slightly and aimed upwards. Palms to the thrower. Thumbs pointing at each other. (Explain it is important to have thumbs pointing at each other to stop the ball hitting the catcher in the face)
- Children practice what has been shown with a partner.
- Play game of 'Captain Ball'.
- Play 'Throwing softball'

10-12
- Teacher demonstrates how to throw a shoulder pass using a beanbag.
  - Start at the shoulder with preferred hand.
  - Opposite forward with toes pointing where you want the ball to go.
  - Push from the shoulder and let your arm fall across the body to end up near the opposite hip.
- Children practise throwing to a partner.
- Teacher demonstrates how to throw under arm.
  - Hand under the ball
  - Opposite foot forward
  - Release the ball at waist height.
- Repeat all throwing types but get children to experiment with different ways of throwing and using different equipment.
  - Vortex
  - Tennis ball
  - Netball
  - Sitting down/kneeling
  - At targets
  - While moving
- Get children to play 'Hit the skittles'. Children try to hit skittles set up a short distance away using underarm
passes. The team to knock over the most skittles is the winner.

- Play 'Zone Ball Passing' game
- Discuss with the children what happens to your throwing with the various ways of throwing.

<table>
<thead>
<tr>
<th>13-14</th>
<th>Kicking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Teacher demonstrates the various ways to kick a ball</td>
</tr>
<tr>
<td></td>
<td>- Inside of foot, outside of foot, instep</td>
</tr>
<tr>
<td></td>
<td>Children experiment with the various ways of kicking</td>
</tr>
<tr>
<td></td>
<td>- A stationary ball</td>
</tr>
<tr>
<td></td>
<td>- A moving ball</td>
</tr>
<tr>
<td></td>
<td>- Over various distances</td>
</tr>
<tr>
<td></td>
<td>- To hit a target</td>
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<tr>
<td></td>
<td>- Between two objects</td>
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<tr>
<td></td>
<td>- With either foot</td>
</tr>
<tr>
<td></td>
<td>- Along a line</td>
</tr>
<tr>
<td></td>
<td>- Into the air and catching it</td>
</tr>
<tr>
<td></td>
<td>Play 'force em back'. Divide into two teams and set up a field with a line at each end. The aim of the game is to try to kick the ball long so that you kick it over the other teams back line. However, if you get caught on the full they get to take two steps forward and then kick it and you are out of the game. The first team to kick the ball over the other teams back line is the winner unless the other team manages to catch all their team out first.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>15-16</th>
<th>Striking (Hitting or Batting)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Teacher demonstrates how to hit the ball with various pieces of equipment, i.e.: left/right hands, paddle bats, off tees and stands, cricket bats, etc</td>
</tr>
<tr>
<td></td>
<td>Set up various stations with each piece of equipment. Children are split into small groups and have a go at each station.</td>
</tr>
<tr>
<td></td>
<td>Play hitting game: continuous cricket</td>
</tr>
</tbody>
</table>
Appendix 2: A 3D Sketch and Floor Plan of the FMS- Polygon


Appendix 3: Ethics Committee Approval

INITIAL APPLICATION APPROVAL
In reply please quote: HE13/374
Further Enquiries Phone: 4221 3386

15 January 2014

Dr Dana Perlman
Office 23.607
Faculty of Education
University of Wollongong

Dear Dr Perlman,

Thank you for your letter dated 6 January 2014 responding to the HREC review of the application detailed below. I am pleased to advise that the application has been approved.

Ethics Number: HE13/374
Project Title: Effects of Plyometric Activities on Motor Performance Skills in Primary School Children Aged Seven to Eight
Name of Researchers: Dr Dana Perlman, Mr Andrew Sortwell

Documents Reviewed/Approved:
1. Initial application
2. Additional information received 6 January 2014
4. Appendix B Plyometric Activities version received 6 January 2014
5. Appendix C Rate of perceived Exertion version received 6 January 2014
6. Appendix D Children's Leisure Activities Study Survey (Parent Questionnaire) version received 6 January 2014
7. Pedometer Diary version received 6 January 2014
8. Appendix F Initial Warm-Up Protocol version received 6 January 2014
9. Appendix G Information Packs version received 6 January 2014 (Letter of Introduction – Parents; Study Description – Parents; Letter of Introduction – Students; Study Description – Students)
10. Appendix H Consent Form for Children version received 6 January 2014
Approval Date: 14 January 2014
Expiry Date: 13 January 2015

The University of Wollongong/ISLHD Health and Medical HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research. The HREC has reviewed the research proposal for compliance with the National Statement and approval of this project is conditional upon your continuing compliance with this document.

A condition of approval by the HREC is the submission of a progress report annually and a final report on completion of your project. The progress report template is available at http://www.uow.edu.au/research/rio/ethics/UOW009385.html. This report must be completed, signed by the appropriate Head of School and returned to the Research Services Office prior to the expiry date.

As evidence of continuing compliance, the Human Research Ethics Committee also requires that researchers immediately report:

- proposed changes to the protocol including changes to investigators involved
- serious or unexpected adverse effects on participants
- unforeseen events that might affect continued ethical acceptability of the project.

Please note that approvals are granted for a twelve month period. Further extension will be considered on receipt of a progress report prior to expiry date.

If you have any queries regarding the HREC review process, please contact the Ethics Unit on phone 4221 3386 or email rio.ethics@uow.edu.au.

Yours sincerely,

Associate Professor Sarah Ferber
Chair, UOW & ISLHD Health and Medical
Human Research Ethics Committee
Appendix 4: Sydney CEO Research Application

G U I D E L I N E S to C O N D U C T R E S E A R C H in
A R C H D I O C E S A N C A T H O L I C P R I M A R Y a n d S E C O N D A R Y S C H O O L S
U N D E R the J U R I S D I C T I O N o f t h e
C A T H O L I C E D U C A T I O N O F F I C E, S Y D N E Y
30 March 2011

The Catholic Education Office (CEO), Sydney requires the following conditions to be met by the researcher(s) prior to approving the conduct of a research study in Archdiocesan primary and secondary systemic schools:

- completion of the CEO, Sydney Application to Conduct Research (see Attachment)
- evidence that the research complies/will comply with all legislation, specifically:
  - Child Protection
  - Privacy
- a copy of the University Ethics Committee Approval is included with the Application (where appropriate/required by the University or Institute)
- nomination by the researcher of the schools proposed to be included in the research study
- agreement by the researcher that it is the prerogative of the Principal whether or not to participate in, continue, or terminate participation in the research project
- agreement by the researcher to provide a copy of the research findings to the CEO, Sydney upon completion.

Proposals to conduct research are ordinarily approved when the research being proposed meets the above criteria and conditions, and will produce outcomes which will explicitly focus on:

- improving student learning outcomes
- the craft of teaching
- the leadership and management of schools and/or education systems
- adding to the understanding of education and the role it fulfills in society.

Research Applications are not approved when the research study as described in the Application is judged to be, or is judged as having the potential to be:

- contrary to Catholic values and teachings
- not primarily focused on the education sector
- adversely impacting on teaching and learning time of students and/or the daily school routine
- repetitive of research studies previously undertaken in Archdiocesan systemic schools
- inflammatory or divisive
- primarily/solely for private gain
- trivial in nature.

Note that the CEO, Sydney has jurisdiction only for systemic schools in the Archdiocese of Sydney. Other Sydney Diocesan systems (Broken Bay and Parramatta) and ALL Congregational/independent Catholic colleges and schools are outside its jurisdiction.
NSW CHILD PROTECTION and COMMONWEALTH PRIVACY ACT LEGISLATION REQUIREMENTS

To be completed and returned with the application package

Approval to conduct research in Archdiocesan Catholic schools under the jurisdiction of the Catholic Education Office (CEO), Sydney is subject to evidence being provided of full compliance with NSW Child Protection and Commonwealth Privacy Act legislation. (Please note that researchers from other States are also required to comply.)

NSW CHILD PROTECTION REQUIREMENTS
The researcher must fully comply with all aspects of the ‘Commission for Children and Young People (CCYP) Act 1998’. Recent legislative amendments as a result of the NSW Government’s Keep them Safe reforms have resulted in changes to the Working with Children Check. Forms can be found on the CCYP website: https://check.kids.nsw.gov.au.

The amendments to the legislation require that researchers in paid child-related employment complete the Applicant Declaration and Consent form. It is the responsibility of the employer to ensure that this requirement is met. It is a further condition of research approval that your research institute/university provides a Compliance Letter on their letterhead, ensuring that the Organisation’s CCYP Employer Identification Number is contained therein. A sample of the required contents of said letter is attached. The signed Compliance Letter must be submitted with the research application package. A photocopy of the letter will be provided to you for sighting by the Principal at each participating school should your application be approved.

If the researcher is in a voluntary/unpaid capacity (e.g., university students completing graduate or postgraduate study with a research component), they are required under the legislation to complete a Volunteer/Student Declaration form. Working in an unpaid capacity means that the researcher does not meet the requirements for a Working with Children Background Check (employment screening) and therefore any contact with students must be supervised by a member of the school staff. A photocopy of the signed form will be provided to you for sighting by the Principal at each participating school should your application be approved.

COMMONWEALTH PRIVACY ACT
The privacy of the school and that of any school personnel or students involved in your study must, of course, be preserved at all times and the researcher must comply with the requirements of the Commonwealth Privacy Amendment (Private Sector) Act 2000. In complying with this legislation, the CEO, Sydney has decided that, for the purposes of research applications, students are not to be identified by anything other than age and/or gender.

Please note that your application is unable to be assessed for approval until all supporting documentation is submitted with the research application package.

7 October 2010
Application to Conduct Research Checklist:
To be completed and returned with the application package

Please tick the following items and ensure that all supporting documents are submitted with your completed research application form.

☐ University Ethics Approval Documentation enclosed

☐ Meeting NSW Child Protection Requirements

Will you receive payment for the research?
Yes □ □ No □

Is direct unsupervised contact with students required?
Yes □ □ No □

* If yes to both questions, a Working with Children Background Check ‘Letter of Compliance’ from your employer (on letterhead) is enclosed

* If no, a signed Volunteer/Student Declaration is enclosed

Yes □ □ No □

If you are conducting this research in a voluntary capacity, the legislation requires that you complete a Volunteer/Student Declaration. Enclosed?

Yes □ □ No □

Please Note: The policy of the CEO, Sydney is that volunteers must be supervised by a member of staff; i.e. no direct unsupervised contact with students is allowed.

☐ Copy of all research instruments / questionnaires enclosed

☐ List of Sydney Catholic primary/secondary schools to be approached.

- A list of Archdiocesan systemic schools may be found on our website at www.ccosyd.catholic.edu.au. Please note that the CEO, Sydney does not have jurisdiction over the schools listed as ‘Congregational’. These are Independent Catholic Colleges and you must seek approval directly from each school.

Please note that your application is unable to be assessed for approval until all supporting documentation is submitted with the research application.
Application to Conduct Research in Schools of the Archdiocese of Sydney under the Jurisdiction of the Catholic Education Office, Sydney

If considered relevant, please attach one additional detail documentation in support of this application.

<table>
<thead>
<tr>
<th>APPLYING/INSTITUTION DETAILS</th>
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<tbody>
<tr>
<td>1. Name of applicant</td>
</tr>
<tr>
<td>2. Address for correspondence</td>
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<tr>
<td>3. Contact phone no</td>
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<tr>
<td>4. Institution for which research is being undertaken (include address)</td>
</tr>
<tr>
<td>5. Course being undertaken (where applicable)</td>
</tr>
<tr>
<td>6. Name of Supervisor of your proposed study</td>
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<table>
<thead>
<tr>
<th>DETAILS OF THE RESEARCH PROPOSAL</th>
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<tbody>
<tr>
<td>7. Title of proposed research study</td>
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</table>
| 8. Brief description of project (include aims, significance, intended research methodology and principal hypothesis(es) where applicable) | AIMS
The aim of the study is to examine the effects of infusing plyometric-based activities within a conventional Health Physical Education practical lesson, on motor performance skills of seven and eight year olds.

HYPOTHESIS
The addition of a plyometric intervention programme to traditional PDHPE practical lesson will confer positive changes in motor performance skills of seven and eight olds.

SIGNIFICANCE
The turn of the century has been characterized by vast technological progress. Children now find themselves in an environment full of sedentary alternatives such as television and computers. This has contributed to a decline in the motor behaviour of children and consequently poor motor...
proficiency. Poor motor proficiency can lead to a vicious cycle of physical inactivity and limited participation in physical activity and sport.

Movement skills help children develop self-confidence, motor competence, and provide them with the opportunity to be physically fit and participate in recreational activities and games. Thus, without developing such movement skills efficiently, the body is unable to experience the level of physical activity needed to maintain healthy hearts, lungs, bones and muscles. Children with low motor competence are more likely to have lower levels of physical fitness, lower levels of physical activity and a greater risk of obesity.

Some recent observations have indicated that plyometric activities may enhance a child’s motor performance skills. Motor performance skills consist of the jump, run, skip, hop, kick, throw, balance, agility which form the basis of performing and learning of complicated sport, physical activities and movement skills common to the community. Research focusing on seven and eight year old children participating in polymeric activities may provide the foundation for new strategies to improving motor performance skills and the likelihood of participation in physical activity.

Plyometric training or programs are a safe and effective method for children to enhance neuromuscular function and specific motor ability core traits. These two main enhancements improved by plyometric training are also strongly associated with enhanced coordination, running speed, speed of movement, jumping ability, proprioception, muscular power and strength. Therefore, participation in plyometric activities may be an appropriate intervention for improving motor performance skills (skills which form the basis of performing and learning of complicated sport, physical activities and movement skills common to the community).

Health and Physical education is the only learning area which focuses heavily on development of movement skill and concepts needed to participate in physical activities with competence and confidence (ACARA & Australian Curriculum, 2012). The acquisition, development, and improvement of motor performance skills and movement skills is an important component of physical education for children and adolescents because it enables students to confidently and competently participate in a range of physical activities. In the draft “Shape of the Australian Curriculum: Health and Physical Education” (SACHPE), there is emphasis on the students, *developing expertise and physical fitness in movements since it forms a prelude for lifelong physical activity participation and to appreciate the significance of physical activity and sport in Australian Society* (ACARA & Australian Curriculum, 2012, p. 2).

In SACHPE in relation to primary education, improving movement skill performances is a common theme for primary school students. This is important since research has shown that children who have better motor skill performance ability will participate more regularly in physical activity as a lifelong activity. Children who are not exposed to an environment with opportunities to enhance motor performance skills (e.g., catching, throwing, running, kicking, and hopping) are more likely to be less active during adolescence, which may manifest into sedentary lifestyle behaviours during adulthood. Below are points from the SACHPE which highlight this theme for these students:
Students will be given opportunities that challenge them to extend their personal capabilities and experiences through participation in a range of physical activities."

Students in these years will have a greater ability to combine movement skills and should be given opportunities to creatively sequence a range of different movements, performing more complicated movement patterns and improving their movement performances in a range of physical activities."

In the current New South Wales (NSW) K-6 Syllabus there is also significant emphasis on the importance of developing movement skills, enhancing motor skill performance, and ultimately increasing the likelihood of lifelong physical activity.

**METHODOLOGY**

A group of 60 primary school students aged seven to eight years of age from John the Baptist Primary Catholic School at Bonnyrigg Heights, will be recruited for this study. Randomisation will be performed at the ‘class level’ and it will be blinded. Two out of the four existing Grade 2 classes at John the Baptist Primary Catholic School will be randomly selected either as the experimental or control group. Data will be collected using a pre-test/post-test design whereby participants will be asked to complete a range of tests which assess motor performance skills, lower and upper body muscular power. Both groups will engage in the same health, physical education practical content. The only difference will be that the treatment group will be provided an alternative warm-up which includes plyometric activities. To monitor the types of physical activity outside the study both groups, will answer surveys with the assistance of their parents at the start, during and end of the study. Pedometers will also be used to monitor the level of physical activity movement at the start, during and end of the study.

9) What research instruments/ questionnaires are to be employed?

- Children’s Leisure Activities Study Survey
- Pedometers
- Just Jump Contact Mat
- FMS-Polygon Test
- Upper body and lower body performance tests
## DETAILS OF THE RESEARCH PROPOSAL (cont'd)

<p>| | | |</p>
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<thead>
<tr>
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<tr>
<td>10</td>
<td>Commonwealth Privacy Act</td>
<td>In complying with this legislation, the CEO, Sydney has ruled that for the purposes of research applications students are not to be identified by anything other than age and/or gender.</td>
</tr>
</tbody>
</table>
| 11 | Has your study received the endorsement of the Ethics Committee (or equivalent) of the institution where you are working or attending?  
(please attach relevant documentation) | YES ☑   | NO ☐ |

## SCHOOL TYPE / SUBJECT SPECIFICATION

<p>| | | |</p>
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<tbody>
<tr>
<td>12</td>
<td>Number/type/particular school(s) you wish to involve in your study</td>
<td>Only one primary school is required to be involved in the study. The school I wish to be involved in this research is John the Baptist Primary School at Bonnyrigg Heights.</td>
</tr>
</tbody>
</table>
| 13 | Number and specification of student, teacher or other subjects required |   | • 60+ students (preferably two classes only)  
• No teachers are required. |
| 14 | Age/grade of student subjects | 7 – 8 years of age / Grade 2 |

## TIMING

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<tbody>
<tr>
<td>15</td>
<td>Proposed commencement date of research</td>
<td>14th of July, Week 1 Term 3 2014</td>
</tr>
<tr>
<td>16</td>
<td>Number of hours/days/weeks of school time required (estimate)</td>
<td>1 hour, two days a week, from week 1 to week 10 throughout Term 3 in 2014</td>
</tr>
<tr>
<td>17</td>
<td>Anticipated completion date of study</td>
<td>19th of September, week 10 2014</td>
</tr>
</tbody>
</table>

## ADDITIONAL INFORMATION/OUTCOMES

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| 18 | Brief outline of any other information pertinent to this application | This research has been discussed with Mr Anthony Lo Cascio who is the Principal of John the Baptist Primary School. The research will be within the current approved Physical Education and Sport lessons. He is happy for the research to be conducted at John the Baptist Primary School as long as the Sydney Catholic Education Office grants permission.  
As a PDHPE Teacher at Freeman Catholic College which is situated next to John the Baptist Primary School, I share a good relationship with the Primary School providing senior students to assist with the Swimming Carnivals and Cross Country events. I feel that the school will be happy to be involved in the research. |

Research Application March 30
The primary focus of this research is education/teaching and learning. Specify briefly anticipated research outcomes which will directly benefit Catholic schools, students and teachers.

This research will provide Catholic School Teachers with new strategies to further develop and enhance fundamental movement skills which are a priority in the NSW K-6 Primary PDHPE Curriculum. Anticipated research outcomes which align with the Primary Physical Education Curriculum include:

1. Enhanced fundamental movement patterns and coordinated actions of the body. Children do not naturally develop fundamental movement skills as they grow. Opportunities should be provided for these skills to be developed, learnt and encouraged. Plyometric activities infused within the lesson will increase the likelihood of the mastery of Fundamental Movement Skills such as throwing, catching, running and jumping which opens up a vast array of sport, leisure and recreation options for the individual.

2. Improved skills that enable action for better health and movement outcomes. Understanding about health and movement is utilised when students have the necessary ability and self-confidence. The skills of moving with efficiency and confidence empower students to take action leading to better health, improved performance and enhanced self-esteem. Not all students will have the same degree of control over their health. However, by infusing plyometric activities into the lesson there will be an emphasis on developing skills and understanding of those factors that influence health which will best prepare students to work towards better health for themselves and others.

20 Reporting Research Outcomes
If this application is successful, it is a condition of approval that the applicant is prepared to submit to this office a summary of major research findings and/or recommendations as soon as practicable after completion of the study. Endorsement of this document by the applicant will be taken to mean that the researcher undertakes to report on the outcomes of the research as outlined above.

21 Meeting NSW Child Protection Requirements
Have you completed the ‘Application to Conduct Research Checklist’ and attached all relevant documentation required? Your application to conduct research WILL NOT BE CONSIDERED if this document has not been completed and attached to the application.

Signature of applicant: .................. Date: ..................

Signature of supervisor: .................. Date: ..................

Completed application should be submitted to: Mrs Kathy Campbell
Catholic Education Office Sydney
Head: Policy & Corporate Services
Policy and Corporate Services
PO Box 217
LEICHARDT NSW 2040

If submitting documentation electronically ensure signatures are present as required.

Research Application March 30
27 February 2014

Ref: Research Application 878

Andrew Sortwell

Dear Andrew,

RE: RESEARCH APPLICATION REF: 878– LETTER OF APPROVAL

Thank you for the submission of your application to conduct research in Archdiocesan Catholic Schools under the jurisdiction of the Catholic Education Office (CEO) Sydney.

After further consideration, approval is given by CEO Sydney to conduct this study. This approval is granted subject to full compliance with NSW Child Protection and Commonwealth Privacy Act legislation. It is the prerogative of any Principal or staff member whom you might approach to decline your invitation to be involved in this study or to withdraw from involvement at any time. Any study involving the participation of students will require written, informed consent by parents/guardians.

Permission is given for you to approach the Principals of the schools nominated, listed below, requesting participants for your study: “Effects of Plyometric Activities on Motor Performance Skills in Primary School Children Aged Seven to Eight”.

John the Baptist Catholic Primary School, Bonnyrigg Heights Mr Tony Lo Cascio

COMMONWEALTH PRIVACY ACT
The privacy of the school and that of any school personnel or students involved in your study must, of course, be preserved at all times and comply with requirements under the Commonwealth Privacy Amendment (Private Sector) Act 2000. In complying with this legislation, the CEO Sydney has decided that individual research participants should not be identified in the report.

FURTHER REQUIREMENTS
It is a condition of approval that when your research has been completed you will forward a summary report of the findings and/or recommendations to this office as soon as results are to hand.

All correspondence relating to this Research should note ‘Ref: Research Application 878’.
Please contact me at this office if there is any further information you require. I wish you well in this undertaking and look forward to learning about your findings.

Yours sincerely,

[Signature]

Dr Michael Bezzina
Director of Teaching and Learning
Email: research.centre@syd.catholic.edu.au
Appendix 6: Letter to Principal

Andrew Sortwell

School Principal
John the Baptist Primary School
Bonnyrigg Heights 2177
Mount Street NSW

Dear Tony

The title of my research is 'Effects of Plyometric Activities on Motor Performance Skills in Primary School Children Aged Seven to Eight'.

Development of fundamental movement skills is an important area of inquiry within physical education. Plyometric activities have been shown to be a safe and effective method for children to enhance neuromuscular function and sporting performance. Therefore the aim of this study is to examine the effects of infusing plyometric based activities within a conventional Physical Education lesson, on fundamental movement skills of seven and eight year olds.

A group of approximately 60 primary school students aged seven to eight years of age need to be recruited for this study. Data will be collected using a pretest/posttest design whereby participants will be asked to complete a range of tests which assess fundamental movement skills, lower and upper body muscular power. Classes will be randomly assigned to one of two groups: treatment or control. Both groups will engage in the same health, physical education practical content. The only difference will be that the treatment group will be provided an alternative warm-up which includes plyometric activities. The intervention will be for a period of 8 weeks. Therefore the pre-testing for occur in week 1, the intervention from week 2 to week 9, and then post testing in week 10. At the moment I'm hoping that to do the research in term 3 or Term 4, 2014.

The benefits of this study will provide an examination into the potential benefits of plyometric activities and improved muscular power on fundamental movement skills. The study will also provide evidence and support for the inclusion of plyometrics into the Health Physical Education National Curriculum.

Expectations of the School and Teachers

The expectation of the school is that the students will be available for pre testing and post testing in week 1 and week 10 of the term. The total time for the tests per student will be no more than 20 minutes per student. A teacher will NOT be required for supervising the testing.

Another expectation of the school is that the students will be able to participate in the Physical Education lessons twice a week with at least a two a day gap between each lesson.
An expectation of the teachers is that they will help supervise the intervention group’s 15-20 minute warm-up which includes plyometrics with the researcher (me). The researcher will lead and conduct the warm-up with the intervention group.

**Benefits to the School and Teachers**

1. A specialist PDHPE teacher will take the Physical Education lesson for both the treatment and control group. This will provide relief time for the teachers.
2. A specialist PDHPE teacher can assist or even develop the PDHPE programs based on the new national curriculum for selected stages. Also happy to provide any in-service in areas of Health and Physical Education.
3. Write an article for the Catholic Education magazine ‘About Catholic School’, highlighting the educational research and innovation occurring at John the Baptist Primary School.
4. Write articles for the school newsletter touching on topics such as: nutrition and academic performance, cardio-respiratory fitness and academic potential, and other health and physical education related topics. Happy to do this throughout 2014.
5. Assistance with any sporting events or gala days during the term in which the research is occurring.

I am more than happy to have a meeting with you to discuss any questions or the logistics in regards to this research study. I will be taking Long Service Leave in term 3, or Term 4 2014 to ensure that I can perform the research and also make a positive contribution to the school and staff.

Kind Regards

Andrew Sortwell
Appendix 7: Parent and Student Information Pack

Letter of Introduction (Parents)

Dear Parent or Caregiver

Letter of Introduction

My name is Andrew Sortwell and I am a PhD student from the Faculty of Education at Wollongong University, Wollongong. I am undertaking postgraduate research to explore the effect of plyometric activities on fundamental movement skills and motor performance.

Plyometric is a form of exercise which uses throws, jumps, hops, and other rapid movements to increase the ability of the muscle to quickly contract. The game of hop scotch is an example of a plyometric activity. This research attempts to measure the effect of plyometric activities on physical performance and motor performance skills in children aged 7-8 years in mainstream schooling.

The project has been granted ethical approval by the University Human Research Ethics Committee. This approval requires me to ensure that informed consent and confidentiality issues are safeguarded and that all information gathered is treated with the utmost respect.

I would ask you to read the attached Information Sheet. If you have any complaints about the ethical conduct of the research or you wish to raise any concerns please contact:

Ethics Officer
Human Research Ethics Committee,
University of Wollongong
Tel: 4221 3386
Email rso-ethics@uow.edu.au

If you would like more information about this project, please do not hesitate to contact me on:

Mobile

Email as250@uowmail.edu.au
Study Description (Parents)

Study Title: Effects of plyometric activities on motor performance skills in primary school children aged 7-8 years.

This study is being conducted by Andrew Sortwell who is a postgraduate research student from the Department of Education, at Wollongong University.

Development of motor performance skills is an important area of inquiry within physical education. Plyometric activities have recently been shown to be a safe and effective method for children to enhance neuromuscular function and sporting performance. Plyometric is a form of exercise which uses throws, jumps, hops, and other rapid movements to increase the ability of the muscle to quickly contract. The game of hop scotch is an example of a plyometric activity. Therefore the aim of this study is to examine the effects of infusing plyometric based activities within a conventional Health and Physical Education lesson, on motor performance skills of seven and eight year olds.

The research proposes to recruit sixty primary school students who are aged 7 or 8 years. Two existing classes in Grade 2 will be recruited and randomly selected at the class level, as the experimental or control group. The students will not know if they are in the experimental or control group. Only the experimental group will participate in the 8-week plyometric activities infused into their Physical Education lesson for this study. The control group will continue their usual participation in Physical Education activities and will only be allowed to participate in the plyometric activities after the completion of this study. Participation in this research is voluntary. If you decide to participate and then wish to discontinue at any time, your decision will be respected without comment.

The study aims to improve the motor performance skills of children by giving them improved neuromuscular performance. Findings may lead to a new understanding of the physical learning needs of children in this age group to develop basic movement skills. The researcher will provide feedback to participants involved in the study when this is requested and is practicable.

The project will involve:

- Two assessment sessions with your child which will be conducted by a person qualified to administer motor performance and upper and lower body muscular power tests. The assessment session will be held on school premises during school time. The total time needed for all tests each session will be approximately 15 minutes.
- Each week students will be involved in two Physical Education lessons. Students may perform plyometric activities as part of their warm-up for the lesson.
- Completion of the Children's Leisure Activities Study Survey three times over a school term. The survey will require you to assist your child to complete it. The total time required to complete the Children's Leisure Activities Study Survey is approximately 5 minutes.
- Wearing of a pedometer (device used to measure steps taken), and recording this data from the pedometer at various times throughout the school term.
Any information obtained during this study and that identifies you or your child will be kept confidential. This will be disclosed only with your permission or as required by law. Confidentiality will be maintained by using a “number system” that links a number to all results. So, you or your child’s name will never be disclosed to any party. Data will be securely locked. Except for the researchers and supervisors, no other person will have access to any data. All data will be destroyed after 5 years. There is a possibility that this study may be published in a Peer Reviewed Journal. In this case you will be informed before publication. The purpose of any publication is to make a positive contribution to the research of this field of study. Strict confidentiality for the entire duration of the study will apply.

Participation in this study does not involve any known risks and assessments do not present any known safety hazards to participating children.

If you have any complaints about the ethical conduct of the research or you wish to raise any concerns please contact:

Ethics Officer
Human Research Ethics Committee,
University of Wollongong
Tel 4221 3386
Email rsoc-ethics@uow.edu.au

If you and your child would like to participate in the recruitment process for this study, please complete the attached consent form and return to me by (DATE)

<table>
<thead>
<tr>
<th>Andrew Sortwell</th>
<th>Research Team Supervisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile</td>
<td>Dr. Dana Periman</td>
</tr>
<tr>
<td>Email <a href="mailto:as2000@uowmail.edu.au">as2000@uowmail.edu.au</a></td>
<td>Tel 02 42213885</td>
</tr>
<tr>
<td></td>
<td>Email <a href="mailto:dperiman@uow.edu.au">dperiman@uow.edu.au</a></td>
</tr>
</tbody>
</table>
Letter of Introduction (Students)

Dear Student

My name is Andrew Sortwell and I am a research student at the University of Wollongong.

I am researching how a type of physical exercise known as plyometrics can improve your movement skills like run, skip, and throw. Plyometrics is a name used for fast rapid movements similar to jumping and bounding. We want to know if this type of physical exercise can improve your ability to move and we think that this research could help us tell that. For this research we require children aged 7 or 8 years to participate.

I am going to give you information and invite you to be part of this research study. You can choose whether or not you want to participate. We have discussed this research with your parent(s)/guardian and they know that we are also asking you for your agreement. If you are going to participate in the research, your parent(s)/guardian also have to agree. But if you do not wish to take part in the research, you do not have to, even if your parents have agreed.

You may discuss anything in this form with your parents or friends or anyone else you feel comfortable talking to. You can decide whether to participate or not after you have talked it over. You do not have to decide immediately.

I would ask you to read the Information Sheet for more information. If you have any concerns or problems about the way this study will be conducted you may contact:

Ethics Officer
Human Research Ethics Committee,
University of Wollongong
Tel 4221 3386
Email rso-ethics@uow.edu.au

If you would like to take part in the selection process for this study, I would be very pleased if you could sign the Statement of Consent.

If you would like more information about this project, please do not hesitate to contact me on:

Andrew Sortwell
Mobile
Email as259@uowmail.edu.au
Study Description (Students)

Study Title: Effects of plyometric activities on motor performance skills in primary school children aged 7-8 years.

This research is being performed by Andrew Sortwell who is a research student from Wollongong University. This research will involve primary school students who are aged 7 or 8 years. The aim of this study is to examine the effects of infusing plyometric based activities within a conventional Health and Physical Education lesson, on motor performance skills of seven and eight year olds. Plyometrics is a name used for fast rapid movements similar to jumping and bounding.

You are free to choose whether or not you would like to be involved in this research. If you decide to be involved and then you wish to stop being involved at any time, your decision will be accepted.

For the research you will stay with the students in your class. Your class will be chosen randomly to participate in a regular physical education lesson warm-up or a warm-up which includes plyometric activities.

The research is to improve the movement skills of children by increasing physical abilities. This research could assist in finding out how to help children improve their ability to run, jump, throw, hop, skip and catch. The researcher will always give students who are involved in the research information when asked.

Firstly, we would like to measure some of your movement skills and abilities.

Secondly, we may provide you with a new warm-up at the start of each Physical Education lesson.

Thirdly, we would like you during various times through the school term to fill in a Leisure Diary with your parent or guardian and monitor your steps taken through a day. Completing the diary may take 5 minutes.

Any information obtained during this research and that identifies you will be kept confidential. This information will only be given out with you and your parents’ / guardians permission. Confidentiality will be maintained by using "a number system" that links a number to all results. So your name will never be given to someone else. Information will be locked securely. Except for the researchers and supervisors, no other person will have access to any information. All information will be deleted after 5 years.

If you would like more information you or your parents/guardian may contact me by using contact details below. If you have any concerns or problems about the way this study will be conducted, please contact:
Ethics Officer
Human Research Ethics Committee,
University of Wollongong
Tel 4221 3386
Email rso-ethics@uow.edu.au

If you would like to participate in the recruitment process for this study, please complete the attached consent form and return to me by (DATE)

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<thead>
<tr>
<th>Andrew Sortwell</th>
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</thead>
<tbody>
<tr>
<td>Mobile</td>
<td>Dr. Dana Perlman</td>
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<tr>
<td>Email <a href="mailto:as259@uowmail.edu.au">as259@uowmail.edu.au</a></td>
<td>Tel 02 42213885</td>
</tr>
<tr>
<td></td>
<td>Email <a href="mailto:dpertman@uow.edu.au">dpertman@uow.edu.au</a></td>
</tr>
</tbody>
</table>
Appendix 8: Consent Form

Consent Form for Children

Research Title:
Effects of Plyometric Activities on Motor Performance Skills in Primary School Children Aged 7-8.

Researcher’s Name:
Andrew Sortwell, - Email as259@uowmail.edu.au

Research Team Supervisor’s Name:
Dana Fertman, - Email dperltman@uow.edu.au

I understand the research is about performing plyometric exercises which involve throws, jumps, hops and other similar powerful movements.

I have read the information sheet and have had the opportunity to ask the researcher any further questions. I understand that I choose to be involved in this research and I may stop being involved at any time.

I understand that the risks to me in this study are small and I have read the information sheet and asked any questions I may have about the risks. I understand that I will be involved in the following;

- Two fifteen minutes fitness activity sessions each week for a period of ten weeks.
- Various measurements of movement skills and abilities.
- Complete a weekly Leisure Activity diary.
- Wearing of a pedometer to measure steps taken, and recording this information at various times throughout the school term
- Answer questions on how hard I tried during each Physical Education lesson.

If I have any concerns or problems about the research, I can contact the Ethics Officer, Human Research Ethics Committee, Office of Research, University of Wollongong on 4221 3386 or email rso-ethics@uow.edu.au.

By signing below I am consenting to (please tick):

☐ Participating in a series of Physical Education lessons involving fitness activities with my class and the researcher.
☐ Completing the physical activity diary.
☐ The wearing of a pedometer, and recording my daily steps and distance.
☐ Answering questions regarding how hard I tried during the fitness activities.
☐ Being involved in the measurement of my movement skills.
☐ Being involved in the measurement of my movement abilities.

I understand that information from me will be used for research and possibly other published studies and I consent for it to be used in this manner.

I give permission for my child ____________________________ to participate in this Research.  (Child’s name)

Parent/Guardian Signature ____________________________ Date__________________

Name (please print) ____________________________ Date__________________

Child’s signature ____________________________ Date__________________
## Appendix 9: Physical Activity Readiness Questionnaire

### Physical Activity Readiness Questionnaire (PAR-Q)

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do you currently suffer from asthma or any breathing-related condition?</td>
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<tr>
<td>2. Have you ever consulted your doctor as a result of suffering from a heart-related condition?</td>
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<tr>
<td>3. Have you/do you suffer from any chest pains which may be aggravated by exercise?</td>
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<tr>
<td>4. Do you suffer from bouts of dizziness or from feeling faint?</td>
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<tr>
<td>5. Have you ever been told by a medical consultant that you suffer from a bone and/or joint condition which might be further aggravated by exercise?</td>
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<td></td>
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<tr>
<td>6. Have you ever been diagnosed with high blood pressure?</td>
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<tr>
<td>7. Have you ever been diagnosed with diabetes?</td>
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<tr>
<td>8. Are you unaccustomed to regular vigorous exercise?</td>
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<tr>
<td>9. Is there a significant physical reason not mentioned above why you should not take part in the research project?</td>
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</table>

If you have circled ‘YES’ to any of the questions, please provide further details in the space below. Also, if there are any health and fitness related conditions that could affect your participation in the research which are not covered in questions 1-8, please provide further information below.

Should your situation change regarding any of the conditions mentioned above, please notify one of the researchers/member of staff/teacher as soon as possible.

<table>
<thead>
<tr>
<th>Signed (participant):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Signed (parent/guardian):</td>
<td></td>
</tr>
<tr>
<td>Signed (principal investigator):</td>
<td></td>
</tr>
<tr>
<td>Date:</td>
<td></td>
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</tbody>
</table>
Appendix 10: FMS-Polygon

FMS-POLYGON TESTING SET UP INSTRUCTIONS and SCRIPT

Investigator will read to the child:

This test has a total of 4 tasks. You are to complete the four tasks as fast as you can. There is no rest between each task. You can ask questions if you do not understand the task after the demonstration. Then, I will ask you to perform the test four times. You will have a 2-minute rest between each attempt.

You will start this test on my command. The prompting words will be GET READY, GO. You will start when you hear GO. After finishing, wait for your next turn.

Are you ready to start?

FMS POLYGON TASKS - Demonstration

Task One - TOSSING AND CATCHING A VOLLEYBALL AGAINST THE WALL CONSECUTIVELY

Directions to the Child: Please, stand on this line facing the wall. Using both hands throw the ball inside the square on the wall as fast as you can. You are to catch the ball with both hands. You will perform this six times as fast as you can. Then leave the ball and commence the next task.

Tester: Demonstrate overhand throwing at the square on the wall and catching with both hands.

Task Two - RUNNING ACROSS OBSTACLES

Directions to the Child: You are to run towards the sponges and leap over as fast as you can. Pass through the cones and move immediately to the medicine balls to commence the next task.

Tester: Demonstrate running and leaping over the sponges.

Task Three - CARRYING THE MEDICINE BALLS

Directions to the Child: Bend the legs and pick up a 3 kg medicine ball. Then move as fast as you can to the gymnastics vault and place the medicine ball on top. Return to the line and pick up the second 3 kg medicine ball. Move as fast as you can to the gymnastics vault and place the second medicine ball on top. Then move to the last task.
Tester: Demonstrate bending the legs and picking up the medicine balls. Demonstrate carrying the balls, placing it on the gymnastic vault.

Task Four - STRAIGHT RUNNING

Directions to the Child: Run as fast as you can in a straight line to the finish line and passing through the cones.

Tester: Demonstrate running to the finish line and through the cones.
Appendix 11: Squat Jump Instructions and Script

Squat Jump Instructions and Script

Research assistant demonstrates the squat jump highlighting the 90-degree angle at the knee joint and how the jump belt will be attached.

**Research assistant will read to the child:**

I will attach the jump belt.

Stand on the mat.

I will reduce the slack in the string on the belt.

On my command ("Squat"), you will squat down and hold still in the position.

You will place your hands on your hips where they will remain for the jump.

On my command ("Jump") you will jump as high as you can.

I will then write down the reading which is displayed on the belt.

You will be given rest and then perform the next jump.
Preparation/Test:
• Before commencing the squat jumps, ensure that each student has performed an appropriate warm-up*.
• All jumps are to be performed using the belt jump.
• Attach the jump belt tightly around the student’s waist.
• Ensure the student stands on the jump belt rubber mat.
• Ensure there is no slack on the jump belt string.
• The student should assume and maintain start position with hands-on-hips.
• Starting from an upright position, the student slowly squats down to a depth corresponding to approximately 90 degrees of knee flexion.
• After a slight pause of three seconds, the student is then required to perform a vertical jump for maximal height with no countermovement of the upper or lower body.
• The student is required to keep their upper body in an upright position throughout all phases of the test and keep their hands in the start position (i.e. on hips).
• Record squat jump number and the height achieved for each jump.

Technique:
• A valid squat jump is one in which the student performs maximal vertical jump movement while maintaining an upright body. The student’s arms should remain in the start position throughout the test.

Technical Violations:
The following technical violations will result in the trial being invalid.
• Not holding the squat position before squat jump.
• Failing to land where they commenced the jump.
• Knee flexion greater or less than 90 degrees.
• Moving their hands to from their hips.
• Performing the jump with an excessive forward lean of the upper body.

*Warm-up
• Jog 15 metres, twice
• Jog with high knees 15 metres, twice
• Skip 15 metres
• Leg Swings, Forward/Back x 10 each leg, Side/Side x 10 each leg
• Arm rotations, ten each arm
Appendix 12: Drop Jump Instructions and Script

Drop Jump Instructions and Script

Research assistant demonstrates the drop jump from the 10cm box.

Research assistant will read to the child:

Step onto the box. Place your hands on your hips where they are to remain the whole time.

On my command ("GO"), you will step off the box and upon landing on the mat jump as high as possible with as short a ground contact as possible.

Jump like a bouncing ball.

When you land after jumping up off the mat, land with legs straight and toes touching the ground first.

You will have two trials and then three attempts from each box height, which will be measured.
**Preparation/Test:**
- Before commencing the drop jumps, ensure each student has performed an appropriate warm-up*.
- The student needs to stand on the edge of the box (10 cm high) and place both hands on their hips.
- The student commences the drop jump from an upright position. Next the student is required to step off the box and upon landing, perform a vertical jump for maximal height.
- Emphasise to the student, jumping for maximal height whilst minimising ground contact time.
- The student is required to keep their upper body in an upright position and hands-on-hips throughout all phases of the test.
- The drop jump box height commences at 10 cm and then progressively increases to 20 cm and then 30 cm.
- During the landing phase, the knee angle during the ground contact should be 180 degrees and stretched feet in plantar extension.
- All jumps are to be performed on the Just Jump Timing Mat.
- Record number, contact time and height achieved for each drop jump.

**Technique:**
- A valid drop jump is one in which student drops from the box and performs maximal vertical jump movement with minimal ground contact time, whilst maintaining an upright body position and maintaining hands on hips.

**Technical Violations:**
The following technical violations will result in the trial being invalid.
- Applying an incorrect technique when dropping for the box.
- During the drop jump allowing their hands to lift off the hips.
- On completion of the drop jump, landing with legs bent and or landing on heels first.
- Excessively leaning forward with their upper body.
- During the initial stage of the drop jump, having excessive ground contact time.

*Warm-up*
- Jog 15 metres, twice
- Jog with high knees 15 metres, twice
- Skip 15 metres
- Leg Swings. Forward/Back x 10 each leg, Side/Side x 10 each leg
- Arm rotations ten each arm
Appendix 13: Medicine Ball Throw Instructions and Script

Medicine Ball Chest Throw Instructions and Script

Research assistant demonstrates the medicine ball throw while retelling the script below.

Research assistant will read to the child:

Sit on the floor with your back against the wall and legs straight
Hold the ball with both hands, resting it on your lap
On my command ("GO"), you will lift the medicine ball to your chest ensuring your elbows are in contact with the wall.
Using both hands throw it as hard as you at an approximate angle of 45°.
Show the student the poster illustrating 45 degrees.
You will have two trials and then three attempts which will be measured.
Preparation/Test:
• Before commencing the medicine ball chest throw, ensure that student has performed an appropriate warm-up*.
• The student should sit on the floor with their back against the wall.
• Ensure the medicine ball is covered in gymnastics chalk.
• The student starts the medicine ball throw with their elbows against the wall.
• The student starts from an upright position. Next, the student is instructed to toss the ball as far as they can with both hands, at an approximate angle of 45°.
• Torso and hip rotation are prohibited.
• Two trials and three approved attempts are to be made with each ball toss with one-minute rest between each attempt.
• The distance of the medicine ball throw is measured using a measuring tape which is taped to the floor to withstand the force of the ball landing on it. The distance measured is from the wall to the nearest edge of the mark on the floor made by the ball. Only the best attempts with each ball to be used for further analysis.
• Record the medicine ball chest throw number and the distance thrown.

Technique:
• A valid attempt is one in which the medicine ball is thrown with both hands, whilst maintaining an upright position and no hip/torso rotation.

Technical Violations:
The following technical violations will result in the trial being invalid.
• The incorrect technique when starting.
• Ball landing outside the 90cm lane.
• Moving the back away from the wall during the ball toss.

*Warm-up:
• Jog 15 metres, twice
• Arm rotations ten each arm
• Arm swings across the front of body and back x 10
**Appendix 14: Eight Week Plyometric Exercises**

**8 Week Plyometric Program**

**Weeks 1-3**

<table>
<thead>
<tr>
<th>Day A</th>
<th>Day B</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Sets x 10 Repetitions</td>
<td>2 Sets x 10 Repetitions</td>
</tr>
<tr>
<td>Ball squats</td>
<td>Jump and freeze</td>
</tr>
<tr>
<td>ABC push-ups</td>
<td>Double leg -backward jump</td>
</tr>
<tr>
<td>Sticky knees with soccer ball (Heel raises)</td>
<td>Triple &quot;X&quot; jump</td>
</tr>
<tr>
<td>Standing jump and reach for the stars</td>
<td>Chest pass</td>
</tr>
<tr>
<td>Medicine ball chest pass</td>
<td>Medicine ball throw downs</td>
</tr>
<tr>
<td>Medicine ball throw downs</td>
<td>Lateral taps</td>
</tr>
<tr>
<td>Single leg pops</td>
<td>Single leg pops</td>
</tr>
<tr>
<td>Straight jumping relay (one set only)</td>
<td>Figure 8 relay (one set only)</td>
</tr>
</tbody>
</table>

**Weeks 4-6**

<table>
<thead>
<tr>
<th>Day A</th>
<th>Day B</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Sets x 8 Repetitions</td>
<td>2 Sets x 8 Repetitions</td>
</tr>
<tr>
<td>Jump and turn 90 degree</td>
<td>Hurdle hops</td>
</tr>
<tr>
<td>Push ups on knees</td>
<td>Lateral hops</td>
</tr>
<tr>
<td>Zig Zag double leg drill</td>
<td>Zig Zag double leg jump drill</td>
</tr>
<tr>
<td>Medicine ball one arm shoulder Pass</td>
<td>Medicine ball one arm shoulder pass</td>
</tr>
<tr>
<td>Medicine ball Overhead throw down</td>
<td>Rapid fire medicine ball throw downs</td>
</tr>
<tr>
<td>Medicine ball push pass</td>
<td>High 5 drill</td>
</tr>
<tr>
<td>Take your marks and jump</td>
<td>Scissor jump with medicine ball</td>
</tr>
<tr>
<td>Power skipping relay (one set only)</td>
<td>Ladder hop relay (one set only)</td>
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<tr>
<td>Day A</td>
<td>Day B</td>
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<tr>
<td>2 sets x 6-8 Repetitions</td>
<td>2 sets x 6-8 Repetitions</td>
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<tr>
<td>Medicine ball jumps</td>
<td>Hexagon drill</td>
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<td>Push ups on step</td>
<td>Single leg hops</td>
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<tr>
<td>Single leg zig zag drill</td>
<td>Long jump sprint</td>
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<tr>
<td>Lunge chest pass</td>
<td>Medicine ball overhead throw down</td>
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<tr>
<td>Medicine ball Overhead throw down</td>
<td>Medicine ball push pass</td>
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<tr>
<td>Medicine ball push pass</td>
<td>Jump and turn (180 degrees)</td>
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<tr>
<td>Take your marks and jump</td>
<td>Tuck Jumps</td>
</tr>
<tr>
<td>Single leg hop relay (one set only)</td>
<td>Power hop relay (one set only)</td>
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</tbody>
</table>

**Ball Squats**

**Start:**

- Stand tall with your feet shoulder width apart and hold a soccer ball against your chest in an upright position.
- Keep the head up and look forward.

**Action:**

- Move the hips backward and downward until the knees are bent 90 degrees, like sitting back in a chair. Then return to the starting position and repeat.
A-B-C Push Up

Start:

- Start in the traditional push up position with both arms extended and both feet on the ground.

Action:

- While maintaining a rigid body position, lift the right hand and touch the chest then return the right hand to the ground.
- Repeat with the left hand and alternate until the desired number of repetitions is complete.

Sticky Knees with Soccer Ball

Start:

- Student places a soccer ball between their knees.

Action:

- The student then tries to jump as quickly as possible along a 4-metre course of cones.

Stand Jump and Reach For The Stars

Start:

- Stand with feet shoulder width apart and both arms fully extended overhead.

Action:

- Bend your knees and explode upward, reaching as high as possible overhead.
- Land softly with the knees bent and repeat again.

Chest Pass (seated)

Start:

- Students face partner about 3 m away.
- Players hold the ball at chest level with both hands.

Action:

- In pairs students perform chest passes as quickly as possible.
**Medicine ball Throw Downs**

**Start:**
- Students face partner about 3 m away.
- Hold the medicine ball with both hands and move it to the starting position above the back of the head.

**Action**
- Take one step forward and throw the medicine ball down and repeat.

**Single Leg Pops (skipping)**

**Start:**
- Stand comfortably with the feet shoulder width apart and both arms bent 90 degrees.

**Action:**
- This exercise is an exaggerated skipping motion.
- Lift the right knee upward until the thigh is parallel to the ground. Pop off the left foot and rapidly bring the left thigh parallel to the ground as the right foot returns to the starting position. Move the left arm upward with the right knee and the right arm starting position with the left knee.
- Rapidly repeat each side for the desired number of reps.

**Straight Jumping Relay**

Each student in the relay will jump continuously to the 10-metre mark, turn around and sprint back.

**Jump and Freeze**

**Start:**
- Stand tall with the feet shoulder width apart.

**Action:**
- Bend at the knees and quickly jump as far forward as possible. Immediately upon touching down, freeze and hold the position for three to five seconds. Then repeat for repetitions.
**Double Leg Backward Jump**

Start:
- Stand with your feet shoulder width apart, chest over the knees, arms at your sides and elbow bent 90 degrees.

Action:
- Bend at the knees and jump backwards. Use quick double arm action.
- Keep the elbows at 90 degrees for body control immediately upon touching down.
- Freeze for three to five seconds and then repeat.

**Triple X Jump**

Start:
- Stand with your feet shoulder width apart.

Action:
- Student has to jump rapidly into each box in sequential number order.

**Lateral Taps**

Start:
- Start with one foot on the medicine ball and the other to the side of the ball on the ground. Keep both arms extended out to your sides and parallel to the ground.

Action:
- Hop laterally over the ball while tapping the top of the ball with the inside foot. Keep the arms parallel to the ground during the movement.
- Hop back in the reverse direction and repeat for the desired number of reps.

**Figure 8 - Jumping Relay**

Each student in the relay will jump along number eight 10 metre course, jumping continuously and returning to the starting line.
Jump and Turn 90 Degrees

Start:

- Stand with your feet about shoulder width apart. Face an object as a point of reference.

Action

- Jump up as high as you can, using your arms to help, and while in the air turn 90 degrees to the right. Land and immediately repeat the jump, turning 90 degrees back to the left so that you are back in the starting position. Repeat for the desired number.
- Try to keep your chest over your toes as much as possible to avoid falling backward.

Push Ups On Knees

Start:

- Get in the standard push up position with feet apart, legs extended, and arms straight with both hands on the floor about shoulder width apart.

Action:

- Lower the chest toward the floor by bending the elbows to approximately 90 degrees then return to the starting position and repeat.
- If a standard push up is not possible, working from the knees is acceptable initially.

Zig Zag Double Leg Jump Drill

Start:

- Stand with your feet shoulder width apart at one end of the line.

Action

- Using your arms to help lift your body, jump up and land on the other side of the line while moving forward. Immediately repeat the jump to the other side of the line, again as far forward as possible. Each jump counts as one repetition.
Medicine Ball One Arm Shoulder Pass (seated)

Start:
- In pairs, students face the partner with a distance of three metres between them.
- Student holds the ball in one hand above the shoulder with the other hand keeping it steady.

Action:
- Student steps toward partner and passes it to partner using both hands.

Medicine ball Overhead Throw Downs

Start:
- Students face partner about 3 m away.
- Hold the medicine ball with both hands and move it to the starting position behind the back of the head.

Action
- Take one step forward and throw the medicine ball down towards a partner.

Medicine Ball Push Pass

Start:
- Hold a medicine ball at chest level with your feet shoulder width apart.

Action:
- Squat down to the ready position, then quickly explode upward, lifting your body off the ground, extending both arms, and pushing the ball up and towards the partner, who is standing a safe distance away.
- After the ball lands the partner retrieves it and repeats the drill in the same manner.

Take Your Marks and Jump

Start:
- Stand in a ready set go position.

Action:
- Jump using both arms to help lift the body as high as possible.
- Land and assume similar position as at the start and immediately repeat.
Power Skipping Relay

Start:

- Stand with your feet comfortably apart.

Action:

- Hold both arms at your sides at a 90-degree angle. Move forward in a skipping motion while raising the lead knee forward towards your chest. Try to touch the foot with both hands.
- Repeat the motion with the opposite leg and continue skipping for 10 metres and then returning to the finish line.

Hurdle Hops

Start:

- Line the cones up approximately 30 to 40 centimetres apart.
- Stand at one end of the liner of cones.

Action:

- Rapidly jump forward over each cone with both feet.
- Keep your body vertical and do not let your knees cave in when you land.
- Use a double arm swing to maintain balance and get more height with each jump.
- Repeat the series of jumps.

Lateral Hops

Start:

- Place the cones about 12 to 18 inches apart.
- Stand perpendicular to the line of cones with your feet shoulder width apart.

Action:

- Jump sideways down the row of cones, landing on both feet after each jump.
- Once you clear the last cone, walk back to the start and repeat while facing the opposite direction.
Rapid Fire Medicine Balls Throw Downs

Start:

- Hold the medicine ball with both hands and move it to the starting position behind the back of the head.

Action:

- Take one step forward and throw the medicine ball down as fast as possible.

High Five Drill

Start:

- Stand with your feet shoulder width apart about one metre away from a partner.

Action:

- Bend at the knees and ankles, explode up into the air as high as possible (together if done with partner), and reach one hand up and touch hands together.
- Land in a controlled manner with soft knees, and immediately jump again as high as possible and touch hands.
- If a partner is unavailable, perform this exercise by jumping as high as possible while reaching up with one arm.

Push Up

Start:

- Get in the standard push up position with your feet apart, legs extended, and arms straight. Place both hands on the floor at least shoulder width apart.

Action:

- Slowly lower your chests toward the floor by bending both elbows, then return to the starting position by pushing off the floor. Repeat for the desired number of repetitions.
Scissor Jump with Medicine Ball

Start:

- Stand with your feet about half a metre apart in a lunge position with the left leg forward and the knee positioned over the ankle.
- Keep the back foot on the toes and the front foot flat on the floor.

Action:

- Slowly lower your hips so that the front thigh becomes parallel with the floor and the back knee almost touches the ground. Then return to the starting position by jumping and reversing feet positions.

Ladder Hop Relay

Start:

- Stand near the starting cone standing on one leg.

Action:

- Hop as fast as you can along the ladder and tag the next team member.
- Continue this till each team has had a turn.

Medicine Ball Jump

Start:

- Stand with your feet shoulder width apart and hold a medicine ball against your chest in an upright position.
- Keep your head up and look forward.

Action:

- Squat down in a controlled manner.
- Jump up as high as you can and drop into the squat position to jump again.
Push Up on Step

Start:

- Get in the standard push up position with your feet apart, legs extended, and arms straight. Place both hands on the first step of the seating at least shoulder width apart.

Action:

- Slowly lower your chests toward the step by bending both elbows, then return to the starting position by pushing off the step. Repeat for the desired number of repetitions.

Single Leg Zigzag drill

Start:

- Stand on one foot to the side of the line near one end (line is 10 metres long).

Action:

- Hop on one leg back and forth over the line as you move forward.

Lunge Chest Pass

Start:

- Hold a medicine ball in front of your chest while standing about four metres from a partner.

Action:

- While lunging forward on to one foot, quickly pass the ball off your chest to your partner.
- The partner catches the ball while stepping backward with one leg, then lunges forward while quickly passing it back.

Single Leg Relay

Start:

- Stand in the athletic position.

Action:

- Hop as quickly 10 metres to the line on your right foot and touch the cone and then return to start on hopping on your left foot and tagging the next student.
Hexagon Drill

Start:

- Start in the centre of the star.

Action:

- Jump straight to one of the points of the star. Then continue to jump point to point of the star. Once around the star counts for one repetition.

Jump and Turn

Start:

- Start with your feet shoulder width apart in the athletic position and face an object as point of reference.

Action:

- Jump as high as possible and turn 180 degrees so that you are facing the opposite direction when you land. Upon landing, immediately jump up and turn 180 degrees in the reverse direction so that you land in the starting position.

Tuck Jumps

Start:

- Stand in the athletic position with your feet shoulder width apart.

Action:

- Jump as high as possible while attempting to bring both knees toward your chest.
- Touch the knees with your hands at the highest point before returning to the ground.
- Quickly jump again and repeat for the desired number of reps.

Single Leg Hops (using ladder run)

Start:

- Stand on one leg at one end of the ladder.

Action:

- Push off the standing leg and hop forward, landing on the same leg. Upon landing immediately take off again and continue to hop over the ladder. Use a strong-arm swing to increase jump height and distance. At the end of the ladder, walk back to the starting position and repeat using the other leg.
Long Jump and Sprint

Start:

- Stand next to one cone with your feet shoulder width apart.

Action:

- Using a big arm swing, long jump as far as possible. Upon landing with both feet together, immediately sprint forward five metres to the second cone.
- Walk back to the starting position and repeat for the desired number of repetitions.

Power Hop Relay

Start:

- Stand in athletic position.

Action:

- Aiming for maximum height, hop on your left foot 10 metres to the cone and return hopping on your right foot and tag the next in line.
Appendix 15: Plyometric Group Warmup Fidelity Checklist

Treatment Fidelity Checklist

<table>
<thead>
<tr>
<th>Treatment Integrity</th>
<th>Tick if observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate focus for the session (rapid movement from eccentric to concentric)</td>
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<tr>
<td>Plyometric activities performed</td>
<td></td>
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<tr>
<td># of activities _______ # of sets _______ Total # of reps _______</td>
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<tr>
<td>PE teacher and assistant assured correct technique and appropriate feedback</td>
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<tr>
<td>Each exercise last 15 to 20 seconds</td>
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<tr>
<td>At least 30 seconds rest between exercises</td>
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<tr>
<td>Set warm-up performed</td>
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<tr>
<td>Rate of Perceived exertion assessed</td>
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<tr>
<td>Concerns reported: 0=no concern, 1 = sprain/strain, 2 = muscle soreness, 3= safety concern, 4 = fatigue, 5 = injury, 6 = fall.</td>
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<tr>
<td>Date: __________________________</td>
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<tr>
<td>Start time __________, End Time __________</td>
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<tr>
<td>Total length of warm-up : _______ minutes</td>
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</tbody>
</table>
### Appendix 16: Plyometric Training Logbook

#### Week 1-3 Day A - Log Sheet

<table>
<thead>
<tr>
<th>Exercise List</th>
<th>Repetitions</th>
<th>Weight of Medicine Ball</th>
<th>Completed within 20 seconds</th>
<th>Eccentric to concentric</th>
<th>30 seconds rest after each set</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First rotation</strong></td>
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<tr>
<td>Ball squats</td>
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<tr>
<td>ABC push-ups</td>
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<tr>
<td>Sticky knees with soccer ball (heel raises)</td>
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<tr>
<td>Standing jump and reach for the stars</td>
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<tr>
<td>Chest pass</td>
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<tr>
<td>Medicine ball throw downs</td>
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<tr>
<td>Single leg pops</td>
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<tr>
<td>Straight jumping relay</td>
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<td><strong>Second rotation</strong></td>
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<td>Ball squats</td>
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<td><strong>First rotation</strong></td>
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<td>Jump and freeze</td>
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<td>Double leg- backward jump</td>
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<td>Triple “X” jump</td>
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<td>Figure 8 relay</td>
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<td>30 seconds rest after each set</td>
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<td>Take your marks and jump</td>
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<td>Jump and turn (180 degrees)</td>
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<td>Tuck jumps</td>
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<td>Long jump sprint</td>
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<td>Jump and turn (180 degrees)</td>
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<td>Tuck jumps</td>
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<td>Power hop relay</td>
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Appendix 17: Comparison Group Warmup Protocol

**General Warm-Up**
Walking 30m x 4 (length of basketball court)
Brisk walking 30m x 4 (Length of basketball court)
Side Step walk right x 30m, side step walk left x 30m
Follow the leader’s actions

**Dynamic Stretching**
Leg Swings (Forward/Back x 10 each leg, Side/Side x 10 each leg)
Walking Knee Hug
Slow squat to stand x10
Spiderman Climb (length of basketball court) x 2
Overarm rotations x 10
Arm swing across chest x 10
Comparison Group Fidelity Checklist

<table>
<thead>
<tr>
<th>Comparison Group Warm-up Integrity</th>
<th>Tick if observed</th>
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<tr>
<td>Brisk walking 30m x 4 (length of basketball court)</td>
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<tr>
<td>Side Step walk right x 30m, side step walk left x 30m</td>
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<td>Follow the leader’s actions</td>
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<td><strong>Dynamic Stretching</strong></td>
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<td>Leg Swings (Forward/Back x 10 each leg, Side/Side x 10 each leg)</td>
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<tr>
<td>Walking Knee Hug</td>
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<tr>
<td>Slow squat to stand x10</td>
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<tr>
<td>Spiderman Climb (length of basketball court) x 2</td>
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<tr>
<td>Overarm rotations x 10</td>
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<tr>
<td>Arm swing across chest x 10</td>
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<tr>
<td>PE teacher and assistant assured correct technique and appropriate feedback</td>
<td></td>
</tr>
<tr>
<td>No plyometric exercise or training or activities</td>
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<tr>
<td>Concerns reported: 0 = no concern, 1 = sprain/strain, 2 = muscle soreness, 3 = safety concern, 4 = fatigue, 5 = injury, 6 = fall.</td>
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<tr>
<td>Date: _________________</td>
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<td>Start time _________, End Time __________</td>
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<tr>
<td>Total length of warm-up: __________ minutes</td>
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## Appendix 19: Comparison Group Logbook

### Comparison Group Logbook

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<tr>
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<tr>
<td>Brisk walking 30m x 4 (Length of basketball court)</td>
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<tr>
<td>Side Steps walk right x 30m. Side Step walk x 30m</td>
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<tr>
<td>Follow the leader’s actions activity</td>
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<tr>
<td>Leg swings (Forward Back x 10 each leg. Side/side x 10 each leg)</td>
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<td>Walking knee hug</td>
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<td>Slow squat to stand x 10</td>
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<tr>
<td>Spiderman climb (length of basketball court) x 2</td>
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<tr>
<td>Overarm rotations x 10</td>
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<tr>
<td>Arm swing across chest x 10</td>
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</table>