EXAMINING THE ASSESSMENT AND DEVELOPMENT OF A FUNDAMENTAL MOTOR SKILL AND THE EFFICACY OF PEER TEACHING INSTRUCTIONAL APPROACHES

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This dissertation is submitted in total fulfilment of the requirements for the degree of
Doctor of Philosophy

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Submitted April 2022

Abstract

The overall purpose of this dissertation was to examine the process of assessing and developing the Fundamental Motor Skills (FMS) of overarm throwing. This dissertation involved two foci: qualitative assessment of FMS and the efficacy of peer teaching approaches. The first focus was to contribute to qualitative assessment of FMS research by examining an assessment system commonly used to assess overarm throwing development. The second focus was to examine the efficacy of peer teaching instructional approaches on improving overarm throwing performance of pre-service physical education (PE) teachers to determine whether these approaches could facilitate pre-service PE teachers to efficiently develop FMS proficiency. PE teachers who can proficiently perform FMS are better equipped to teach these skills; their demonstrations provide the learners a "blueprint" of the skill they are trying to acquire.

The research includes four separate studies. The first two studies examined Roberton's levels (Roberton & Halverson, 1984), a qualitative assessment system used extensively for over four decades to research overarm throwing development, primarily examining the technique of children and older throwers. Study 1 attempted to validate one of the backswing sequences (Haywood et al., 1991) to authenticate it for assessing the backswing component of university-aged throwers. The findings provided preliminary support that the Haywood et al. backswing sequence, previously only validated for assessing the backswing technique of older throwers, was suitable for assessing the backswing of the university-aged throwers.

Study 2 examined the impact of the follow-through on throwing velocity. Findings showed the follow-through had the second largest impact on throwing velocity of all the six components, providing preliminary support for the inclusion of the follow-through component to the existing five components of Roberton's (Roberton & Halverson, 1984) levels, making this system more accurate and comprehensive.

Study 3 and 4 both utilised a quasi-experimenal between-subjects pre-test, intervention, post-test, and retention test designs. The participants were allocated to one of three experimental groups: a Video Analysis Group (VAG), a Verbal Group (VG), and a Control Group (CG). During the interventions the VAG and VG worked in pairs in a Reciprocal style of peer teaching (Mosston & Ashworth, 2002). The VAG and VG interventions were identical except the VAG had access to video analysis technology and the CG completed unrelated course work. Study 3, a single session intervention, and Study 4, a three-session intervention, attempted to ascertain whether video analysis affects throwing technique of participants working in reciprocal peer teaching settings. The findings indicated the impact of video analysis may be dependent on the number of intervention sessions. In Study 3, video analysis in a single session intervention appeared to accelerate the participants throwing improvement. Study 4 revealed video analysis was not vital over the course of the three sessions. The VAG and VG achieved similar throwing improvements that were superior to the CG who did not experience the peer teaching intervention.

The findings from this dissertation have identified scope for the Roberton's levels (Roberton & Halverson, 1984) to be refined and the two peer teaching instructional approaches examined have been shown to be effective when trying to develop overarm throwing. Furthermore, these findings can inform Physical Education Teacher Education Programs, potentially preparing graduate PE teachers more effectively to develop their students' FMS, which may increase the involvement of children and adolescents in sport and physical activity because they will have the necessary skills to successfully engage in these activities.

Dedication

I dedicate this dissertation to my wife Dee, and my children Cooper, Ashlee, and Sophie. The completion of this research has been a team effort, thank you for your unconditional love and encouragement throughout this project. This project would not have been possible without your unwavering support.

Acknowledgements

I would like to acknowledge the people who have guided and supported me throughout the completion of this dissertation. First, I would like to acknowledge my principal supervisor, Associate Professor Christopher Mesagno. The support and guidance you have provided will not be forgotten, your professionalism, enthusiasm, and willingness to give up your time to help me develop as a researcher has been invaluable.

To my associate supervisor, Dr. Mandy Plumb, thank you for the significant contribution you have made to this dissertation. Your guidance, particularly in the early stages of this project, helped shape the experimental designs of the four studies allowing the early progress which gave me the confidence and motivation to keep moving forward.

I would also like to thank my other associate supervisors, Professor Michael Spittle and Associate Professor Nicola Johnson. Your assistance during this journey helped me develop as a researcher and your support has motivated me to keep developing my knowledge in this field.

I would also like to thank several of my colleagues within Federation University, and from outside of the University, for their help with this dissertation. Specifically, Dr. Scott Talpey, Nev Down, Associate Professor Warren Young, Associate Professor Sean Müller, Professor Kathy Williams, Rod Hall and Myles Strous. Our lunch time discussions, pilot testing sessions and other catch ups were not only enjoyable, but they also allowed me to refine numerous aspects of this project. Your friendship and encouragement helped motivate me throughout this journey.

I also want to acknowledge that I was supported by an Australian Government Research Training Program (RTP) Fee-Offset Scholarship through Federation University Australia.

Statement of Authorship

Except where explicit reference is made in the text of this dissertation, this dissertation contains no material published elsewhere or extracted in whole or in part from a dissertation by which I have qualified for or been awarded another degree or diploma. No other person's work has been relied upon or used without due acknowledgement in the main text and bibliography of this dissertation.

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CHAPTER 1

INTRODUCTION

It is widely accepted that regular participation in physical activity has positive health benefits for children and adolescents. A review of systematic reviews of physical activity literature (Warburton & Bredin, 2017), which included data from millions of participants, revealed regular physical activity was associated with a reduced risk of diverse health issues (e.g., cardiovascular disease, type 2 diabetes, hypertension, heart disease, and stroke). Regular physical activity not only reduces the risk of negative health outcomes but is also linked to numerous physical and mental health benefits. According to the U.S. Physical Activity Guidelines Advisory Committee (2018) higher physical activity levels are associated with beneficial outcomes for weight status, bone health, brain health, and cardiometabolic risk status. Barnett et al. (2009) stated regular physical activity can result in important short- and long-term health benefits for children and adolescents in physical, cognitive, emotional, and social domains.

Despite the benefits of being physically active, children and young people are not participating in the recommended levels of physical activity on a regular basis. A report from the Australian Institute of Health and Welfare (AIHW), in 2011-2012, found that only one-third of children, and 1 in 10 young people completed the recommended 60 minutes of moderate to vigorous physical activity per day (Australian Institute of Health and Welfare, 2019).

One explanation for some children and young people not achieving the recommended levels of physical activity is their inability to proficiently perform Fundamental Motor Skills (FMS). FMS are made up of stability, locomotor and manipulative skills. Stability skills involve controlling the body, for example balancing the body through twisting and bending. Locomotor skills relate to moving the body and include skills such as running, skipping, and leaping. Manipulative skills relate to controlling and projecting objects and include skills such as throwing, catching, bouncing, kicking, and striking (Spittle, 2021). These FMS are the foundation skills that allow the performance of specialised movement skills that are required for participation in many organised and non-organised physical activities (Cliff et al., 2009; Morgan et al., 2013; Okely et al., 2004). Children unable to develop this motor competence are less likely to participate in sport or physical activity because they lack the skills required to successfully engage in these activities (MacNamara et al., 2011). Ensuring young children can perform FMS competently by the time they reach adolescence will increase the likelihood they will be more active throughout their lives (Barnett et al., 2009).

Most of the responsibility of developing young people's FMS generally falls to Physical Education (PE) Teachers. As such, it is important that PE teachers have the knowledge, skills, and expertise required to carry out this crucial task. A common saying in coaching and teaching circles is, "you should practice what you preach", which is true when teaching FMS. The more effectively PE teachers can perform FMS, the more effectively they can demonstrate them. Effective demonstrations provide their learners a "blueprint" of these critical skills (Lee et al., 1994), allowing them to more effectively learn those skills (Gabbei, 2011; Pulling & Allen, 2014).

PE teachers are expected to perform and analyse a huge list of motor skills. Due to the crowded curriculum of Physical Education Teacher Education (PETE) programs, there is a limited number of face-to-face classes available to help pre-service PE teachers to learn to analyse and perform all these skills. With limited classes available, it is critical that Physical Education Teacher Educators implement teaching strategies that ensure the future PE teachers acquire these skills efficiently.

Two strategies frequently used when trying to teach FMS are video analysis and peer teaching. Video analysis is when learners are provided video replays of their performances. While this strategy is common in coaching and PE settings, there is a dearth of research regarding the effectiveness of this technology (Magill & Anderson, 2021; Phillips et al., 2013; Spittle, 2021). Peer teaching (Mosston & Ashworth, 2002) is when students work in pairs to improve each other's skills. One student practices the skill and the other observes and provides feedback, periodically these roles are reversed. The overall purpose of this dissertation is to examine the assessment of the FMS of overarm throwing and the efficacy of video analysis and peer teaching for the development of the FMS of overarm throwing.

Aims of the Dissertation

The current dissertation is made up of two foci, and within each foci there are two studies. Predicated on the review of literature, the purpose of the first two studies in the first foci was to examine Roberton's levels (Roberton & Halverson, 1984), a qualitative assessment system commonly used to assess overarm throwing development. Roberton's levels use a body component approach, dividing the body into segments or components, each component is then broken into levels that are qualitative descriptions of the throwing sequences that learners demonstrate as they perform the skill over time (Roberton & Konczak, 2001). The levels are ordered according to their appearance in most individuals as the performance of the motor skill develops. The first two studies of this dissertation will contribute to throwing development research and attempt to validate one of the backswing sequences (Haywood et al., 1991) and the follow-through, with the follow-through component not currently included in Roberton's levels. These components will then be used to effectively assess the overarm throwing of participants in Study 3 and 4.

While over 40 years of research has validated Roberton's components and levels (Roberton & Halverson, 1984) longitudinally and cross sectionally, the Haywood et al. (1991) backswing sequence has only been used to assess the backswing performance of older throwers. To use this sequence to assess the university-aged participants in the video analysis peer teaching studies (Study 3 and 4), the levels must be validated for use with university-aged throwers. Study 1 in this dissertation is a validation study to ensure the six level Haywood et al. sequence is suitable for assessing the backswings of the university-aged throwers.

Generally recognised as the final phase of the throwing action, the follow-through is essential to throwing performance (Hands & McIntyre, 2015; McCaig & Young, 2015; Ulrich, 2000; Werner et al., 2008), and decreases the likelihood of injury (McCaig & Young, 2015; Whiteley, 2007). Study 2 is an exploratory study to examine the impact the follow-through has on throwing velocity and ascertain its importance to throwing performance. The results could provide evidence for the inclusion of this additional component to the existing five components.

The aim of Study 3 and 4 in the second foci of this dissertation was to examine the effect of peer teaching instructional approaches on improving overarm throwing performance. Specifically, Study 3, a single session intervention, and Study 4, a three-session intervention attempted to determine whether video analysis affects the throwing technique of students working in reciprocal peer settings.

Chapter Organisation

Each chapter introduces the relevant background information. Chapter 1 introduces the overall purpose of the dissertation, the two foci of the dissertation, and the two studies within each foci. Chapter 2 reviews the literature associated with qualitative assessment of FMS, peer teaching, and video analysis. Chapter 3, 4, 5, and 6 are the independent, but interrelated, study chapters. Finally, a summary and general discussion of all four interrelated studies, the theoretical and practical implications, limitations, and potential future research are presented in Chapter 7.

The chapters for the four studies have been written as stand-alone research chapters, with each chapter including a brief, but relevant, background introduction that is covered in detail in the literature review chapter (Chapter 2). This intentional repetition will ensure readers are able to digest the important background information for each study as required, without needing to revisit information in the literature review chapter. All four studies have been written for journal submission, excluding the reference lists, which will be included as one full reference list at the end of the dissertation.

The studies in Chapters 3-6 are in various forms of "publication" status. The throwing data collected in Chapter 3 (Study 1) is part of a larger combined study, with additional samples from Australia and the United States. This data included throws performed by primary, high school, university students, and adults up to 57 years of age. The decision was made to combine the Chapter 3 (Study 1) data with the additional data because the combined data could more effectively validate the Haywood et al. (1991) backswing developmental sequence across a wider, more "typical" age range of performers. The combined data was examined and written up as a manuscript that was submitted and accepted to the *Journal of Motor Learning and Development*. The stand-alone manuscript in Chapter 3 has not been peer-reviewed or submitted for publication by itself. Like Chapter 3 (Study 1), the focus of Chapter 4 (Study 2) was also motor development and assessment, thus, the Chapter 4 (Study 2) manuscript has been submitted and is currently in its second review of the submission process at the *Journal of Motor Learning and Development*. Study 3 and 4 have a larger focus on motor learning and pedagogy, and will be submitted to a journal with a pedagogy focus.

The American Psychological Association (APA) 7th is the referencing style implemented in this dissertation. APA 7th, an author/date system, was selected because it is a style that is frequently used in the field of sport pedagogy and physical education.

CHAPTER 2

REVIEW OF LITERATURE

One of the most important roles of a Physical Education (PE) teacher is to assist students to develop the fundamental motor skills (FMS) that will allow them to participate in physical activities with competence and confidence throughout their lives. FMS, which are foundation skills that provide the building blocks for more advanced sport-specific motor skills (Jarvis et al., 2018; Logan et al., 2018; Spittle, 2021), are considered important prerequisites for physical activity and sport participation (Angell et al., 2018; Cattuzzo et al., 2016; Gu et al., 2019; Stodden et al., 2008). FMS are comprised of stability, locomotor, and manipulative skills. Stability skills involve the control of the body, for example balancing the body through bending and twisting. Locomotor skills involve moving the body through space, such as running, skipping, hopping, and leaping. Manipulative skills encompass controlling and projecting objects like throwing, catching, striking, and kicking (Spittle, 2021).

The ability to perform FMS in a proficient manner has been defined as motor competence (Cattuzzo et al., 2016; Robinson et al., 2015). According to the Victorian Curriculum Assessment Authority (2020), an integral focus of PE is for primary and secondary school students to develop proficiency in movement skills. This has been substantiated by other researchers who have suggested PE classes are an effective forum to develop motor competence (Gu et al., 2019; Overdorf & Coker, 2013). As such, PE teachers play a critical role in developing students' motor competence, whereby they need the necessary skills to assess motor skill performance.

Assessing Motor Skills

One skill PE teachers require is the ability to accurately assess motor skill performance (Ciapponi, 1999; Gangstead & Beveridge, 1984; Kelly & Moran, 2010; Lounsbery & Coker, 2008; Ward et al., 2020). A teacher's ability to accurately ascertain learner's movement deficiencies, and then provide appropriate feedback, is a major determinant of a teacher's effectiveness at developing a learner's motor skills (Bilodeau & Bilodeau, 1969; Hoffman, 1983). The ability of a teacher to discriminate between actual and desired performance underpins that teacher's capacity to provide the appropriate feedback to assist the development of a learner's performance (Ward et al., 2020). Teachers and motor developmentalists have used two basic measures to gauge change in motor behaviour: quantitative and qualitative assessment.

Quantitative Assessment

Quantitative assessment measures the outcome or "product" of the movement and generally involves numerical scores (Logan et al., 2017). Quantitative assessment includes, for example, the distance or speed a ball is thrown, the time taken to run or swim a certain distance, or performance accuracy (Spittle, 2021). Quantitative assessment of performance is generally efficient; measuring the distance of a throw or jump can be completed quickly with minimal training required for this type of performance assessment.

Qualitative Assessment

The most commonly used form of assessment in a PE setting is qualitative assessment (Knudson, 2013). Qualitative assessment, also referred to as movement analysis, skill analysis, or motor skill analysis, focuses on the process of how the skill was performed in comparison to established standards (Walkley & Kelly, 1989) and assesses the verbal descriptions of the qualitative changes that occur in movements (Roberton & Konczak, 2001). This form of assessment typically involves criterion-reference where the performance quality is evaluated against an established set of qualitative descriptors, which identify how the skill should be performed (Kelly & Moran, 2010). Qualitative teaching assessment examples would be systematically observing a student's performances and identifying discrepancies between the actual and desired performance characteristics (Gangstead & Beveridge, 1984).

There have been several limitations associated with qualitative assessment of FMS such as the overarm throw. One limitation is the subjective nature of qualitative assessment, which allows for various assessors to interpret movements differently. This combined with the multiple assessment instruments utilised by practitioners, makes national comparisons between learners difficult (Hands, 2002). Another limitation is that the time required to qualitatively assess large numbers of learners (e.g., the learners in a PE class) is high. Considerable time is also required to learn how to assess motor skills using qualitative analysis particularly for those with insufficient training in skill assessment. Quantitative assessment, conversely, is an easier option when working with large numbers of students (Roberton & Konczak, 2001).

There are also several strengths associated with qualitative assessment when examining skill development. First, qualitative assessment is a more accurate performance measure when compared to product measures like speed and distance, which also reflect body size and strength, disadvantaging smaller students and athletes (Haywood & Getchell, 2014; Roberton & Konczak, 2001; Williams et al., 1991). Second, qualitative assessment is more closely related to the knowledge of performance feedback that PE teachers more commonly provide to help learners improve performance (Roberton & Konczak, 2001). Information obtained through qualitative assessment informs the movement professional what skill components need more practice resulting in the assessment being completed in a more meaningful context (Hands, 2002). Finally, the process-product relationship indicates that good form (process) leads to good performance outcomes (Pinheiro & Simon, 1992; Roberton & Konczak, 2001; Todd et al., 2020). Roberton and Konczak (2001) investigated the process-product relationship to determine if the throwing technique of learners filmed from 6 years to 13 years successfully accounted for throwing velocity. The longitudinal results indicated 69-85% of the total velocity variance each year could be attributed to throwing technique. These findings support researchers who identify that assessment of qualitative differences in throwing performance can be superior to measurement of quantitative values (Williams et al., 1991). Thus, qualitative assessment will be used to evaluate performance throughout this dissertation.

Qualitative Assessment Systems

Some qualitative assessment systems assess the proficiency of throwing performance using checklists, with assessors utilising these checklists to decide whether critical components are performed proficiently (Bayless, 1981; Ciapponi, 1999; Kelly et al., 1989; Young et al., 2014). The *Get skilled get active* FMS resource (NSW Department of Education and Training, 2000) and the *Fundamental motor skills: A manual for classroom teachers* (Department of Education Victoria, 1996) are resources developed for teachers that break FMS down into components. Each component is assessed using a checklist to assist with the observation of the skill and help the assessor make judgements about the presence or absence of each performance criteria (Logan et al., 2017). Qualitative rating scales are also used to assess performances. Rating scales using scores (from 1 – 5), levels (beginner, intermediate, advanced), or descriptions (always, usually, sometimes, rarely, never) can measure the presence or quality of the throwing components identified (Spittle, 2021). Rubrics that describe component characteristics can also qualitatively assess performance; the descriptors detail progression on skill performance according to the performers' competence level (Spittle, 2021). Assessment systems frequently used by motor developmentalists measure the development of motor skills by breaking each skill into 'stages', ‘sequences’, or ‘levels’ (Ehl et al., 2005; Gromeier et al., 2017; Halverson et al., 1982; Haywood, 2012; Langendorfer & Roberton, 2002; Palmer et al., 2018; Palmer et al., 2020; Roberton, 1977, 1978; Roberton & Halverson, 1984; Roberton & Konczak, 2001; Schott & Getchell, 2021; Todd et al., 2020). These levels describe common sequences of qualitative changes that learners exhibit as they perform the same motor task over time. These descriptions are listed according to the order in which they appear (Roberton, 1977; Roberton & Konczak, 2001). Wild (1938) conducted a seminal study that examined the development levels of throwing technique, which sought to identify the characteristics demonstrated by children between the ages of 2 and 7 and then from 7 to 12 years. Wild found there were six whole body movements that were later converted to four, which could be tentatively assigned to developmental levels. As throwing mechanics improved, the throwers moved from level one to level four. According to stage theorists, levels occur in an invariant order, meaning individuals cannot skip levels and higher levels never occur before lower levels (Roberton, 1977).

Until now, assessment of motor patterns had categorised movements into total body configurations; the implication being that all performers look the same at some point in time (Roberton, 1977). A pre-longitudinal study (Roberton, 1977) involving 73 children between the ages of 6.4 years – 8.0 years performing the overarm throw was conducted to examine the ‘stage theory’ that human movement develops in an inflexible sequence. This study used a body component approach (i.e., breaking the throwing action into components), instead of the throwing action of the whole body being assessed. The children performed 10 throws that were recorded with their pelvic-spine and arm movements categorised according to proposed levels. The results indicated support for the five categories proposed for arm development but did not support the eight proposed pelvic-spine categories. The findings provided evidence that the whole body approach lacked versatility and was limited in its explanation of throwing development. One child may progress ahead with trunk action while another child may progress with arm action, even though the other components may not have advanced; as a result, two performers could look very different (Roberton, 1977).

Since the Roberton (1977) study, researchers have extensively examined throwing development, leading to a shift away from a whole body to a body component approach (Ehl et al., 2005; Gromeier et al., 2017; Halverson et al., 1982; Haywood et al., 1991; Langendorfer & Roberton, 2002; Palmer et al., 2018; Roberton, 1978; Roberton & Halverson, 1984; Roberton & Konczak, 2001; Runion et al., 2003; Williams et al., 1991, 1998). Advocates of the body component approach (Haywood, 2012; Haywood et al., 1991; Stodden et al., 2009; Williams et al., 1991) suggest that the body components develop and progress at their own rate, thus, should be assessed independently (Hands, 2002). These studies evaluated each component on an ordinal developmental scale (e.g., 1 – 4), the higher levels representing more developmentally advanced movement patterns (Logan et al., 2017). To ensure clarity, throughout this dissertation, the term 'developmental level' will describe the individual motor patterns for each component and 'developmental sequence' will discuss the order or arrangement of those levels for each component.

Through cross-sectional and longitudinal studies, researchers have validated sequences of levels for the trunk, humerus, and forearm component actions of children and adolescents (Halverson et al., 1982; Roberton, 1977, 1978). The levels proposed for the backswing component have also received preliminary validation (Williams et al., 1990). Some components have been refined, dropped, and additional components added. These modifications have been further validated, with studies indicating nearly all participants experiencing the proposed levels as their movements develop (Haywood et al., 1991), and nearly all participants moving through the levels in the hypothesised order (Williams et al., 1990). Haywood et al. (2012) explained that the wide use of these levels has seen robust developmental validity. Roberton and Konczac (2001) have suggested the component approach provided a more precise description of the movement changes than the whole body approach.

Within biomechanics, kinematics is the branch of mechanics concerned with the movement of objects without considering the cause of the motion such as displacement, acceleration, and velocity. Two studies (Stodden et al., 2006a; Stodden et al., 2006b) that examined the relationship between kinematics, and throwing velocity and Roberton's (Roberton & Halverson, 1984) developmental levels, provided further support for the validity of Roberton's levels assessment system. Results showed that the kinematic variable of stride length correctly predicted Roberton's stepping action levels; the kinematic measures related to trunk action, paralleled Roberton's trunk action development (Stodden et al., 2006a) and humerus and forearm levels accurately reflected humeral and forearm kinematic movement patterns (Stodden et al., 2006b).

Roberton's (Roberton & Halverson, 1984) developmental levels have been refined through more than 40 years of research. These components, which have been validated longitudinally and cross sectionally

(Roberton & Halverson, 1984; Williams et al., 1990), provide the most detailed, and effective qualitative assessment system for assessing the overarm throw for force. Thus, Roberton's levels is the qualitative assessment system adopted to measure throwing performance throughout this dissertation. My qualitative assessment experience and research in this field that helped me to decide on Roberton's levels as the assessment system, also led me to identify that while the components and the levels have an extensive validation history and are currently the soundest qualitative assessment system available, research is needed to determine if the assessment of throwing development using Roberton's (Roberton & Halverson, 1984) levels can be improved. For example, a validation study is needed to confirm that assessing the backswing of university-

aged throwers

with the Haywood et al. (1991) sequence, a sequence developed to assess older throwers, is appropriate. A second necessary study relates to the potential for the follow-through component to be added to the existing five components. The inclusion of the follow-through component may improve the accuracy of throwing development assessment.

Backswing Levels Validation

One of the five components acknowledged as critical to performance of the overarm throw is the backswing because it limits the arm movement possible in the forward swing motion (Langendorfer et al., 2012). There have been multiple sequences that have been proposed over the years, the original sequence (Langendorfer, 1980) included four levels. Level 1 described the initial throwing attempts where there was no backward movement of the hand and the ball was thrown from the position that the thrower first grasped the ball. Level 2 was demonstrated when the ball was lifted behind or alongside the head with elbow flexion, but the ball never moved above head height. A Level 3 backswing was when the ball was moved to a position behind the head via a circular overhead movement with an extended elbow. Finally, a Level 4 backswing was when the ball was moved to a position behind the head via a circular, down and back motion, with the ball being carried below the waist.

The majority of the early research investigating Roberton’s (Roberton & Halverson, 1984) developmental levels examined the development of children’s throwing. The backswing developmental levels originally proposed, however, may not have been comprehensive for assessing the throwing of other age groups (Haywood et al., 1991; Langendorfer, 1980; Williams et al., 1990). Examining the backswing of older throwers, the Haywood et al. (1991) revisions of the Langendorfer (Langendorfer, 1980) developmental sequence, identified two qualitatively different backswing patterns not included in the original developmental levels. To examine this further, 21 participants between 67 and 77 years took part in a study to validate the adaptation of Roberton’s developmental levels for the overarm throw for comprehensive lifespan assessment. Results confirmed that two new hypothesized backswing movements should be added to the original developmental levels. One of the new patterns involved a lateral backswing movement where the ball moved sideways to a position that was approximately 90^0 to the trunk. The second new backswing pattern was similar to the highest existing level, however, early elbow flexion resulted in the ball moving into a frontal or oblique plane rather than the sagittal plane. The two new backswing patterns were added to the original four levels, providing a comprehensive list of backswing movements. Based on my experience assessing the overarm throwing technique of primary, secondary, and university students, I believe the new movements are not confined to older throwers and the additional levels should be used to assess the backswing of all throwers. To examine this, this dissertation will conduct a study to determine whether the Haywood et al. levels are suitable for assessing the backswing component of the overarm throw for male and female university-aged throwers.

Follow-Through Component Validation

The overarm throw is arguably one of the most studied FMS (Southard, 2009), which has created considerable diversity of opinion relating to the critical components that should be assessed when viewing throwing performance (Whiteley, 2007). Roberton's developmental levels (Roberton & Halverson, 1984) originally comprised three components (trunk, forearm, and humerus); over time the levels for these components have been refined, with the step and the backswing added to eventually total five critical components (Haywood et al., 1991).

One component that should be added to Roberton's (Roberton & Halverson, 1984) existing five components to further develop the robustness of Roberton's levels is the follow-through component. Generally identified as the final phase of the throwing action, the follow-through begins at the point of ball release and finishes at the completion of the throw (Seroyer et al., 2010). The follow-through is important when trying to improve throwing performance (Braatz & Gogia, 1987; Hands & McIntyre, 2015; Ulrich, 2000; Werner et al., 1993); when teaching and assessing the overarm throw (Department of Education Victoria, 1996; NSW Department of Education and Training, 2000), and decreases the likelihood of injury (Dillman et al., 1993; McCaig & Young, 2015; Whiteley, 2007).

The significance of the follow-through to throwing performance can also be linked to throwing mechanics research, which has identified several temporal and kinematic parameters that relate to throwing velocity. Research has identified that increased trunk rotation speed, increased external shoulder rotation, and increased forward trunk tilt positively influence throwing velocity. All these parameters relate closely to an effective follow-through after ball release (Stodden et al., 2006a; Stodden et al., 2006b; Werner et al., 1993). No research, to date, has confirmed whether the follow-through, however, enhances the velocity of a thrown ball. A validation study is needed to examine the impact of the follow-through on thrown ball velocity, and the follow-through validation study in this dissertation could potentially confirm the addition of the follow-through component to Roberton's existing five components. This may assist coaches and teachers when measuring throwing performance by improving the accuracy of throwing development assessment.

Gender Differences of the Overarm Throw

The overarm throw has been extensively researched from a developmental perspective, with studies indicating significant gender differences in throwing performance on measures of accuracy, velocity, and developmental levels (e.g., Beseler et al., 2021; Ehl et al., 2005; Halverson et al., 1982; Johnson et al., 2020; Lorson et al., 2013; Williams et al., 1996b). One throwing study (Halverson et al., 1982) that examined children's throwing technique and velocity longitudinally, in kindergarten, first grade, second grade, and seventh grade, found males threw significantly faster and with more advanced technique than females. In each session, participants were asked to throw the tennis ball "hard" for 10 trials, velocity results revealed the gender difference increased each year. By seventh grade, boys developmental progress and throwing velocity was 5-6 years ahead of the girls. Halverson et al. explained this difference may be a result of females not having the same level of experience in overarm throwing.

An alternate explanation for this gender difference is males are stronger (e.g., Pedegana et al., 1982; van den Tillaar & Ettema, 2004). Pedegana et al. examined the relationship between anthropometry, isometric strength, and throwing velocity in handball and found that body size had a strong influence on throwing velocity and isometric strength. Throwing towards a 0.5 m x 0.5 m target at 7 m distance, male participants threw significantly faster (23.2 m per second) than females (19.2 m per second). The velocity differences showed a gender influence, but the difference was only small when muscle bulk was considered. In contrast to these "classic" explanations, studies have revealed throwing velocity is related more to technique than to gender (e.g., Beseler et al., 2021; Roberton & Konczak, 2001). According to Roberton and Konczak, once the component levels are identified, gender is an irrelevant predictor of throwing velocity. These contrasting explanations show that further research is required to determine the cause of the gender difference.

As discussed, qualitative assessment informs the movement professional what components need refining, which is passed onto the learner in the form of feedback to assist in the refinement process. The next section of this dissertation will examine feedback and its impact on learning.

Feedback

The information that learners receive from motor skill performances, known as feedback, has been identified as the second most important factor in the learning process behind actual physical practice (Bilodeau & Bilodeau, 1969). There are two predominant types of feedback: task-intrinsic and augmented feedback.

Task-Intrinsic Feedback

Task-intrinsic feedback is the sensory feedback that is naturally available when performing a skill (Magill & Anderson, 2021). Information such as, in tennis, the sound of the tennis ball hitting the strings of the racquet, the visual information of the ball's flight path, the tactile information coming from the racquet handle and the proprioceptive information felt by the player holding the follow-though position after hitting the groundstroke.

Augmented Feedback

Augmented feedback is supplementary information provided to the learner by an external source that is beyond the task-intrinsic information naturally available to them (Oñate et al., 2005). An augmented feedback example in tennis is a player receiving feedback from the coach that their ball toss was too low when performing a serve. According to Magill and Anderson (2021), augmented feedback plays two roles in skill learning. First, augmented feedback facilitates the achievement of the task goal. Second, augmented feedback motivates the learner to continue working hard to achieve goals.

The two prominent categories of augmented feedback are knowledge of results (KR) and knowledge of performance (KP). KR is external feedback relating to the outcome (result) of a motor skill performance (Magill & Anderson, 2021). An example is a long jumper being notified of the distance of her last jump. KP is feedback about the movement characteristics that led to the performance that was produced (Chiviacowsky & Wulf, 2007); for example, a golf coach instructing a golfer the backswing was too short.

Accurate augmented feedback is essential to improve learners' performance (Magill & Anderson, 2021). Specifically, augmented feedback helps learners identify errors in skill execution, alerting them to the differences between the desired performance and the current state of skill execution (Hodges et al., 2003). One challenge faced by PE teachers and coaches is trying to ascertain the best way to deliver augmented feedback.

Provision of Feedback

The most common and convenient form of augmented feedback is verbal feedback (Magill & Anderson, 2021). Feedback can also be provided non-verbally through a "thumbs up" signal or a smile to a learner. Advances in technology have allowed the use of sensory technology to provide augmented feedback, which is termed biofeedback. Biofeedback involves sensors that measure body and equipment position that is communicated to the athlete via visual or auditory signals to help them achieve desirable movements (Umek & Kos, 2018). Another popular method of providing visual feedback, often used by coaches, is video analysis.

Video Analysis

In coaching and instruction, video analysis (also called video feedback, videotape feedback, or video replay) is replaying of video footage back to the learner to assist in the learning process. According to Koh and Khairuddin (2004), video analysis has three major purposes: provide a visual demonstration to assist new skill learning and develop new movement patterns, supplement verbal feedback, and improve learners' observational capabilities. Knudson (2013) suggested that video analysis is a technique that can be used to extend observational capability for evaluating and diagnosing a performance. Furthermore, Dobre and Gheorghe (2021) stated that video analysis allows athletes to compare their subjective perception of their performances with an objective and irrefutable reality.

The provision of video analysis feedback is more complicated (Palao et al., 2013) and time consuming (Knudson, 2013; Palao et al., 2013; Weir & Connor, 2009) than verbal feedback. For video analysis to be beneficial, the results need to be significantly better than verbal feedback. Video analysis will be the term used throughout this dissertation to explain when video feedback footage is analysed by participants.

Video Analysis Research

Early research examining the value of video analysis in comparison to verbal feedback has been equivocal. Initially, Rothstein and Arnold (1976) reviewed 52 studies that involved the provision of video feedback to learners and found 33 studies showed no significant differences between video analysis and other experimental conditions. Recent research has continued to be mixed, with studies indicating video analysis does not result in improved learning compared to learners who did not receive video analysis feedback. For example, Kernodle et al. (2001) examined the effect of two methods of teaching the overarm throw with the non-dominant arm. Participants completed three sessions per week, for two weeks each performing 400 throws in total. One group received verbal information to assist the correction of errors, while one group received the same verbal feedback supplemented with video analysis. Kernodle et al. found no advantages of video analysis when trying to learn non-dominant arm throwing. In fact, the verbal feedback only group showed greater improvement in throwing technique compared to those who also received video analysis feedback. Kernodle et al. suggested the additional video feedback may have been overwhelming and interfered with the learning process, adding that early in the learning process, video feedback may not be essential if verbal feedback is available.

Swimming research (Ferracioli et al., 2013) also found verbal and video analysis feedback to be equally effective for learning breaststroke swimming technique. Thirty-seven inexperienced college students, who received either video analysis feedback, verbal feedback, or no feedback, participated in a study to examine the effect video analysis had on learner motivation levels and which feedback type improved breaststroke swimming more effectively. The video analysis and verbal group improved breaststroke technique by 50.4% and 56.3%, respectively, both outperforming the control group who improved by 26.9%. Discussing the non-significant statistical difference between the video analysis and verbal groups, Ferraciolo et al. suggested the learners might not have been capable of extracting the appropriate information from the large amount of feedback presented in the video footage. The learners were able to learn from some, but not all, of the information available in the video footage.

The effectiveness of video analysis and verbal feedback has been compared in a tennis serving study (Van Wieringen et al., 1989). The aim was to determine the impact of video analysis feedback on serving performance, with the hypothesis that video analysis would result in higher achievement scores and higher movement scores. Sixty-six participants, who had at least two years playing experience and played C and D level tennis competition, were involved in a pre- and post-intervention design. Pre-testing involved 20 serves, with “form” and accuracy of serves recorded. Following the pre-testing, participants were randomly allocated into one of three groups: traditional, video analysis, and control groups. The video analysis group and the traditional training group completed two training sessions a week for 5 weeks. Each session lasted 40 minutes, 30 minutes serving practice and the remaining 10 minutes analysing and discussing different video recordings. The video analysis group analysed and discussed their own serving footage, whereas the traditional training group analysed and discussed ground strokes and volleying footage of top-level players. The control group did not receive any tennis serve training. Participants then completed the post-testing. Results indicated that, while the traditional and video analysis groups outperformed the control group, there was no significant difference between the scores of these two groups who experienced serving training. Van Wieringen et al.

identified that the additional video analysis of their serving did not provide the video analysis group any apparent advantage over the traditional training group who did not receive video feedback on their serving. As such, these results did not reflect favourably on the use of video analysis.

Jennings et al. (2013) conducted a track cycling study to examine the effect of video analysis on performance of the cycling stand start. The 19 participants recruited from a national talent identification program were randomly allocated to either the traditional verbal group or the video self-modelling intervention group. The traditional group received verbal augmented feedback, and the video self-modelling intervention group watched video replays of their track starts. Results indicated no significant difference between the self-modelling feedback and the verbal feedback, with both groups improving their standing start performances and self-efficacy beliefs. Performance assessment included a subjective technique assessment, which was the mean of the scores of two expert coaches, one who was blind to the intervention, and one who was not blind to the intervention. Limitations of the study may include (but are not limited to) a small sample size, which decreases generalisability of the results and that both assessors were not blind to the intervention, which may lead to less impartial assessment.

While some studies have not reflected favourably on the use of video analysis, studies have identified video feedback to be beneficial for grab start swimming dive (Robles, 2013), basketball jump-landing tasks (Oñate et al., 2005), the learning of a gymnastic skill (Potdevin et al., 2018), and hurdling (Palao et al., 2013). Robles (2013) examined whether verbal and video analysis (experimental group) was more effective than verbal feedback (control group) alone when trying to improve learners' grab start swimming dives. One of the two more common starting positions used by competitive swimmers, the grab start dive involves swimmers having both feet at the front of the blocks, both hands grabbing the front edge of the block. The 40 participants enrolled in swimming classes, who had no experience with grab start diving, were randomly allocated into either the experimental or the control group. After receiving verbal instructions about how to perform the grab start, the control group participants performed a grab start, which was video recorded (pre-test). They then received verbal feedback to help them improve their performance, with their second dives (post-test) again video recorded. The experimental group completed the same procedure along with video analysis. Pre- and post-test dives indicated that, although both groups improved grab starts, the experimental group was more effective. Robles explained that the immediate visual feedback helped the learners to examine and re-examine their movement patterns in a controllable and rich visual presentation.

Coaches and PE teachers use different types of feedback to help learners and athletes improve performances. Giannousi et al. (2017) examined the effects of different types of feedback on the technique and speed of novice freestyle swimmers. The seven-week study involved 60 male first year university students being allocated to three experimental groups (i.e., self-modelling, expert-modelling, verbal group) or a control group. The self-modelling group observed video footage of their performances accompanied by verbal cues from the coach. The expert-modelling group received video feedback of an expert swimmer and the video footage was accompanied by verbal instructions from the coach. The verbal group received verbal instructional cues directed to the critical components of the skill. The control group received traditional verbal feedback containing a summary of KP feedback. The pre, post, and retention test results showed the freestyle swimming technique of all four groups improved with the self-modelling feedback intervention most effective, followed by the expert-modelling, verbal feedback, and finally the traditional summary feedback (control) group. The performance scores of the self-modelling and expert-modelling students were significantly better than the verbal and control group students. Giannousi et al. concluded that video analysis combined with verbal cueing was more effective than the verbal feedback techniques.

Benefits of Video Feedback

Empirical research of video analysis has identified several beneficial effects that have significantly influenced coaching and training methods. This section will highlight some of the positives associated with video feedback.

Changes in Video Technology

Video analysis technology has been utilised in PE classrooms for decades, and the pioneer users of this technology found it time consuming (Leight et al., 2009; Mohnsen & Bolt, 2000). After filming the footage with large cumbersome Video Home System (VHS) cameras, teachers would then remove the VHS cassette and move to a classroom where they could show the footage on a VHS player and television set (Laughlin et al., 2019). This time-consuming process may have negatively impacted the effectiveness of these early attempts to provide video feedback. According to Hamlin (2005), if recorded performances are not reviewed and the opportunity to practice is not available immediately, too much time may pass and the learner may not remember the changes. Over the years technology has developed (Leight et al., 2009) leading to a number of benefits for those implementing video analysis. One benefit is the ease of carrying out video analysis using the latest technology. The VHS cameras have been replaced by mobile devices such as mobile phones and tablets armed with user-friendly video analysis apps. These increasingly affordable devices now allow recorded footage to be viewed immediately by the learner. This immediate feedback was identified to be important because it allowed the learner to efficiently plan a strategy to improve the next performance (Roberts & Brown, 2008; Robles, 2013). Easy access provided by these devices also allows frequent rotation between the reviewing of video footage and actual practice (Darden, 1999; Rothstein, 1980).

Observation Capability

Technology developments have also afforded users improved observational capabilities, with users now able to capture fast elements of movement that cannot be seen in real-time (Knudson, 2013). Skills such as the overarm throw, a golf swing, or tennis serve have fast movements or components, which cannot be easily observed by the naked eye (Wilson, 2008). By video recording these skills, the footage can be replayed an unlimited number of times without the teacher having to worry about the learner becoming fatigued (Wilson, 2008). Using video analysis applications (apps), teachers and learners can watch footage in slow motion or frame by frame, allowing them to identify critical components of skills more easily (Beseler & Plumb, 2019; Hamlin, 2005), ultimately helping teachers to hone observation skills (Koh & Khairuddin, 2004).

Side by side or split screen comparisons are another option offered with these apps, allowing two videos to be synced and viewed at the same time. For example, a learner who is making technique errors when throwing, can record one of their throws and then record one of the peers who is demonstrating strong throwing technique. Those two throws can then be synced and viewed at the same time on a split screen. This is an effective method for the learner to identify proper technique and error detection. This split screen option also allows a skill to be filmed from two different angles. A golf swing filmed from side on and from behind can then be shown side by side, giving the learner the chance to see faults they could not see before, all at the same time.

Motivation and Engagement

Another benefit of video analysis is the positive impact it has on learners' confidence and motivation (Darden & Shimon, 2000; Darden, 1999; Ferracioli et al., 2013; Heynen, 2008; Koh & Khairuddin, 2004; Kretschmann, 2017; Laughlin et al., 2019; O'Loughlin et al., 2013; Tearle

& Golder, 2008; Weir & Connor, 2009). One proposed theory to explain motivational factors that contribute to performance and learning is Optimizing Performance through Intrinsic Motivation and Attention for Learning (OPTIMAL) theory (Wulf & Lewthwaite, 2016). Wulf and Lewthwaite suggested attentional and motivation factors contribute to performance and learning by strengthening the link between movement goals and actions. Wulf and Lewthwaite indicate that confidence is a predictor of performance and self-efficacy, identifying research that has revealed video feedback has enhanced the learning of swimming strokes and trampoline skills. They also identified video analysis resulted in greater satisfaction with performance and intrinsic motivation.

In sport psychology, motivation is considered as behaviour directed towards a goal or the internal and emotional interest in something (Ferracioli et al., 2013). Similar to sport, classroom performance is impacted by a learners' motivation, with teachers and coaches identifying strategies to help motivate the learners and athletes. Video analysis is one strategy that can help motivate and engage learners. A study conducted by Weir and Connor (2009) examined the impact video analysis had on learners' motivation, by investigating the use of digital video as a teaching, learning and assessment aid in PE. The first phase of the two-year study which involved 12 Irish secondary schools, examined how digital video could be implemented with a particular focus on its potential to enhance the provision of feedback. Comparing students from a class who had access to digital video technology and a class that did not have access to this technology, teachers reported video footage helped them highlight various aspects of quality performance, which they believed was a significant teaching and learning aid. The students' responses supported these views when they stated video footage allowed them to identify their strengths and weaknesses, elaborating that this was the best aspect of the entire project.

Mobile devices such as tablets and mobile phones allow students to take greater ownership of their learning. The intuitive touch-based interface of these mobile devices, allow even young learners to control this technology, giving them a sense of empowerment (Obrusnikova & Rattigan, 2016). Krettschmann (2017) investigated the impact of video analysis presented on a tablet to help fifth grade swimmers improve freestyle technique, while another group of fifth graders were provided traditional feedback that did not include video technology. At the end of the seven-week intervention, results identified that the tablet video analysis group felt the technology helped them identify what they were doing wrong and understand the instructions given by the teacher, positively impacting motivation levels. Jambor and Weeks (1995) also substantiated that instructor feedback made more sense to learners after they had viewed video replays.

Among the justifications given to explain why students are motivated by video technology is the belief that pupils see video analysis as new and exciting (Tearle & Golder, 2008). Casey and Jones (2011) examined the effectiveness of video technology when used to help engage underachieving and disaffected students in PE. The small project included 27 year seven students from a mixed gender class in Australia. Results showed that introducing video technology into PE lessons had a significant impact on student engagement. Semi structured interviews identified several benefits that came from implementing video technology into lessons. One benefit, a deeper understanding of the throwing and catching skills they were learning about, increased confidence, and helped them enjoy PE classes more. Another benefit of viewing replays of their performances was an improved ability to identify the technique errors they were making. Finally, being able to help peers become better throwers increased enjoyment, which was also linked to improved ability to identify technique errors.

Learner Control

An additional benefit of video analysis feedback is the ability for the learner to take control of learning (Hamlin, 2005; Harris, 2009; Janelle et al., 1997; O'Loughlin et al., 2013; Obrusnikova & Rattigan, 2016). An example of this control is learners deciding when they receive feedback. A self-controlled feedback study (Janelle et al., 1997) examined whether learners who had control over the video analysis feedback they received would learn more effectively than learners who had no control over the feedback schedule, and received feedback either after every five trials, or received yoked feedback that was matched with the self-controlled group. Participants performed an overarm throw with the non-dominant hand. The self-control group improved throwing and maintained the improvement more effectively than those with no control over the video feedback (yoked and summary group). Janelle et al. suggested that those who took control over feedback were encouraged to learn for themselves, in the process, assuming more responsibility for their learning, which may have led to improved motivation.

Video analysis provides scope for learners to have more control of their learning and be less reliant on teachers. If a smart phone is mounted on a tripod or if learners work in pairs to film each other, the need for a teacher to view each student’s motor skill performances decreases because learners can view their recorded skills and make decisions to improve technique. Hamlin (2005) suggested that video analysis allows students to “step outside themselves” (2005, p. 8), resulting in learners being more actively involved in making adjustments to their technique. O’Loughlin and colleagues (2013) also substantiated that self-assessment that occurs in video analysis enables learners to become more active in the learning process.

According to Harris (2009), video analysis technology allows a shift from traditional behaviourist teaching to a constructivist approach that involves learners being more active in their learning. Students can take control of learning, in the process developing critical thinking skills. This was supported by Obrusnikova and Rattigan (2016) when they stated the intuitive touch-based interface of mobile devices allows even young children to control their learning, which results in self-reliance and a sense of ownership.

Disadvantages of Video Analysis

Video feedback research has also identified several disadvantages, which includes video feedback can overwhelm, distract, and decrease practice time. These potential issues will now be discussed.

Video can Overwhelm

Video analysis provides the learner with a rich source of visual and auditory information (Lieberman & Franks, 2008), which can be too much for some learners to process (Bertram et al., 2007; Darden & Shimon, 2000; Kernodle et al., 2001; Liebermann et al., 2002; Spittle, 2021). According to Lieberman et al. (2002), this overwhelming feeling may particularly affect inexperienced learners. Kernodle et al. (2001) found females who received verbal feedback learnt to throw with their non-dominant hand more effectively than those who received video replay and verbal feedback combined. Suggesting the combination of video analysis and verbal feedback provided the learners too much information to process and interfered with learning.

A potential limitation coupled with video analysis providing too much information is that learners do not have a “correct” mental representation of what the movement should look like (Sidaway & Hand, 1993). As such, less experienced learners may need additional guidance to understand what is meant by ideal performance. If the correct performance of the skill can be modelled to learners, learners develop a mental representation of the movement and they can use the model as a reference point for correct technique (Casey & Jones, 2011; Obrusnikova &

Rattigan, 2016). Video modelling will be discussed in more detail when discussing the importance of learners understanding the critical components of a skill.

A contributing factor of learners feeling overwhelmed may be their limited understanding of what aspects of the footage in which they should focus. As a result, learners often fixate on irrelevant aspects of the footage. Cueing learners' attention to relevant information within video analysis can decrease the likelihood learners are overwhelmed by video feedback (Kernodle et al., 2002).

One specific problem related to learners not concentrating on relevant information in videos is that some learners are not familiar with seeing themselves on video and may be shocked or feel uncomfortable when viewing themselves for the first time (Darden & Shimon, 2000; Darden, 1999; Jambor & Weekes, 1995). This new experience may result in learners focussing on superfluous information (Ferracioli et al., 2013). Ensuring multiple video analysis sessions are provided to learners may overcome the problem of learners being overwhelmed.

A meta-analysis of 52 video replay studies concluded that a minimal amount of exposures was required for video replay to be effective (Rothstein & Arnold, 1976). This was supported by Hebert and Landin (1997) who explained that learners did not learn anything for the first two days of viewing video footage. According to Darden and Shimon (2000), students need time to successfully retrieve the most important information from video replay. The benefits of multiple video feedback sessions was also highlighted in a study of athletes given repeated opportunities to observe their tennis skill executions (Hebert et al., 1998). Results showed the number of replay session exposures impacted the effectiveness of video feedback. Qualitative analysis of the college player comments identified video feedback became more useful and informative with successive observation sessions. The comments in subsequent sessions identified more complex thought processing linking mechanics and shot outcomes, with a focus on the participants identifying the keys to success. Hebert et al. stated that for video analysis to be effective, learners must be allowed to practice and observe performance replays over multiple sessions. In the same vein, Rothstein (1980) suggested a minimum of five sessions over a semester is required for significant improvement.

Video Analysis can be Time Consuming

Implementing video analysis can be time consuming; leading to teachers feeling overwhelmed (Knudson, 1997; Liebermann et al., 2002; Palao et al., 2013; Potdevin et al., 2018; Weir & Connor, 2009). Weir and Connor (2009) conducted a study to examine the use of digital video in PE. Staff involved in the study suggested that implementing video analysis requires considerable preparation and planning, identifying the time-consuming nature of video analysis as the worst issue. Weir and Connor identified that these preparation demands decreased as the teachers became more familiar with the technology. Another study (Palao et al., 2013) examining the effectiveness of video analysis on the learning of hurdling technique also identified time commitment as a negative of video analysis technology. The quasi-experimental design study involved three existing classes (17, 21 and 22 students per class) that completed a five-lesson unit using one of three feedback methods: verbal feedback by the teacher, video analysis and teacher feedback, or video analysis and student feedback. The results indicated that, while all interventions significantly improved technique, the video analysis teacher feedback group achieved the most positive overall results, including improved technique, increased knowledge and the highest level of practice. The video analysis student feedback group significantly improved technique and achieved the highest level of quality practice. The verbal feedback by teacher group improved technique and knowledge; however, they also produced lower quantity and quality practice during the sessions. The teacher at the centre of this hurdling study, who did not have a strong technology background, stated without the assistance of the research team he would have been overwhelmed by the technology.

Video Analysis can Decrease Practice Trials

The time-consuming nature of video analysis in a learning setting can negatively impact the practice trials performed. Rink (2003) suggested that the number of practice trials performed by learners has a positive relationship to learning. Silverman (1985) examined the effect of practice trials and student engagement on achievement and found that the number of practice trials performed by learners learning the survival float, was a positive predictor of achievement. Thus, PE teachers should ensure that students get the opportunity to perform the skills they are learning as often as possible, and that using video analysis can reduce physical activity in those lessons. Learners spend more time observing and analysing performances and less time performing the skills. Boyce et al. (1996) reported learners receiving video analysis feedback in a 30 minute session, spent on average six minutes and 30 seconds actually performing the skill, compared to the verbal groups, which spent on average 17 minutes and 30 seconds. One study (Guadagnoli et al., 2002) did, however, find that this decreased time practicing did not negatively impact the learners' performance. These findings demonstrated the trade-off between instruction time and practice time was justified.

Implementing Video Analysis

Weir and Connor (2009) identified that video analysis should only be used to achieve a worthwhile educational experience, adding that teachers should only implement this technology if it allows a teaching purpose to be achieved more effectively or efficiently without its use. The students' initial excitement of using video technology will dissipate, so the use of video analysis technology should still have a purpose. Teachers should consider certain factors when implementing video analysis in PE classes including (but are not limited to): the learners' skill level, the learners' age, improvements may not be immediate, and immediate practice.

Learners' Skill Level

One consideration when implementing video analysis is the learners' skill or ability level. Researchers have indicated that the effectiveness of video analysis may depend on the skill level of the learners (Boyce et al., 1996; Darden & Shimon, 2000; Darden, 1999; Hebert et al., 1998; Rikli & Smith, 1980; Rothstein, 1980). Rikli and Smith (1980) examined the effectiveness of video analysis delivered at different stages of the participants' stage of learning the tennis serve. The study participants were either advanced beginners (24 men and 24 women) or intermediate (24 men and 24 women) tennis players. Ability level was determined by a subjective rating scale, where advanced beginners were slightly more experienced than beginners, but less experienced than intermediate players. Participants were allocated to one of four intervention groups: early, middle, combination, and control groups. The early group received video analysis early in their instructional cycle, the middle group received video analysis midway through the instruction, the combination group received video analysis both early and midway through their instruction, and the control group received no video analysis feedback and only traditional verbal feedback. Participants worked in small groups with a qualified tennis instructor, with serving form recorded at the start, and at the completion of the intervention. Five phases of serving technique (footwork, body movement, ball toss, arm pattern – Phase 1, and arm pattern - Phase 2) were analysed. The pre- and post-test serving technique rating scores showed that all three video analysis groups improved significantly compared to the control group for the footwork and arm pattern-Phase 1 dependent variables, with no significant performance differences between the three video analysis groups. Follow-up analysis revealed that only the intermediate participants in the video analysis groups improved footwork more than the control participants. The advanced beginners in the video analysis groups showed no significant improvements in footwork when compared to the control group. Furthermore, questionnaire responses indicated that 86% of participants felt video analysis was effective in improving their serving technique, 14% were either unsure or felt video analysis had not been effective. Rikli and Smith suggested that video analysis can be beneficial in limited situations and is probably not as effective as its extensive use would suggest.

Higher level golfers have also been shown to benefit more from video analysis than lower-level golfers. Bertram et al. (2007) examined the effect video analysis had on participants' golf swings. The 48 novice (handicap above 25) and skilled (handicap between zero and 10) golfers completed a 12-shot pre-test that recorded swing characteristics (e.g., club head speed, club face angle at impact, and tempo). After pre-testing, participants were randomly allocated to one of three intervention groups: verbal coaching, video analysis, and self-guided intervention. Those in the verbal coaching intervention received a 20-minute lesson from a golf pro where they hit a total of 30 shots and received standardised (scripted) verbal feedback. Those in the video analysis intervention followed the same procedures except they also received a video replay after shots 5, 10, 15, 20 and 25, and were able to replay the swing three times at normal speed, three times in slow motion, and another three times at normal speed. During replay viewing, participants discussed the footage with the pro. Those in the self-guided intervention hit 30 shots over a period of 20 minutes and received no instruction. Following the interventions, and a 15-minute rest period, participants completed a 12-shot post-test, with no feedback provided, like the pre-test. Like the Rikli and Smith (1980) study, results indicated that the video analysis feedback was more effective for the more highly skilled learners, with significant improvements to the consistency of their swing tempos, indicating differential results based on learners' skill level. The novice performers who received the same video analysis feedback did not show the same improvement and, in fact, the video analysis feedback impeded learning and resulted in poorer swing tempo consistency in their post-testing. Bertram et al. explained that novices were potentially trying to assimilate large amounts of internal and external feedback, possibly exceeding their cognitive load. An alternate explanation may be that the novice performers did not have a clear mental representation of the desired movement pattern they were attempting to produce, and after viewing their replays they were unable to reproduce the desired movement (Sidaway & Hand, 1993). Rothstein (1980) also suggested that skilled learners are able to identify their weaknesses and are more capable of modifying their future performances.

Learners' Age

Age should also be considered when implementing video analysis, where younger learners may not benefit from video analysis as much as older learners. Boyce et al. (1996) examined how to deliver feedback to elementary school students learning different motor skills. Teacher delivered feedback, peer feedback and video analysis were used to teach third graders to perform an overhead basketball pass and fifth graders to perform a tennis forehand. The results showed that the third graders learnt more effectively when they received verbal feedback compared to receiving video analysis feedback or peer feedback, which indicated younger learners may not be capable of processing all the information presented in the video analysis feedback. Furthermore, video analysis produced the best learning for the older fifth graders. Apparently, older students benefit more from video analysis than the younger learners, particularly when the video analysis is accompanied by teacher-directed cueing.

Improvements may not be Immediate

Video analysis may not lead to immediate improvements in performance; therefore, the short term and long-term effects of video analysis is another factor that should be considered when providing video analysis feedback. Research (Guadagnoli et al., 2002) has indicated that video analysis may not achieve immediate performance improvement in post-testing, however, given time to understand technique adjustments, performance improvements may be shown in retention testing. Guadagnoli et al. (2002) examined the efficacy of video analysis relative to verbal feedback and self-guided golf practice. In Guadagnoli et al.'s study, 30 community golfers holding handicaps ranging from 7 to 16 completed pre-testing that involved measuring performance accuracy and distance of 15 shots with a 7-iron. Participants then completed four 90-minute practice sessions in one of three groups: verbal feedback from a PGA teaching professional, verbal and video analysis feedback from a PGA professional, and self-guided practice where participants received no feedback. After the four practice sessions, participants completed an immediate post-test and a 2-week delayed retention test. Results indicated no significant improvement for any group post-testing, but during the retention test the video analysis group hit the ball farther and more accurately than the verbal feedback group, which in turn, performed better than the self-guided group. Guadagnoli et al. explained that these results might have occurred because the participants were trying to adjust to the technique changes during the practice sessions in the post-testing. Over time, the two instruction groups may have become comfortable with these swing modifications, leading to better performance during the retention-testing.

Immediate Practice

Sessions involving video analysis should be structured so that learners have the opportunity to practice immediately after viewing the footage, allowing them to correct the errors instantly (Rothstein, 1980). Darden (1999) recommended frequent rotation between video analysis and actual practice, allowing learners to attempt to improve the errors witnessed in the video analysis. Roberts and Brown (2008) supported this stating video analysis enables learners to see their performances, receive feedback, then practice the errors immediately, which often results in performance improvements. One teacher providing frequent video analysis feedback to an entire PE class is challenging, thus, one method that can increase the frequency of feedback is using video analysis in a peer teaching setting (Ayvazo & Ward, 2009; Cervantes et al., 2013; Johnson & Ward, 2001; Mosston & Ashworth, 2002).

Peer Teaching

Feedback frequency can be increased when students work with a partner. Peer teaching, often referred to as peer tutoring (Byra & Marks, 1993; Johnson & Ward, 2001), or reciprocal peer teaching (Mosston & Ashworth, 2002), is an instructional method where students are placed in pairs. While one person practices a skill, the other provides feedback.

Reciprocal Peer Teaching Explained

One commonly used form of peer teaching is Mosston and Ashworth's (2002) Reciprocal Teaching (RT) where learners generally work in pairs (dyads) to improve each other's skill level. One student acts as the doer (or tutee) and performs the task and the partner acts as the observer (or tutor) and is responsible for providing immediate and ongoing feedback to the doer. The provision of this feedback is guided by a criteria sheet (or checklist) designed by the teacher. When instructed, the pair swaps roles and repeats the process. Peer teaching engages the learner in the learning process and encourages higher-order thinking (Harris, 2009), which enhances the observer's cognitive processing, motivation and attention directed to the task (Ensergueix & Lafont, 2010). Students working in pairs to analyse each other's technique empowers them to take control of their learning, which results in a constructivist approach leading to students who are engaged and active in their learning. Peer teaching assists learners to develop a better understanding of the learning process (Byra & Marks, 1993), which occurs through observing the doer's performances, comparing that performance to the checklist and assessing its effectiveness, and providing feedback. This instructional method also allows efficient feedback to be provided to the doer, which allows more time to perform a skill correctly. The sooner the learner knows how they performed, the greater the chances of improving performance (Mosston & Ashworth, 2002). The structure of reciprocal peer teaching allows it to be effectively combined with video analysis. This combination allows the doer to witness themselves performing the skill, at the same time hearing the observer describe the performance, this helps them understand their performance kinaesthetically (Hamlin, 2005). For the remainder of this dissertation, reciprocal peer teaching will be referred to as peer teaching.

Implementing Peer Teaching

There are several considerations when implementing peer teaching, which include (but are not limited to) ensuring the students understand what the session involves, the roles within the session, and the content they will be teaching and learning. For peer teaching to be effective, the teacher cannot just assign students to work in pairs. Mosston and Ashworth (2002) explained that prior to the pairs being arranged and any practice taking place, the teacher should ensure the students understand what the session is going to involve and the roles that will be performed. The role of the doer, the observer, and the teacher should be clarified, and then the subject matter explained and demonstrated, including a thorough description of how the checklist will be used and how constructive feedback will be provided. Technique explanation videos can be used to clarify the component of the skill that the students will learn. The teacher should also explain the logistics of the equipment distribution, practice time and space allocation. Most importantly, students are allowed to ask questions. Once the logistics of the session have been clarified, the students can then be arranged into pairs.

Arranging Pairs

The arranging of pairs is another consideration when implementing peer teaching. Byra and Marks (1993) examined the effect of pairing students with friends or non-acquaintances. It was found that observers who were working with friends provided feedback more frequently, resulting in a higher number of correct responses, which led to improved motivation and engagement with the learning tasks (Siedentop & Tannehill, 2000). Learners selecting their partners results in sessions beginning more swiftly and more productively (Mosston & Ashworth, 2002). Furthermore, doers felt more comfortable when they received feedback from friends compared to non-acquaintances. With an understanding of the importance of feedback provision (Bilodeau & Bilodeau, 1969), students should be allowed to pick their own partners. In line with these considerations, the students in the peer teach studies within the present dissertation selected their own partners.

The Teacher's Role

For peer teaching to be effective the teacher should take the role of facilitator (Jambor & Weekes, 1995). As facilitator, the teacher avoids giving the pairs the answer, instead asks questions to guide the students to the information they require. When interacting with the pairs, the teacher should only communicate with the observer to ensure the authority of the observer is not taken away (Mosston & Ashworth, 2002). Based on this information, the researcher will only communicate with the observer in the peer teaching studies of this dissertation.

Understanding the Critical Components of a Skill

A strong understanding of the critical components of the skill being analysed is critical for the success of peer teaching. One way to develop an understanding of the critical skill components is through technique explanation videos, often referred to as modelling (Obrusnikova & Rattigan, 2016). Video modelling provides the learners a model of best practice that gives them a reference point for the ideal performance (Casey & Jones, 2011), which is especially effective in early instruction (Magill & Anderson, 2021). The modelling videos use footage and verbal narration to highlight the critical skill components as well as important teaching cues and common errors demonstrated by learners (Morrison & Reeve, 1986). The ability to observe skills in a controlled presentation is particularly important for learners who are still developing an understanding of how to perform a novel skill for the first time. According to Guadagnoli et al. (2002), while a learner is developing a mental representation of the skill, a demonstration or model must be provided. Video demonstrations of the desired movements are effective in assisting learners to develop a perceptual blueprint or cognitive representation of a desired action (Horn et al., 2002). Horn et al. conducted a study involving 21 female novice soccer players, examining the effectiveness of video modelling and point light models in facilitating learning of a short soccer chip. Participants were placed into video, point-light and control groups. The video group practice sessions involved three cycles of viewing video modelling of a female national soccer player performing a soccer chip followed shortly after with practice. The point-light group completed similar practice with the video footage only showing dots of light at 18 of the major joint centres of the model. The control participants completed the same practice except they did not view any video footage. Performers were advised to perform the short chip over a 35-centimetre barrier, accurately and with the correct technique. The results of the pre- and post-intervention testing indicated that while video and point-light groups were not able to significantly improve the soccer chip accuracy from pre- to post-testing, they accelerated the learning process and developed a global movement pattern superior to the control group. Considering the superior performance results associated with more advanced movement patterns (Roberton & Konczak, 2001), accelerating the acquisition of superior movement patterns through video demonstrations is an appealing option.

Critical Component Checklists

To assist peer teaching, pairs should be provided a critical component checklist that they use as a guide when they are analysing video footage, which directs attention to the critical skill components in the peer teaching arrangement (Darden & Shimon, 2000; Darden, 1999; Hamlin, 2005; Melville, 1993; Mosston & Ashworth, 2002; Oñate et al., 2005). For example, Bayless (1981) used a between subjects design to investigate the effect of type and length of exposure to a prototypic skill on the assessment of correct and incorrect performances of volleyball spikes, serves and blocks. Two class sessions one day apart were conducted. In the first session, participants received either one or three exposures of the three skills, through either visual or audio-visual mode, and were then tested on their ability to detect errors (pre-test). During the second session, all participants practiced discriminating correct and incorrect performances of the volleyball skills, while following a checklist that guided their attention to the critical components of the skills (post-test). The results of the pre- and post-testing indicated that participants in the visual groups were more proficient at detecting technique errors the participants in the audio-visual groups. The results also indicated that the groups receiving only one exposure detected errors more effectively than those who received three exposures, possibly indicating that the additional audio information and the additional exposures interfered with performance. The significant pre- to post-testing improvements indicated that the checklist was beneficial to participants' ability to identify correct and incorrect performance of volleyball skills. One limitation, however, was that there was no control group to determine if these improvements would have occurred without access to the checklist. Since all participants had access to the critical component checklist, conclusions cannot be drawn about whether these improvements may have occurred naturally (and without using the checklist), which reduces the accuracy of the conclusions of this study.

The design of the checklist implemented in the current dissertation was guided by checklist development recommendations identified in the literature (Beseler & Plumb, 2019; Darden & Shimon, 2000; Darden, 1999; Hamlin, 2005; Janelle et al., 1997; Mosston & Ashworth, 2002).

These included a clear description of the skill, the critical components learners should be looking for, pictures of the components and feedback cues to prompt the correct performance. The ultimate aim was to allow learners to take ownership of their learning by engaging them in higher-order thinking where they decide what needs to happen next (Harris, 2009). This results in a shift from the behaviourist approach where the teacher controls proceedings, to a constructivist approach where the learners oversee their learning. Researchers (O'Loughlin et al., 2013; Shepard, 2000) have found that learning through self-assessment increases responsibility for learning, which enables the learners to be more active in the learning process. Checklists can help learners by guiding them to focus on the critical components (Darden & Shimon, 2000), which is particularly important in large classes where it is not feasible for the teacher to provide frequent feedback to all students after viewing their performances.

When developing these checklists, the components of the checklist should be specific so that learners can reliably determine whether they are performing them successfully when they view the video footage frame by frame (Hamlin, 2005). Only the most critical components required for the successful performance of a skill should be included on a checklist (Darden, 1999) because too many components will result in thoughtless, inaccurate analysis of the video footage (Darden & Shimon, 2000). Janelle et al. (1997) suggested that checklists need to be designed to guide the learners but emphasised the importance of the learners being encouraged to learn for themselves.

Effects of Peer Teaching

Peer teaching can impact the amount of skill executions that learners perform during lessons. Johnson and Ward (2001) assessed the effects of peer teaching on the number of trials, and the number, and percentage, of correct trials to determine if peer teaching was effective compared to conventional teaching methods. The pairs worked in peer dyads, one acted as the tutor and one acted as the tutee. A correct trial was defined as a trial that the tutee performed the critical components identified by the teacher for the performance. Results indicated that even though the number of trials significantly decreased in the peer teaching intervention, the number, and percentage, of correct trials increased, likely leading to improved motivation and engagement with the learning tasks. Johnson and Ward suggested that the decrease in the number of trials may be a result of the learners focusing more on the quality rather than the quantity of performances, and the increase in the frequency of individual feedback each tutee received during the sessions. Learners in the tutor role were also required to assess whether the tutee was performing the skill correctly. If there was a technique fault, the tutor had to identify the component that was incorrect. In the peer teaching intervention, tutors accurately assessed their tutees' technique more than 90% of the time, with the superior assessment possibly a result of the more active role the peer teaching learners took in the learning process (Townsend & Mohr, 2002), possibly leading to improved cognitive development (Metzler, 2005).

Gap in the Research

The use of video feedback in PE classes is widespread, however, there has been minimal research examining the efficacy of video analysis (Johnson et al., 2019; Kretschmann, 2017; Palao et al., 2013; Potdevin et al., 2018; Tearle & Golder, 2008; Weir & Connor, 2009), particularly in ecologically valid PE settings (Bronfenbrenner, 1977; Miller-Cotto & Auxter, 2021). Bronfenbrenner (1977) explained that ecological validity refers to the extent to which the environment of a scientific experiment has the properties it is supposed to have in relation to a naturalistic setting. Many video analysis studies (e.g., Bertram et al., 2007; Ferracioli et al., 2013; Kernodle et al., 2001) have been conducted in one-on-one settings often carried out in laboratories. The findings of these laboratory studies are somewhat irrelevant to PE teachers because working one on one with a student is not feasible in a normal class situation. Kernodle et al. (2001) worked individually with 19 to 22 year old females to see if their non-dominant hand throwing could be improved through different forms of feedback. Ferracioli et al. (2013) involved participants working one on one with experimenters to determine the motivational effect of different forms of feedback when learning breaststroke swimming. Bertram et al. (2007) had participants work individually with the experimenter to determine the effect that three different forms of feedback had on their golf swing. This limited research conducted in ecological valid PE settings is a gap in the research. More research involving realistic teacher to student ratios in a class setting is required, rather than experimentally controlled settings.

There is also a need for more research that examines the effect of video analysis conducted over timeframes more suitable for a PE setting. Many studies (Giannousi et al., 2017; O'Loughlin et al., 2013; Palao et al., 2013; Rothstein, 1980; Van Wieringen et al., 1989) have been conducted over unrealistic, drawn-out time frames not feasible for PE teachers. One of the challenges faced by PE teachers is trying to cover the large amount of content they are expected to teach in the PE curriculum. The minimal time PE teachers have with their students makes it challenging to teach all the curriculum content. As such, PE teachers may only have one or two sessions that they can spend teaching each unit of content. As a result, it is not feasible to spend many sessions trying to develop one fundamental motor skill.

Another gap in the research is studies that examine the effect video analysis performed with mobile device technology (Kretschmann, 2017). More research is needed to examine video analysis completed using Smart phones and tablets armed with movement analysis apps. Specifically, research examining the effectiveness of contemporary video analysis technology used in a peer teaching setting.

Research Significance

Learning of motor skills can be impacted by the quality and quantity of feedback during the learning process (Harris, 2009). Researchers have shown that feedback can be enhanced through peer teaching, and it could potentially be enhanced further if learners have access to video analysis technology. According to Potdevin et al. (2018), video analysis is an essential strategy that learners can use during practice to acquire new motor skills. This technology allows greater movement detail to be captured, detail that the naked eye may not see (Knudson, 2013). Not only can the footage be viewed by the tutor to identify strengths and weaknesses, but it can also be replayed to the learner to enhance augmented feedback (Jambor & Weekes, 1995).

For PE teachers to capably implement video analysis into their classes, they need to have the necessary pedagogical-technological skills (Potdevin et al., 2018). Video analysis will have little effect in a PE setting if teachers conducting these sessions are not trained appropriately. Pre-service teachers believe they do not get adequate hands on opportunities to experience the use of technology in the PETE programmes (Casey et al., 2017; Tearle & Golder, 2008). If this study can determine the effectiveness of video analysis used in a peer teaching setting, these findings could help shape the future of PETE training. The ecologically valid activities conducted in studies in this dissertation could be easily implemented into PETE programmes. This is critical because if pedagogies are to be utilised by teachers, the strategies used should be flexible enough to be implemented in different settings (Ayvazo & Ward, 2009). The skills developed by these pre-service PE teachers could be then implemented in primary and secondary school PE classes across the world. Ultimately this could increase teachers' pedagogical-technological skills giving them the confidence to implement technology into their PE classes, the confidence that some are lacking (Casey et al., 2017; Palao et al., 2013; Potdevin et al., 2018). Considering the seemingly unstoppable growth in the way young people are engaging with digital technology in their personal lives, arming PE teachers with these technological skills could give them the important leverage to engage young learners (Casey et al., 2017).

To my knowledge, there has been no research examining the efficacy of video analysis completed in a peer teaching setting. With the video analysis performed with mobile devices, this research could determine whether motor skills can be developed more effectively in a peer teaching setting, using the latest video analysis technology. The findings of this dissertation will assist in the preparation of pre-service PE teachers. By better understanding the efficacy of video analysis used in a pee teaching setting, PE teacher educators could better prepare pre-service PE teachers by strengthening their ability to perform and analyse the overarm throw. Effective video analysis in peer teaching could potentially help pre-service PE teachers acquire FMS more efficiently (Horn et al., 2007), which is important considering the more effectively a PE teacher can perform a motor skill, the better they can teach that motor skill (Gabbei, 2011). Effective video analysis in peer teaching could also improve pre-service PE teachers' ability to perform qualitative movement diagnosis (QMD), with QMD considered one of the most important skills required of PE teachers (Gangstead & Beveridge, 1984; Hoffman, 1983; Kelly & Melograno, 2004; Overdorf & Coker, 2013; Pinheiro & Simon, 1992; Ward et al., 2020).

CHAPTER 3

STUDY 1: QUALITATIVE ASSESSMENT OF THE BACKSWING IN UNIVERSITY STUDENT OVERARM THROWING

Qualitative assessments of motor skills focus on how the skill is performed in comparison to an established set of criteria (Walkley & Kelly, 1989). Qualitative assessment of motor development measures verbal descriptions of the qualitative changes occurring in those movements (Roberton & Konczak, 2001). With over 40 years of research, one of the more prominent qualitative assessment systems used to gauge fundamental motor skill (FMS) changes are developmental movement sequences that Roberton and colleagues hypothesised and validated (Langendorfer, 1980; Roberton, 1977, 1978; Roberton & Halverson, 1984; Roberton & Langendorfer, 1979). Rather than attempting to assess total body configurations, Roberton's levels use a body component approach dividing the body into segments or components. Each component is then broken into levels that are verbal descriptions of the common sequences that learners exhibit as they perform the skill over time (Roberton & Konczak, 2001). The levels are ordered according to their appearance in most individuals as the performance of the motor skill develops (Roberton & Halverson, 1984). The levels form a sequence that can be used to assess male and female throwing development across the lifespan; different individuals proceed along this continuum at different rates (Roberton & Halverson, 1984). As the more advanced levels appear, so too do superior results (Roberton & Konczak, 2001).

The validation of Roberton's assessment system, primarily used to gauge the development of FMS in children and adolescents, involved numerous considerations. First, all people are assumed to experience the levels as they develop (universality) (Williams et al., 1990). Second, the levels are intransitive resulting in an invariant order of change (Haywood et al., 1991; Roberton, 1977, 1978; Roberton & Langendorfer, 1979; Williams et al., 1990, 1991). Third, the levels are accurate and comprehensive, as such, it should be possible to use the levels to assess the development of a wide variety of populations (Haywood et al., 1991).

The overarm throw is the FMS that has been researched most extensively using Roberton's (Roberton & Halverson, 1984) assessment system, where researchers have refined the components and the originally proposed component levels. One of the five components identified as critical to performance of the throw is the backswing, because it constrains the arm movement possible in the forward swing motion (Langendorfer et al., 2012). The importance of this component could explain the multiple sequences that have been proposed over the years. Currently, universal agreement about the optimal sequence has not been reached.

Langendorfer (1980) originally proposed a backswing sequence that included four levels to measure this critical component, describing qualitative differences hypothesised to change sequentially with time. Level 1 describes initial throwing attempts when there is no backwards movement of the hand and the ball is thrown from the position that the thrower first grasps the ball. With practice, the backswing then progresses to Level 2 where the ball is lifted to a position behind or alongside the head with elbow flexion, but the ball never moves above head height. A Level 3 backswing occurs when the ball is moved to a position behind the head via a circular overhead movement with an extended elbow. Finally, a Level 4 backswing is when the ball moves to a position behind the head via a circular, down and back motion, which carries the ball below the waist.

Researchers identified that the backswing developmental levels originally proposed and validated on children may not have been comprehensive for assessing other age groups (Haywood et al., 1991; Williams et al., 1990). Observing older throwers aged between 67 and 77 years, Haywood et al. (1991) identified two movements that were qualitatively different from the original developmental levels. To examine this, 21 participants between 67 and 77 years took part in a study to validate the adaptation of Langendorfer's (1980) developmental levels for the overarm throw for comprehensive lifespan assessment. Testing was completed over two years. Each year participants threw a tennis ball five times for maximal distance and all throws were video recorded. During the second year, a video motion analysis system was used to derive resultant ball velocity from the two frames immediately following ball release. The throws were assessed and modal (i.e., most frequent) backswing levels were determined. Results established that two new hypothesised backswing movements were confirmed and added to the original developmental levels.

Langendorfer's (1980) original backswing levels are described in Table 3.1 as Levels 1, 2, 4, and 6. The assessment of the older throwers found that some participants demonstrated a backswing that involved lateral rotation of the humerus in an abducted position that was approximately 90^0 to the trunk. This "new" action is illustrated in Table 3.1 and Figure 3.1 as Level 3 humeral lateral rotation. Some participants performed a backswing similar to the highest existing level, however, premature elbow flexion resulted in the ball moving into a frontal or oblique plane rather than the sagittal plane, this "new" movement was allocated to Level 5.

Descriptive statistics showed nearly half of the older adults were categorised into one of the two new levels. These new preparatory movements (and throwing levels) may relate to the thrower's lack of flexibility, with the fear of injury when throwing with maximum force also being a potential cause for these new movements. In line with the notion of process-product relationship (Pinheiro & Simon, 1992; Roberton & Konczak, 2001), throwers in the Haywood et al. (1991) study who demonstrated higher levels generated higher mean velocities except for Level 3, which was marginally faster than Level 4.

Table 3.1

Modified Backswing Sequence for the Overarm Throw for Force

Level 1	**No backswing.** Ball in the hand moves directly forward to release from the arm's original position.
Level 2	**Elbow and humeral flexion.** Ball moves away from the target to a position behind or alongside the head by upward flexion of the humerus and elbow.
Level 3	**Humeral lateral rotation.** Ball moves away from the target by lateral rotation of the humerus in a position of 90 degrees abduction.
Level 4	**Circular, upward backswing.** Ball moves away from the target to a position behind the head via a circular overhead movement with elbow extended, or a diagonal lift, or a vertical lift from the hip.
Level 5	**Shortcut circular, downward backswing.** Ball moves away from the target to a position behind the thrower via a circular, down and back motion, which carries the ball below waist height, followed by elbow flexion, at the end of the backswing the ball is forward of the outline of the thrower's body (when viewed from behind).
Level 6	**Circular, downward backswing.** Ball moves away from the target to a position behind the thrower via a circular, down-and-back motion, carrying the hand below the waist, at the end of the backswing the ball is within the outline of the body (when viewed from behind).

Note. Levels have been adapted from Roberton and Halverson (1984) and Williams et al. (1998)

Figure 3.1

Backswing Movement Patterns

The addition of Levels 3 and 5 helped describe two qualitatively different backswing patterns observed in a substantial number of older throwers, making the levels more comprehensive for qualitative assessment of older throwers (Haywood et al., 1991). The adapted backswing levels had yet to be validated for the assessment of younger throwers, which raises the question, is the modified level sequence suitable for assessing the backswing of younger throwers? To compare older and younger throwers, a longitudinal study that examined the changes in throwing patterns of eight older adults for 7 years (Williams et al., 1998) found elderly throwers coordinated their movements in a comparable way to younger throwers. Based on these findings and my experience assessing the overarm throwing technique of primary, secondary and university students, it is proposed that the new movements are not confined to older throwers. Further, the additional levels make backswing component assessment more precise and more sensitive, suitable for assessing the backswing component of university-aged throwers.

In contrast to the Haywood et al (1991) backswing levels, it is proposed that the Level 3 and Level 4 backswing components require re-ordering. The humeral lateral rotation Level 3 backswing allows forearm pronation (Langendorfer et al., 2012) and increased trunk rotation away from the target, which enhances the length of the backswing. This increased backswing length and trunk rotation is associated with projectile velocity and humerus and forearm development (Langendorfer & Roberton, 2002). As a result, the Level 3 backswing is more advanced than the circular, overhead Level 4 backswing and closer to the desired circular, downward Level 6 backswing. This is supported by Haywood et al. (1991) who found that participants throwing with a Level 3 backswing, threw faster than those with a Level 4 backswing. Throwers with a Level 3 backswing tend to demonstrate greater trunk rotation than those with a Level 4 backswing. Greater trunk rotation is associated with more advanced throwing development. Immature trunk rotation perturbs balance less and allows throwers to keep their head and shoulders facing the target (Langendorfer et al., 2012).

Gender differences in throwing performance have been well documented (Beseler et al., 2021; Lorson et al., 2013; Roberton & Konczak, 2001). Males outperform females as early as 5 years of age (Butterfield et al., 2012), and a gender difference is still evident in throwers in their 60s and 70s (Haywood et al., 1991). One common explanation of the gender difference is that males practice throwing more than girls (Johnson et al., 2020; Johnson et al., 2019; Roberton & Konczak, 2001).

Study Aims

The purpose of this study was to validate an adaptation of Langendorfer's (1980) levels for the backswing component of the overarm throw for male and female university-aged throwers. In addition, I wanted to determine whether there is a relationship between backswing level and throwing velocity. Finally, I wanted to determine whether male throwers would outperform female throwers. Validation would be achieved by showing younger throwers also exhibit these new categories proposed by Haywood et al. (1991), and also by showing an association between backswing level and throwing velocity.

It was hypothesised that the Haywood et al. comprehensive sequence will be suitable for assessing the backswing component of the overarm throw for male and female university-aged throwers. It was hypothesised that there will be a positive relationship between backswing level and throwing velocity. It was further hypothesised that those throwing with a Level 3 backswing will throw faster than those with a Level 4 backswing. It was hypothesised that velocity will depend on gender with males expected to throw with higher velocity than females. It was also hypothesised that there will be an interactive effect of gender and backswing level on throwing velocity.

Method

Participants

One hundred and two university students and staff between 17 and 57 years of age, enrolled in or teaching in a variety of undergraduate university programs participated in the throwing study (M_{age}= 24.36; SD_{age} = 9.87 years). Testing was completed during orientation week at the university over two years and included 60 males (M_{age}= 22.71; SD_{age} = 9.21 years) and 42 females (M_{age}= 26.71; SD_{age} = 10.40 years) who were naïve to the purposes of the study.

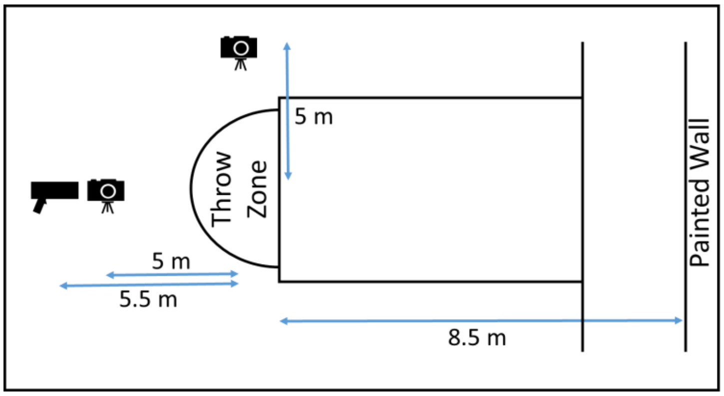
Equipment

The venue for the testing was a single basketball court gymnasium at a regional university in Victoria, Australia. All four walls of the 33.5 m by 21.3 m facility were constructed of solid brick material strong enough for tennis balls to be thrown against.

Participants threw standard tennis balls with a weight of 58 grams and a diameter of 6.5 cm towards a rectangular target (height 180 cm x width 280 cm) painted on a wall. Individual throws were filmed at a rate of 50 frames/second by two Sony Cybershot DSC-RX100 Mark I digital video cameras (Sony Corporation, Tokyo, Japan) with shutter speeds of 16.67 milliseconds, placed to the open side (facing the thrower's chest) and rear of the thrower. Each camera was placed on a tripod at a height of 1.3 m. The camera from behind was set up directly behind the line of the participant's ball release at a distance of 5 m. The camera on the open side was set up perpendicular to ball release and direction of the throw at a distance of 5 m (Figure 3.2). The radar gun manufacturer guidelines identified that radar guns work on the Doppler principle, meaning velocity readings will only be accurate when the projectile is moving directly towards or directly away from the gun. Following these guidelines, I stood behind the rear camera, recording ball velocity information using a Stalker Pro radar gun (Stalker Pro, Applied Concepts, Texas, USA) positioned on a tripod 5.5 m behind the position of ball release at the height of 1.6 m.

Figure 3.2

Camera and Radar Positions (for Left Hand Throws)



Prior to the study commencing, preliminary testing was conducted to validate radar gun accuracy by comparing the velocity simultaneously measured by the radar gun with speed measured using a high speed Redlake camera (PCI 2000 S, Redlake Imaging Corporation, San Francisco, USA). The camera, which was calibrated with a steel ruler in the footage, filmed five throws perpendicular to ball release and direction of the throw. The camera was positioned at the greatest distance from the action to reduce parallax error. The camera recorded images at 1000 frames a second with a shutter speed of 1/2000th of a second. The high shutter speed gave sharp un-blurred images of the ball. Ball release speed was calculated by measuring the distance the ball travelled after leaving the hand over 10 frames. Speed was then calculated by dividing the distance travelled by the time taken which was 10ms. The mean of the throws measured by the Redlake camera and the radar were 30.596 and 30.561 m/s respectively. The mean error (-0.035) and standard deviation of mean error (0.135) produced a mean absolute deviation of 0.054, and a percentage difference of -0.114 between the radar gun and the Redlake camera. Before each testing session the calibration procedures in the operation manual for the radar gun were followed to check the calibration of the radar gun with the manufacturer provided tuning fork.

Throwing Task Specifications

To perform the throws, participants were positioned within the semi-circle at the top of the basketball key to ensure the entire throwing performance was captured by the video cameras (Figure 3.3). The distance from the front of the throwing zone to the wall was 8.5 m. To assist footage assessment, two stands were positioned in view of the rear camera. One stand held the participant’s identification number, the other held a laminated sheet identifying the number of the throw being performed.

Figure 3.3

Throwing Position

The footage from the two cameras was synced on Adobe Premiere Pro Creative Cloud video editing software 2014 (San Jose, CA: Adobe Systems Incorporated) to obtain simultaneous side and rear views of each performance. Individual video files for each participant were produced; these were viewed and analysed using the Kinovea video player program (Version 0.8.27) [Computer software], available from https://www.kinovea.org/. The Kinovea program allowed the footage to be viewed frame by frame by simply clicking the right or left arrow on the keyboard. A screenshot of Kinovea can be seen in Figure 3.4.

Figure 3.4

Kinovea Assessment Screenshot

Procedure

All aspects of participation in the study were explained, and written consent was obtained prior to the collection of data. The study was approved by the University Human Research Ethics Committee (see Appendix A, B, C). After familiarising each participant with the testing procedure, the participant's gender, height, weight, age, previous throwing experience, and program of study (if applicable) were recorded in a demographic questionnaire (see Appendix D). To help with the assessment of the backswing, the participant placed a self-adhesive sticker that contrasted the colour of their clothing over their belly button. Participants then completed a questionnaire that identified their current and previous involvement in organised sports that involved overarm throwing, and the frequency which the participant was currently and had previously been involved in that throwing sport.

Warm-up and Familiarisation

A systematic review with meta-analysis examining the effects of warming-up on physical performance (Fradkin et al., 2010) concluded that performance improvements are demonstrated after an adequate warm-up. As such, participants completed an individual warm-up according to their preference (Stodden et al., 2001). For example, some jogged around the perimeter of the gym, while others completed other aerobic activities like skipping, side-stepping and high knee running. However, all warm-ups included dynamic stretching. The warm-up was concluded when the participants felt prepared to throw at their maximum velocity (Michael et al., 2013). When assessing motor skill performances, the first few attempts may not reflect the participants' true performance (Coker, 1998). To overcome this problem, the warm-up was followed by a standardised familiarisation (Jennings et al., 2013) throwing session in which participants threw exactly 10 overarm throws. Throws one to three were completed at 50% (of maximum force), throws four to eight were completed at 75% and throws nine and 10 were completed at 100%. This protocol was followed to ensure the throwing intensity increased gradually (Kenney et al., 2019) to avoid the potential for injury. The participant's throwing velocity in the warm-up was observed and monitored by a research assistant.

Participants threw standard tennis balls towards a rectangular target painted on a wall. It was emphasised that the focus of the throw was velocity and that accuracy would not be measured, and that the painted target was only included to ensure directionality. Participants were instructed that throws falling outside the target zone would be ignored and completed again. The testing included five throws for maximum force with the dominant hand; the trial with the fastest velocity was recorded as the thrower's velocity score (Haywood et al., 1991). To decrease the likelihood of fatigue impairing throwing performance, participants rested for approximately 30 seconds between trials (Escamilla et al., 2010). It has been identified that those receiving instructions encouraging them to throw at high velocity tend to throw with more advanced throwing technique (Southard, 2002; Williams et al., 1996a). As such, no instructions were provided about the throwing movement other than to throw the ball as “hard as possible” or “crash the ball into the wall”.

Assessment of Throwing Technique

Prior to the study commencement, to ensure inter-rater reliability, a researcher with over 30 years’ experience categorising motor skills using Roberton’s (Roberton & Halverson, 1984) developmental levels was enlisted to assist me in developing expert knowledge in the assessment of overarm throwing. To do this, we assessed throwing footage not included in the current study. Initially, we independently assessed the footage, met, and then discussed any results that were not identical. Assessment moderation continued until inter-rater reliability of 80% (Langendorfer & Roberton, 2002) was achieved. After assessing 56 throws, the final inter-rater reliability results for each component were Backswing: 83%, Stepping: 85%, Follow-Through: 95%, Trunk: 85%, Humerus: 85%, and Forearm: 85%. I then worked with a generalist trained primary teacher who was teaching as the designated PE teacher at a primary school to develop her assessment skills. After assessing 36 throws, the generalist primary teacher and I achieved inter-rater reliability results of Backswing: 81%, Stepping: 89%, Follow-Through: 97%, Trunk: 83%, Humerus: 81%, and Forearm: 83%. To confirm intra-rater reliability, the primary teacher then assessed another 20 throws one month apart. The intra-rater reliability results were Backswing: 85%, Stepping: 95%, Follow-Through: 95%, Trunk: 85%, Humerus: 80%, and Forearm: 85%. Similar to a previous study (Haywood et al., 1991), from that point the generalist primary teacher, who had no involvement in testing completed the assessment of the throwing footage.

Statistical Analyses

Participants' backswings were assessed using the Haywood et al. (1991) revisions of the Langendorfer (1980) developmental sequence. Each participant's modal backswing categorisation was determined based on their five throws. Descriptive analysis was carried out to identify the frequency with which participants' modal backswing techniques were categorised into one of the six backswing levels (Haywood et al., 1991). A 4 (Level) x 2 (Gender) factorial between-groups analysis of variance (ANOVA) with a level x gender interaction term and adjustments for age, weight, and height, was conducted to determine whether throw velocity was related to backswing level or gender, and whether the relationship between throw velocity and backswing level was dependent on gender. Post-hoc pairwise comparisons of group means, adjusted to control of the experiment-wise error rate, were used to explore the nature of the relationships in more detail. All analyses were conducted using the Statistical Package for Social Sciences (SPSS for Windows, version 24.0).

Results

Modal Backswing Performances

Only backswing component Levels 3, 4, 5 and 6 were demonstrated, which is understandable considering these university-aged throwers self-selected their involvement in this study and participants were not likely to volunteer if they had immature (Level 1 or 2) throwing technique. The number of participants from both years of testing demonstrating a modal backswing performance in each category is shown in Table 3.2, the percentage of males and females demonstrating the different backswings was not equal. Males were generally categorised at higher developmental levels than females (75% vs 54.7% for Levels 5 and 6 combined).

Table 3.2

Backswing Level Frequency

Backswing Level	*N*	Male		Female	
		N	%	*N*	%
Level 3	13	7	11.7	6	14.3
Level 4	21	8	13.3	13	31.0
Level 5	33	19	31.7	14	33.3
Level 6	35	26	43.3	9	21.4
Total	102	60	100	42	100

Correlation

Correlational results indicated a moderate (Cohen, 2013) positive correlation between backswing level and throwing velocity, $r = .373$, $p < .001$.

Throwing Velocity

The maximal throw velocities averaged for each level of backswing are shown in Table 3.3. The results of the factorial between groups ANOVA indicated the main effect of backswing level on throwing velocity was statistically significant, F (3, 91) = 3.374, $p = .022$, partial eta-squared (η^2) = .100. Those categorised with a Level 6 backswing threw significantly faster than Level 3 ($p = .004$), 4 ($p = .035$), and 5 ($p = .031$), backswing throwers. All other comparisons indicated non-significant results ($p > .05$). The mean maximal velocities also indicated the higher levels generated higher throwing velocities except for Level 3, which was marginally faster than Level 4.

Table 3.3

Throw Velocity Mean (M) ± Standard Deviation (SD) Descriptives

Backswing Level	*M* ± *SD* (km/h)	Std. Error	Minimum	Maximum
Level 3	73.65 ± 23.41	6.49	40.90	107.40
Level 4	71.92 ± 23.61	5.15	41.30	121.00
Level 5	80.39 ± 15.92	2.77	46.60	110.30
Level 6	94.46 ± 21.76	3.68	53.10	128.60
Total	82.62 ± 22.35	2.21	40.90	128.60

Note. Backswing Level = Modal score.

Congruent with the findings of Haywood et al. (1991), the mean velocity scores of Levels 3 and 4 were below that of Level 5 and 6 backswings in this study. To further confirm the velocity progression in the different backswing levels, an independent samples t-test was conducted to compare the combined Level 3 and 4 backswings with the combined Level 5 and 6 backswings. The combined Level 3 and 4 mean velocity (M = 72.6, SD = 23.1) was significantly slower than the combined Level 5 and 6 mean velocity (M = 87.6, SD = 20.3), $t(100) = -3.366$, $p = 0.001$.

Gender and Velocity

The factorial ANOVA also examined whether velocity was dependent on gender and backswing level and whether there was an interaction between gender and backswing level. A gender main effect on velocity was significant, F (1, 91) = 37.5, $p < .001$, partial $\eta^2 = .292$, with males (M = 96.53, SD = 16.34) achieving significantly higher velocity than females (M = 62.75, SD = 12.60). There was no interaction between gender and backswing level, F (3, 91) = 1.87, $p = .141$, partial $\eta^2 = .058$.

Discussion

The purpose of this study was to examine whether an adaptation of Langendorfer's (1980) developmental sequence, proposed to assess the backswing of older throwers, is suitable for assessing the backswing of university-aged throwers. The results indicated that the two new backswing movements suggested by Haywood et al. (1991) were not confined to older throwers and were frequently demonstrated by the university-aged participants. Similar to the Haywood et al. study, nearly half of the participants were classified into one of the two new levels. As such, there is evidence to support the first hypothesis that the six-level sequence validated for assessing the backswing of older throwers is also suitable for assessing university-aged throwers.

Researchers (Haywood et al., 1991; Williams et al., 1990) suggested the two new (i.e., lateral rotation & shortcut circular downward) movements being displayed by older throwers may be a result of a smaller range of motion often seen in older throwers, specifically the limited ability to rotate the humerus laterally. Based on the generally accepted belief that university-aged students do not experience these flexibility limitations, the results of the present study indicate these two new movements may not be caused by poor shoulder flexibility. It seems more plausible the new movements proposed by Haywood et al. are backswing movements demonstrated by throwers of all ages as they transition to more mechanically efficient throwers. These new levels have improved Langendorfer's (1980) initial levels, making them more accurate and comprehensive. The older throwers in the Haywood et al. study and the university-aged throwers in the current study demonstrated these new movements because that was how developmentally advanced their throwing was at the time of testing.

Consistent with the results of the Haywood et al. (1991) study, the results of the current study denoted a significant difference between the backswing levels and throwing velocity, indicating participants with more advanced backswing movements generally threw at a higher velocity. These findings provide support for the hypothesis that there is a positive relationship between backswing levels and throwing velocity.

Also consistent with the Haywood et al. study, those in the current study throwing with a Level 3 backswing threw faster than those with a Level 4 backswing, although the difference was not significant. These results provide partial support for the hypothesis that throwers with a Level 3 backswing throw faster than those with a Level 4 backswing. Haywood et al. proposed it was unexpected the Level 3 velocities were higher than the Level 4 velocities, suggesting the Level 3 backswing limits the influence of upper spine rotation and shoulder horizontal flexion to the velocity of the throw. This is a contentious suggestion because it is more plausible that the forearm movement resulting from the lateral rotation of the humerus increases both the trunk rotation away from the target and horizontal shoulder extension during the backswing. The momentum of the forearm moving laterally in a position of 90^0 abduction may cause greater trunk rotation and horizontal shoulder extension, which likely increases the length of the backswing. The increased backswing length allows throwers more time and distance to transfer energy through the kinetic chain from the trunk, to the humerus, forearm, and ultimately to the ball (Stodden et al., 2001). The increased proximal-distal energy transfer is also advantageous for promoting humerus and forearm lag (Ehl et al., 2005; Langendorfer & Roberton, 2002). The trunk rotation causes the humerus and forearm to spatially and temporally lag behind due to their inertial characteristics (Langendorfer et al., 2012). An additional reason the Level 3 backswing is more developmentally advanced than the Level 4 backswing is that the Level 3 backswing is closer than the Level 4 backswing to the most advanced Level 6 backswing. The Level 6 backswing (Figure 3.1) sees the ball move in a down-and-back motion below the waist. The Level 3 backswing sees the ball move laterally away from the target by lateral rotation of the humerus in a position of 90^0 abduction. The Level 4 movements (of which there are three options), all move in an upward direction. As such, the correction needed to remediate the Level 4 backswings into the most advanced Level 6 movement is greater than the correction needed to remediate the Level 3 backswing. One explanation for the Level 3 mean backswing velocity being faster that Level 4 is that time constraints experienced in the sports they have participated in may affect throwing technique developments (Barrett & Burton, 2002; Beseler et al., 2021). For example, in cricket, a fielder on the boundary throwing the ball to the keeper when the batters are not running may exhibit the Level 6 circular, downward backswing where no time pressure occurs, while the time pressure experienced by a fielder when batters are running, may equate to humeral lateral rotation use to release the ball more quickly and efficiently.

The results indicating that combining Level 5 and 6 backswings led to faster velocity than Level 3 and 4 combined backswings are consistent with the findings of Haywood et al. **(**1991**)**, mechanically highlighting the importance of the longer circular, downward backswing. For rigour, the same t-test analyses were conducted on each gender separately where there were gender differences in throwing velocity. The increased shoulder horizontal extension and increased trunk rotation away from the target allows greater force to be produced over a longer duration, as such it was expected that females with Level 5 and 6 backswing threw significantly faster than females with Level 3 and 4 backswings. It was unexpected that there was no significant difference in the velocity of males with a Level 3 and 4 backswing and those with a Level 5 and 6 backswing. Further research needs to be conducted to determine these contrasting results.

Consistent with overarm throwing research findings (Beseler et al., 2021; Butterfield et al., 2012; Ehl et al., 2005; Halverson et al., 1982; Roberton & Halverson, 1984; Roberton & Konczak, 2001; Runion et al., 2003; Williams et al., 1991), male participants demonstrated more advanced technique and threw with higher velocity compared to female participants. The 75% of males categorised into one of the two highest levels of development was higher than the 54.7% of females who achieved those levels of backswing development. As such, there is evidence to support the hypothesis that male throwers would outperform females technically. Many researchers (Halverson et al., 1982; Lorson et al., 2013; Roberton & Halverson, 1984; Roberton & Konczak, 2001) have suggested that males outperforming females is most likely due to males having more throwing experience. Questionnaire results from the current study support this suggestion; males reported more years' experience playing sports that involve throwing (M = 3.93, SD = 6.75) than females (M = 0.93, SD = 2.76).

The results showed velocity was affected by backswing level and by gender; however, there was no significant interactive effect of gender and backswing level on throwing velocity. The effect of the backswing level on velocity is not significantly different for the two genders. These results refute the hypothesis that there would be an interactive effect of gender and backswing on throwing velocity.

Limitations

Participants were randomly invited to participate in this study. Those with lower levels of overarm throwing development may have been less inclined to participate, as such, the participants must be identified as a self-selected sample and results cannot be generalised to all university-aged throwers.

Future Research

Further research needs to be conducted to determine if these six levels are appropriate for assessing the backswing component of primary and secondary aged throwers. If the adapted levels are found to be suitable for younger throwers, those levels can then be used to assess the backswing action of all age groups. Having one, precise, comprehensive assessment system for throwers of all ages would simplify the assessment of the backswing component throughout the lifespan. While the hypothesis that Level 3 throwers would throw faster than Level 4 throwers was partially supported, future research should continue to investigate whether the Level 3 and Level 4 categories need to be re-ordered. Future biomechanical research is also needed to determine a more robust connection between throwing levels and velocity, with an emphasis on examining the reason there were gender differences within the established component sequences (at least in this study).

Summary

The findings of the current study have provided preliminary support for the Haywood et al. (1991) adaptation of Roberton's (Roberton & Halverson, 1984) developmental sequence for the backswing component of the overarm throw within university-aged throwers. Results indicated the additional levels made backswing assessment more comprehensive, with male and female university-aged students frequently demonstrating one of the two new backswing levels, which adds to the research on older throwers. Ultimately, the supplementary backswing movement patterns identified by Haywood et al., were found to be descriptive of university-aged throwers, confirming that it is appropriate for the adapted backswing levels to be used to assess the backswing component of the university-aged throwers throughout the current dissertation.

CHAPTER 4

STUDY 2: FOLLOW-THROUGH VALIDATION

The overarm throw is a phylogenic skill performed by most humans across cultural and ethnic boundaries (Williams et al., 1998). This multisegmental movement pattern is performed in many popular sports and recreational activities (e.g., baseball, softball, cricket, tennis, and volleyball). As such, it is a fundamental motor skill (FMS) studied extensively from a developmental perspective. One prominent system to assess throwing performance, with extensive validation history (Williams et al., 1990), is Roberton's developmental levels (Ehl et al., 2005; Langendorfer & Roberton, 2002; Roberton & Halverson, 1984; Roberton & Konczak, 2001; Runion et al., 2003). This system uses a body component approach. Each critical component is broken into levels; each level is a description of the progressive movement pattern that throwers display as they perform the skill over time.

Extensive research into the overarm throw has created considerable diversity of opinion relating to the critical components that should be assessed when viewing throwing performance (Whiteley, 2007). Roberton and Halverson (1984) developed a popular critical list originally comprising three components (trunk, forearm, and humerus); over time the levels for these components have been refined, with the step and the backswing added to eventually total five critical components (Haywood et al., 1991). Cross sectional and longitudinal research assessing the overarm throw using these five components has been widespread and its validity identified as 'robust' (Beseler et al., 2021; Haywood, 2012).

One component not originally included, or validated, in this assessment system is the follow-through. Commonly identified as the final phase of the throwing action, the follow-through begins at the point of ball release and finishes at the completion of the throw (Seroyer et al., 2010). The follow-through is critical to throwing performance (Braatz & Gogia, 1987; Hands & McIntyre, 2015; Leme, 1978; McCaig & Young, 2015; NSW Department of Education and Training, 2000; Ulrich, 2000; Werner et al., 2008), and decreases the likelihood of injury (Dillman et al., 1993; McCaig & Young, 2015; Whiteley, 2007). The Victorian Department of Education (1996) and New South Wales Department of Education (NSW Department of Education and Training, 2000) both recognise the follow-through as a critical component when teaching and assessing the overarm throw.

This exploratory study will examine the impact of the follow-through on thrown ball velocity to further identify its importance to throwing performance. Findings from this investigation could potentially authenticate the inclusion of this additional component to Roberton's (Roberton & Halverson, 1984) existing five components. Developing a validated follow-through component will aid in understanding the importance of a follow-through in throwing, but also in developing appropriate evaluation criteria for the follow-through, which will support coaches and teachers in instructing and developing the throwing technique of their players and students. This should support improved performance and motor skill development as well as potentially decreasing injury risk, a finding sure to be welcomed by baseball coaches considering the prevalence of shoulder injuries experienced by pitchers (Fleisig et al., 2018), and the findings that flat-ground throwing and pitching have similar biomechanical patterns (Fleisig et al., 2011).

Proposed Follow-Through Levels

The three follow-through developmental levels I have proposed were informed by my teaching observations and previous throwing biomechanics research (Stodden et al., 2006a; Stodden et al., 2006b; Werner et al., 2008), with higher levels indicating more developed follow-through technique. The most immature Level 1 follow-through (Figure 4.1) has little to no follow-through of the throwing hand after the ball is released. Observing the thrower's chest from a position perpendicular to the direction of the throw (from the open side), the throwing hand does not disappear. Level 2 follow-through is performed when the hand continues to follow-through across to the opposite side of the body after ball release; at some stage during the follow-through, the whole hand will disappear behind the thrower's body when viewed from the open side. At no stage during the throw does the hand move below hip height (the greater trochanter of the femur). The most advanced Level 3 follow-through is performed when the hand continues the follow-through down-and-across to the opposite side of the body after ball release. At the end of the follow-through, the whole hand disappears behind the thrower's body when viewed from the open side, with the whole hand eventually moving below hip height.

Figure 4.1

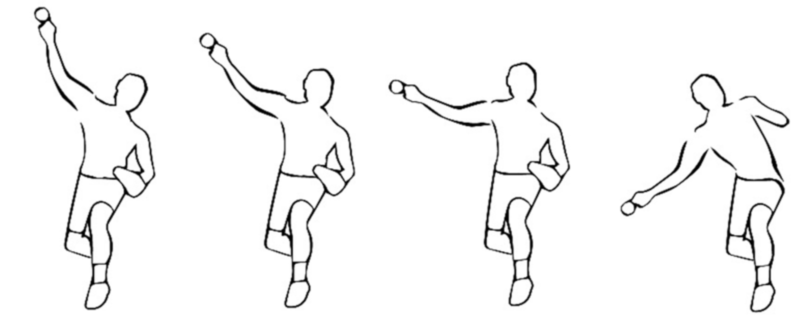
Follow-Through Movement Patterns

The proposed levels have been influenced by throwing mechanics research that has identified several temporal and kinematic parameters relating to throw ball velocity. Biomechanists have used temporal and kinematic variables to describe the impact these have on throwing performance (Stodden et al., 2006b). Roberton's (Roberton & Halverson, 1984) developmental level sequences connect well to these quantitative movement kinematics (Stodden et al., 2006b). Increased trunk rotation speed, increased external shoulder rotation, and increased forward trunk tilt positively influence thrown ball velocity (Stodden et al., 2006b; Werner et al., 2008), all could be improved by ensuring an effective follow-through after ball release. Encouraging a right-hand thrower to throw with increased velocity and follow-through to the left side of the body after ball release may encourage greater trunk rotation during the acceleration phase of the throw. Improving trunk rotation will likely lead to improvements in more distal segments that occur later in the throwing kinetic chain (Stodden et al., 2006b). Due to the inertial characteristics of the collective torso and throwing arm, during the rotation of the trunk the upper arm and forearm are left "lagging" behind, causing an eccentric loading of the trunk musculature (Stodden et al., 2006a), and an increase in external shoulder rotation. Throwers displaying greater forward trunk tilt throw with increased velocity (Werner et al., 2008). Trunk flexion during the acceleration phase transfers forces from the legs and trunk to the throwing arm. During deceleration trunk flexion and elbow extension assists decelerating the upper limb (McCaig & Young, 2015), decreasing the likelihood of injury (Solomito et al., 2021). Teaching throwers to achieve the highest, down-and-across, follow-through level (Level 3) so that the hand moves below hip height and disappears from view when observing from the open side, may help throwers improve their trunk (flexion) tilt. Another approach is to directly emphasize and teach the thrower to rotate and flex their trunk more. Although the follow-through has been identified as a critical component of the throwing motion (Department of Education Victoria, 1996; Dillman et al., 1993; McCaig & Young, 2015; NSW Department of Education and Training, 2000; Whiteley, 2007), no research, to date, has confirmed whether the follow-through enhances thrown ball velocity.

A factor that must be considered when examining the follow-through is throwing styles. There are several different throwing styles that are categorised according to the height of ball release, often referred to as the thrower's "arm slot" (Escamilla et al., 2018). Since most styles (excluding submarine) were demonstrated by participants in the current study, the styles and the number of throwers performing these styles required further inspection. The more common overhand and three-quarter throwers demonstrate a contralateral tilt towards the non-throwing side (Figure 4.2). Sidearm throwers demonstrate a near-vertical trunk position and submarine throwers demonstrate an ipsilateral tilt towards the throwing arm side (Braatz & Gogia, 1987; Escamilla et al., 2018; Matsuo et al., 2002; Truedson et al., 2012). These different trunk orientations impact the hand and forearm path during the acceleration and follow-through phases of these throws.

Figure 4.2

Throwing Styles



To explain the different hand positions at release, Braatz and Gogia (1987) used the face of a clock when viewing a thrower from behind. An overhand thrower's hand at release would be close to 12 o'clock, a three-quarter thrower's hand would be from 1 – 2 o'clock, a sidearm thrower's hand would be close to 3 o'clock and a submarine thrower's hand at release would be between 3 and 4 o'clock. As a result of these movement paths during the acceleration phase, the resulting path of the hand during the follow-through phase is also different. From the high 12 o'clock position at release, the overhand thrower's hand follows through down towards the contralateral ankle, a three-quarter thrower's hand approaches the contralateral knee, the sidearm thrower's hand approaches the contralateral hip, and the submarine thrower's low release point results in the hand moving up towards the contralateral shoulder (Truedson et al., 2012).

Gender Differences

Overarm throwing research has shown significant gender differences in throwing performance, with males throwing more accurately, faster and with more advanced technique (e.g., Beseler et al., 2021; Chu et al., 2009; Ehl et al., 2005; Johnson et al., 2020; Lorson et al., 2013; Williams et al., 1996b). Authors have attributed this to physical differences like males being stronger (e.g., Pedegana et al., 1982; van den Tillaar & Ettema, 2004), others suggesting males generally have more throwing experience (e.g., Halverson et al., 1982; Williams et al., 1990), others have argued that the velocity of a thrown ball is associated more to technique than it is to gender (e.g., Beseler et al., 2021; Roberton & Konczak, 2001), others have suggested males outperforming females is a combination of these factors (Chu et al., 2009). To properly validate the follow-through component for both genders, it was important to examine whether there were gender differences in follow-through development.

Study Aims

The purpose of this study was to examine the association of the follow-through component on thrown ball velocity, potentially justifying the inclusion of the follow-through component to Roberton's (Roberton & Halverson, 1984) five critical components. There were two primary aims within this study. First, to identify whether there was a significant difference between the three proposed follow-through levels and overarm thrown ball velocity. Second, to determine whether the three proposed follow-through levels add predictive power of thrown ball velocity above the other five components identified (Haywood et al., 1991; Roberton & Halverson, 1984). It was hypothesised that there would be a significant difference among follow-through developmental levels and thrown ball velocity. It was also hypothesised that the three proposed levels within the follow-through component would add predictive power of thrown ball velocity over the other five components in Roberton's (Roberton & Halverson, 1984) developmental levels.

Given that researchers (Ehl et al., 2005; Lorson & Goodway, 2008; Lorson et al., 2013; Williams et al., 1996b) have shown that males generally outperform females during throwing execution, a secondary aim was to determine whether gender impacts throwing performance. It was hypothesised that males would demonstrate more advanced throwing technique and throw faster than females.

Method

Participants

A sample size power analysis was based on Analysis of Covariance (ANCOVA) of the velocity, with three researcher-assessed levels of the primary factor follow-through, and adjustment for gender (factor), age, height, weight, and experience (covariates). Lorson et al. (2013) observed (in adolescents and adults of different gender and ages) mean velocities ranging from 15.9 m/s (SD = 2.7 m/s) to 29.4 m/s (SD = 4.7 m/s). Based on these results, we specified differences of 2 m/s between adjacent mean values for the three levels of follow-through, after adjustment for gender and the covariates, and a within-groups SD of 4 m/s. This resulted in an effect size of 0.41, which is a 'large' effect size in terms of the descriptive categories of Cohen (2013). With a significance level of 5% and 80% power, the required sample size calculated using GPower software (Faul et al., 2007) is N = 62 (i.e., three groups of size 21).

The analysis specified above relates to whether follow-through effects thrown ball velocity regardless of the level of the other five skill components. If a composite skill score based on the other five components is included as a further covariate, the question becomes whether follow-through adds extra predictive power over and above the other five components of the skill. In this case, both the (adjusted) differences due to follow-through and the within-groups SD may be reduced in magnitude. If both are reduced in the same proportion, then the effect size, and hence the required sample size, is unchanged.

Seventy-eight University students between 18 and 47 years of age participated in the overarm, dominant hand, throwing study (M_{age}= 21.27; SD_{age} = 3.87 years). Testing included 54 males (M_{age}= 21.57; SD_{age} = 4.13 years) and 24 females (M_{age}= 20.58; SD_{age} = 3.19 years), all of whom were naïve to the purposes of the study. Based on the participants' throwing style (forearm motion during the acceleration phase), five participants were identified as sidearm (forearm horizontal) throwers, which were taken into consideration during the analysis (see exclusion of side-arm thrower section in the results). The remaining 73 participants were identified as overarm or three-quarter throwers.

Equipment

The venue and equipment for the testing were identical to the venue and equipment used in Study 1. The throwing zone, standard tennis balls, painted target, camera and radar gun positions, footage editing, and throwing assessment were also identical to Study 1.

Procedure

Similar to Study 1, Study 2 was approved by the University Human Research Ethics Committee (see Appendices E, F, and G), all aspects of participation in the study were explained to participants, written consent obtained prior to the collection of data. After familiarising each participant with the testing procedure, gender, age, and previous throwing experience were recorded in a demographics questionnaire (see Appendix H). To help with the assessment of the backswing, the participant placed a self-adhesive sticker that contrasted the colour of their clothing over their umbilicus.

Warm-up and Familiarisation

To ensure participants were ready to throw with maximum force, the same warm-up and familiarisation throwing procedure used in Study 1 was performed before testing commenced.

Throwing Task Specifications

Participants were instructed to throw a standard tennis ball with a weight of 58 grams and a diameter of 6.5 cm towards a rectangular target (height 180 cm x width 280 cm) marked on a wall. It was clearly emphasised that the focus of the throw was force, and that accuracy was not being recorded or assessed, and that the large size and location of the target was only to ensure directionality. The testing included three throws for maximum force with the dominant hand; the mean velocity of the three throws was recorded as the participant’s velocity score (Haywood et al., 1991). To decrease the likelihood of fatigue impairing throwing performance, participants rested for approximately 30 seconds between trials (Escamilla et al., 2010). Previous research has indicated that participants receiving instructions encouraging them to throw at high velocity tend to throw with more advanced throwing technique (Southard, 2002; Williams et al., 1996a). As such, no instructions were provided about the throwing movement other than to throw the ball as “hard as possible” or “crash the ball into the wall”. The throws were completed from the semi-circle at the top of the basketball key (Figure 4.3), the same zone used in Study 1.

Figure 4.3

Throwing Position

Statistical Analysis

The mean velocities of the three throws were recorded as the participant's velocity score (Haywood et al., 1991). Similar to Study 1, throwing technique was measured using a modified version of the overarm throw developmental levels (Haywood et al., 1991; Roberton & Halverson, 1984). The additional follow-through component was also assessed and included three proposed levels (Table 4.1). The same throwing assessment completed in Study 1 was carried out by the same assessor. Modal scores for each component were determined for each participant based on the three throws. If a participant's three throws were assessed at different levels, the median level was used.

Table 4.1

Proposed Follow-Through Levels for Overarm Throw

Level 1	**No follow-through.** Arm movement stops when ball is released.
Level 2	**Follow-through across the body.** Throwing hand follows through across the body and finishes above hip height.
Level 3	**Follow-through down-and-across the body.** Throwing hand follows through across the body and finishes below hip height.

The Statistical Package for Social Sciences (SPSS for Windows, version 24.0.) was used to examine whether the follow-through affected throw velocity. To examine the first hypothesis, an ANCOVA of velocity by categories of follow-through was conducted, with adjustments for gender, age, and throwing experience. Previous throwing experience was categorised into three levels based on participants' previous participation in organised sports involving overarm throwing (e.g., cricket, baseball, or softball). Category 1 was for those with no years of experience in a throwing sport, Category 2 was for those with one to nine years of experience, and Category 3 was for those with 10 or more years of experience. The statistical significance level adopted was $\alpha = .05$. To examine the second hypothesis, further analyses that involved adjustments to the original ANCOVA were conducted to determine whether the proposed follow-through levels add predictive power of thrown ball velocity above the other five components. Finally, a stepwise regression analysis was conducted to build an optimal multiple regression model for predicting thrown ball velocity, and to determine the additional percentage of the variation in velocity that could be explained by the component added to the model at each step.

Results

The results are presented in the order of the statistical analyses conducted. First, descriptive statistics related to participants' follow-through level assessment and thrown ball velocity. Second, Fisher's exact tests of gender differences in follow-through levels was conducted. Third, the ANCOVA of velocity on follow-through with adjustments for gender, height, weight, and follow-through by gender interaction. Fourth, the ANCOVA was rerun with sidearm thrower results excluded. Fifth, the ANCOVA was rerun with the inclusion of composite component score as a covariate. Sixth, a repeat of the above sequence of steps with throwing levels collapsed into two categories. Finally, the ANCOVA was rerun with refined composite component score to account for the different number of levels within the different components.

Follow-Through Level Assessment and Thrown Ball Velocities

The number of participants assessed into each of the three levels is shown in Table 4.2. The percentage of males and females demonstrating the different follow-through levels was not equal. Males were generally categorised at higher developmental levels than females (42.6% vs. 16.7% at the highest level). A chi-square test of association was used to examine this further. Some expected cell sizes were still < 5, and so a Fisher's exact test was conducted instead of a chi-squared test. The Fisher's exact test revealed a significant effect, $p = .005$, indicating that males were more likely to be categorised at higher development levels than females.

Table 4.2

Follow-Through Level Frequencies

Follow-Through Level	Male		Female		Combined	
	n	%	*n*	%	*n*	%
Level 1	3	5	7	29	10	13
Level 2	28	52	13	54	41	53
Level 3	23	43	4	17	27	34
Total	54	100.0	24	100	78	100

The male and female average thrown ball velocities for the proposed follow-through levels are shown in Table 4.3.

Table 4.3

Throwing Velocity Means (M) ± Standard Deviation (SD) Descriptives

Gender	Follow-Through	*M* ± *SD* (km/h)	Minimum	Maximum
Male	Level 1	73 ± 16	55	87
	Level 2	103± 18	66	140
	Level 3	109 ± 17	74	136
	Total	104 ± 19	55	140
Female	Level 1	51 ± 5	40	57
	Level 2	70 ± 15	52	99
	Level 3	82 ± 6	75	90
	Total	67 ± 16	40	99

ANCOVA Assumptions

Shapiro-Wilk tests were conducted and histograms of residuals indicated that the ANCOVA assumption of normality was supported. Scatterplots indicated that there was a linear relationship between gender and thrown ball velocity. The assumptions of homogeneity of regression slope and homogeneity of variance were supported by the absence of a significant IV-by-covariate interaction, $F(2, 72) = 0.386$, $p = .681$, and a non-significant Levene's test, $F(2, 75)$ =- 2.015, $p = .140$, respectively.

Impact of Follow-Through on Thrown Ball Velocity

The ANCOVA indicated that, after accounting for the effects of gender, age, and throwing experience, there was a significant effect of follow-through level on throw velocity, $F(2, 72) = 12.276$, $p < .001$, partial $\eta^2 =.254$. Post hoc testing revealed that Level 2 follow-through participants (*M* = 92.4, *SD* = 22.6) threw significantly faster than those with a Level 1 follow-through (*M* = 57.2, *SD* = 13.9, $p < .001$). Furthermore Level 3 follow-through participants (*M* = 105.0, *SD* = 18.21) threw significantly faster than those with a Level 1 follow-through ($p < .001$). The mean velocity of Level 3 throwers was faster than the Level 2 throwers, but the difference was not significant ($p = 1.00$). The ANCOVA also revealed a significant gender effect, $F(1, 72) = 34.146$, $p < .001$, partial $\eta^2 =.322$, with males (*M* = 103.7, *SD* = 18.8) throwing significantly faster than females (*M* = 66.6, *SD* = 15.9).

Throwing experience also had a significant effect on thrown ball velocity, $F(1, 72) = 33.128$, $p < .001$, partial $\eta^2 =.315$. Additional independent sample t-tests revealed mean thrown ball velocity of those with no experience in organised throwing sports (*M* = 77.3, *SD* = 20.9) was significantly slower than those with between one and nine years of experience (*M* = 101.5, *SD* = 17.2), $t(59) = -4.492$, $p < .001$, and those with 10 or more years of experience (*M* = 117.5, *SD*

=13.1), $t(56) = -7.344$, $p < .001$. Those with between one and nine years of experience also threw significantly slower than those with 10 or more years of experience, t (35) = -3.143, $p = .003$.

Age, $F(1, 72) = 0.255$, $p = .615$, partial $\eta^2 = .004$, also had no significant effect on thrown ball velocity.

Exclusion of Sidearm Throwers

Five participants were categorised as sidearm throwers, which could impact the thrower's ability to achieve a Level 3 follow-through because the sidearm motion would be unlikely to result in the hand finishing below hip height after the ball released. Due to this unorthodox technique, even highly developed sidearm throwers may not achieve the highest proposed follow-through level and were excluded from this separate analysis. To examine the impact of the unorthodox sidearm technique, the sidearm throwers were excluded and the ANCOVA of velocity by follow-through level, with adjustments for gender, age, and throwing experience, was conducted. The results revealed a significant follow-through levels main effect, $F(2, 67) = 12.487$, $p < .001$, partial $\eta^2 = .272$. Post hoc testing revealed that participants with a Level 2 follow-through ($M = 90.5$, $SD = 22.1$) threw significantly faster than those with a Level 1 follow-through ($M = 57.2$, $SD = 13.9$), $p < .001$, and those categorised with a Level 3 follow-through ($M = 104.4$, $SD = 18.2$) threw significantly faster than those with a Level 1 follow-through, $p < .001$. The mean velocity of Level 3 throws was faster than the Level 2 throws, but the difference was not significant, $p = .897$. A significant gender effect was revealed, $F(1, 67) = 29.493$, $p < .001$, partial $\eta^2 = .306$, with males ($M = 102.7$, $SD = 18.5$) throwing significantly faster than females ($M = 65.2$, $SD = 14.7$). Throwing experience still had a significant effect on thrown ball velocity, $F(1, 67) = 25.436$, $p < .001$, partial $\eta^2 = .275$. Age, $F(1, 67) = 0.779$, $p = .381$, partial $\eta^2 = .011$, still had no significant effect on thrown ball velocity. As the difference between Level 2 and

Level 3 velocities was not significant in either of the analyses, the sidearm throwers were reinstated back into the analysis.

Inclusion of Composite Component Score as a Covariate

Dillman and his colleagues (1993) reported that even though a good follow-through cannot directly improve thrown ball velocity, it is critical in minimising the risk of injury. It could be argued that the other critical throwing components in Roberton and Halverson's (1984) levels impact thrown ball velocity and a good follow-through is simply a by-product of other critical throwing components. To examine if the follow-through still affected thrown ball velocity after adjusting for the effects of other components, a composite component score for the other five critical components was added as a further covariate to the ANCOVA. The composite score was a simple total of the other critical component scores. The results were unchanged, a significant relationship between follow-through level and the resulting thrown ball velocities, $F(2, 71) = 6.690$, $p = .002$, partial $\eta^2 = .159$, was again revealed. Level 2 follow-through participants threw significantly faster than those with a Level 1 follow-through ($p = .002$), and those with a Level 3 follow-through threw significantly faster than those with a Level 1 follow-through ($p = .003$). Level 2 and 3 thrown ball velocities were not significantly different ($p = 1.00$). Thrown ball velocity was still significantly affected by gender, $F(1, 71) = 35.835$, $p < .001$, partial $\eta^2 = .335$, throwing experience, $F(1, 71) = 12.611$, $p = .001$, partial $\eta^2 = .151$, and the follow-through level still significantly impacted velocity with the additional component total covariate, $F(1, 71) = 19.914$, $p < .001$, partial $\eta^2 = .219$. Age, $F(1, 71) = 0.092$, $p = .763$, partial $\eta^2 = .001$, still had no significant effect on thrown ball velocity.

Collapsing Throwing Levels into two Categories

Based on the findings that there was no significant difference between the Level 2 and Level 3 throwing velocities, it was decided to collapse the Level 2 and Level 3 follow-through levels into one level. The proposed Level 1 would remain, while the proposed Levels 2 and 3 combined and would now be known as Level 2 (1 = 1) (2, 3 = 2). For the sake of thoroughness, the ANCOVAs explained previously were completed on the recoded levels, the results were unchanged.

The number of participants assessed into the two levels is presented in Table 4.4. The percentage of males and females demonstrating the different follow-through levels was not equal. Males were generally categorised at the higher developmental level than females (94.4% vs 70.8% at the highest level). A chi-square test of association was used to examine this further. One expected cell size was still < 5, and so a Fisher's exact test was conducted instead of chi-squared test. The Fisher's exact test revealed a significant effect, $p = .008$, indicating that males were more likely to be categorised at higher development levels more than females.

Table 4.4

Follow-Through Level Frequency

Follow Through Level	Male Frequency	Male %	Female Frequency	Female %	Combined Frequency	Combined %
Level 1	3	6	7	29	10	13
Level 2	51	94	17	71	68	87
Total	54	100	24	100	78	100

The male and female average throwing velocities for the recoded follow-through levels are shown in Table 4.5.

Table 4.5

Recoded Mean Throw Velocity Mean (M) ± Standard Deviation (SD)

Gender	Follow-Through Level	*N*	*M* ± *SD* (km/h)	Minimum	Maximum
Male	Level 1	3	73 ± 16	55	87
	Level 2	51	106 ± 17	66	140
	Total	54	104 ± 19	55	140
Female	Level 1	7	51 ± 5	40	57
	Level 2	17	73 ± 14	52	99
	Total	24	67 ± 16	40	99

Note. Follow-Through Level = Modal score.

To examine whether the two new follow-through levels impacted thrown ball velocity, the whole sequence of ANCOVA analyses was repeated. An ANCOVA of velocity by categories of follow-through, with adjustments for gender, age, and throwing experience, was conducted again. The results revealed there was a significant difference between follow-through development and the resulting thrown ball velocities, $F(1, 73) = 24.158$, $p < .001$, partial $\eta^2 = .249$. Post hoc testing revealed that those categorised with a Level 2 follow-through ($M = 97.4$, $SD = 21.7$) threw significantly faster than those categorised with a Level 1 follow-through ($M = 57.2$, $SD = 13.9$) ($p < .001$). Thrown ball velocity was significantly impacted by experience, $F(1, 73) = 37.905$, $p < .001$, partial $\eta^2 = .342$, and gender, $F(1, 73) = 35.117$, $p < .001$, partial $\eta^2 = .325$. It was found that age did not significantly impact thrown ball velocity, $F(1, 73) = 0.259$, $p = .612$, partial $\eta^2 = .004$.

To determine if the two recoded follow-through levels still affected throw velocity after adjusting for the effects of other component scores, the composite component score for the other five components was again added as a further covariate. The results once again identified a significant relationship between follow-through development and the resulting throw velocity, $F(1, 72) = 13.385$, $p < .001$, partial $\eta^2 = .157$. The composite component score covariate was found to have a significant effect on thrown ball velocity, $F(1, 72) = 20.693$, $p < .001$, partial $\eta^2 = .223$, as did throwing experience, $F(1, 72) = 13.661$, $p < .001$, partial $\eta^2 = .159$, and gender, $F(1, 72) = 36.639$, $p < .001$, partial $\eta^2 = .337$. Age, $F(1, 72) = 0.092$, $p = .762$, partial $\eta^2 = .001$, did not significantly affect thrown ball velocity.

Refined Composite Component Score

To account for the different number of levels within the different components, the formula $\sum(s-1)/(n-1)$, (where s = modal skill score, n = number of levels in each component) was used to refine the composite component score so that each component had equal weighting. The ANCOVA of velocity on follow-through with adjustments for gender, age, and throwing experience was conducted to determine whether the follow-through level still affected velocity after the refined composite score was added. Similar results were revealed, showing a significant relationship between follow-through development and the resulting throw velocity, $F(1, 72) = 12.768$, $p = .001$, partial $\eta^2 = .151$. The refined composite component score covariate was found to have a significant effect on thrown ball velocity, $F(1, 72) = 16.386$, $p < .001$, partial $\eta^2 = .185$, as did throwing experience, $F(1, 72) = 14.165$, $p < .001$, partial $\eta^2 = .164$, and gender, $F(1, 72) = 36.503$, $p < .001$, partial $\eta^2 = .336$. Age, $F(1, 72) = 0.002$, $p = .963$, partial $\eta^2 < .001$, did not significantly affect thrown ball velocity.

Stepwise Regression

A stepwise regression analysis was performed to build an optimal multiple regression model for predicting thrown ball velocity, and to determine the additional percentage of the variation in velocity that could be explained by the component added to the model at each step. The results shown in Table 4.6 indicate 33.3% of the variation in velocity can be explained by variation in the upper arm (humerus) alone, a further 11.9% by variation in the follow-through, a further 8% by variation in the backswing, a further 2.8% by variation in the forearm action, and a further 2.8% of the variation in velocity can be explained by variation in the stepping action.

Table 4.6

Stepwise Regression of Throwing Component on Velocity

Model	*R*	R^2	*Adj* R^2	SE of the Estimate	Change Statistics					Durbin-Watson
					R^2 Change	F Change	*df1*	*df2*	*p*	
1[a]	.58	0.33	0.33	20.4	0.33	38.0	1	76	<0.001	
2[b]	.67	0.45	0.44	18.6	0.12	16.2	1	75	<0.001	
3[c]	.73	0.53	0.51	17.3	0.08	12.7	1	74	0.001	
4[d]	.75	0.56	0.54	16.9	0.03	4.7	1	73	0.034	
6[e]	.77	0.59	0.56	16.5	0.03	4.9	1	72	0.031	1.504

a. Predictors: (Constant), Humerus Mode

b. Predictors: (Constant), Humerus Mode, Follow-Through Mode

c. Predictors: (Constant), Humerus Mode, Follow-Through Mode, Backswing Mode

d. Predictors: (Constant), Humerus Mode, Follow-Through Mode, Backswing Mode, Forearm Mode

e. Predictors: (Constant), Humerus Mode, Follow-Through Mode, Backswing Mode, Forearm Mode, Step Mode

f. Dependent Variable: Velocity Mean

Discussion

The purposes of this study were to examine how the the follow-through component is related to thrown ball velocity, to determine if there was a difference between the three proposed follow-through levels and velocity of a thrown ball, and to ascertain whether the three proposed levels added predictive power of thrown ball velocity above the other five critical throwing components in Roberton's developmental levels (Haywood et al., 1991; Roberton & Halverson, 1984). It was hypothesised that there would be a significant difference between follow-through development and thrown ball velocity, and that the three proposed levels within the follow-through component would add predictive power of thrown ball velocity over the other five components in Roberton's (Roberton & Halverson, 1984) developmental levels.

Follow-Through Impact on Thrown Ball Velocity

It is commonly accepted that better throwing technique leads to increased thrown ball velocity (Lorson et al., 2013; Roberton & Konczak, 2001; Stodden et al., 2005; Stodden et al., 2006a; Wild, 1938). Roberton and Konczak (2001) identified children's throwing velocity could be reliably predicted by assessing participants' throwing technique using Roberton's levels (Roberton & Halverson, 1984). The importance of the follow-through in the overarm throw has been identified, however, this importance has been more commonly linked to injury prevention, not thrown ball velocity (Braatz & Gogia, 1987; Huijbregts, 1998; McCaig & Young, 2015; Whiteley, 2007). Whitely (2007) suggested that a thrower's follow-through cannot impact velocity because once the ball has left the thrower's hand, the throwing movement has no effect on thrown ball velocity. The results of the initial ANCOVA for the current study provided a different view, revealing several significant results relating to thrown ball velocity. After accounting for the effects of gender, throwing experience, and age, the more advanced the follow-through technique, the faster the thrower was able to release the ball. To emphasise the robustness of the findings, the data were scrutinized using different analyses, which produced a similar result that Level 2 and 3 follow-through velocities were significantly faster than Level 1 follow-through velocities. Although the small sample of Level 1, compared to the more robust Level 2 and 3 throwers, should be acknowledged.

It could be argued that the follow-through is a by-product of the other critical components of the throw being performed effectively. The results of the current study provide a different view, indicating that the follow-through still affected thrown ball velocity even after adjusting for the effects of Roberton's (Roberton & Halverson, 1984) other critical components. Being categorised into more advanced follow-through levels, resulted in increases in thrown ball velocity. For the sake of thoroughness, a similar result occurred when the two higher levels were combined and the levels were recoded to Level 1 and 2. The results indicated the two follow-through levels add extra predictive power of thrown ball velocity over and above the composite score of the five existing components that have received extensive research attention, because level 2 and 3 were not different, the first hypothesis was partially supported.

Congruent with the findings of Roberton and Konczac (2001), the stepwise regression analysis revealed the component that had the largest effect on velocity was the (humerus) component. The follow-through component was shown to have the second largest impact on the velocity of a thrown ball, greater than the backswing, forearm, step and trunk components, providing support for the inclusion of the follow-through component to Roberton's (Roberton & Halverson, 1984) five critical components.

Gender Effect on Throwing Performance

Males were generally categorised at higher developmental levels and threw faster than female participants, and the results indicated follow-through development had the same impact on thrown ball velocity for males and females. These findings are congruent with many throwing studies (Beseler et al., 2021; Ehl et al., 2005; Halverson et al., 1982; Lorson & Goodway, 2008; Thomas & French, 1985; Williams et al., 1996b). For example, Halverson et al. (1982)

conducted a longitudinal study examining the throwing of participants from kindergarten to second grade and then refilmed and analysed throwing in seventh grade. Results indicated the rate of development for girls was 5-6 years behind the throwing development of boys. This significant effect of gender has not been isolated to young throwers, but also found with young teenagers (Petranek & Barton, 2011), adolescents and young adults (Beseler et al., 2021; Lorson et al., 2013), and older adults (Williams et al., 1993, 1996a). Seventh grade boys who outperformed girls in a longitudinal throwing study suggested they had experienced more overarm throwing (Halverson et al., 1982). The results of this study substantiate the suggestion that the reason males outperform females is because they have more throwing experience. It was revealed that those with 10 or more years of experience in organised throwing sports threw significantly faster than those with between one and nine years of experience, who in turn threw significantly faster than those with no experience in organised throwing sports.

Practical Implications

The results indicated that, not only did the follow-through still affect thrown ball velocity after adjusting for the effects of Roberton's (Roberton & Halverson, 1984) other critical components, but also had the second largest impact on thrown ball velocity of all six components. The practical implications of these findings are that teachers should encourage throwers to follow-through effectively to help increase thrown ball velocity, and to potentially decrease the risk of injury. There were no gender differences in the relative contribution of the six components to the velocity of the throw, as such the feedback emphasising follow-through technique should be the same regardless of gender. From an assessment perspective, the follow-through is a component that should be added to the existing five components within Roberton's levels. Furthermore, to decrease the throwing performance gap between males and females, girls should be encouraged to participate in sports that involve overarm throwing from an early age. Increasing younger girls' experience in these throwing activities can lead to improved throwing technique and velocity, potentially increasing the likelihood they will stay involved in these throwing sports (Johnson et al., 2019).

Limitations

When interpreting the findings of the current study, some limitations should be considered. Participants were randomly invited to participate in this study, therefore, participants with lower levels of overarm throwing development may have been less inclined to participate. As a result, the participants must be identified as a self-selected sample. Furthermore, the number of participants in Level 1 was low, which is another limitation. Future research should replicate this study with a larger sample of randomly selected participants, representative of all age groups and throwing levels. Such research could examine whether the levels are appropriate for assessing the follow-through component of primary and secondary school aged throwers and older adult throwers. The current study only examined how the follow-through was related to thrown ball velocity. Future research could examine follow-through technique and injury risk.

Summary

The findings of the current study have provided preliminary support for the inclusion of the follow-through to the five existing components within Roberton's (Roberton & Halverson, 1984) developmental levels. Results indicated the follow-through had the second largest impact on thrown ball velocity of all six components, and the two levels were shown to add extra predictive power of the velocity of a thrown ball over the five existing components. The inclusion of the follow-through component could assist teachers and coaches to facilitate learner and athlete development, it could also improve the accuracy of throwing development assessment. Emphasising effective follow-through technique could also help decrease the high incidence of throwing injuries in sports like baseball (Fleisig et al., 2011; Fleisig et al., 2018).

CHAPTER 5

STUDY 3: EXAMINING THE AFFECT OF PEER TEACHING INSTRUCTIONAL APPROACHES ON IMPROVING THROWING TECHNIQUE PERFORMANCE AND INTERVENTION PERCEPTIONS IN A SINGLE PEER TEACH SESSION

The use of video replay to provide feedback is widespread in coaching and in Physical Education (PE) teaching settings, however, there is limited research identifying the effectiveness of this feedback in the skill acquisition process (Magill & Anderson, 2021; Phillips et al., 2013; Potdevin et al., 2018; Spittle, 2021; Weir & Connor, 2009). Video analysis research (Hebert et al., 1998; Rothstein, 1980; Rothstein & Arnold, 1976) has identified that learners should practice and analyse video replays for multiple sessions to achieve significant performance improvement. According to Rothstein (1980), a minimum of five sessions over a semester is required for significant improvement, however, it is impractical for PE teachers to complete five peer teach sessions over a semester for one FMS. Thus, this chapter describes a study that examined the effect of two peer teaching instructional approaches on improving overarm throwing performance in a single session peer teaching intervention.

Motivation and confidence are important contributing factors to learning and performance. Wulf and Lewthwaite (2016), proposed the Optimizing Performance Through Intrinsic Motivation and Attention for Learning (OPTIMAL) theory of motor learning, which indicates that confidence is a predictor of performance and self-efficacy, and that using video analysis may result in greater satisfaction with performance and intrinsic motivation. To investigate the impact of video analysis on confidence, this chapter will examine the effect of video analysis on participants' perceptions about their ability to perform and analyse the throw and the importance of this technology in peer teaching experiences.

Furthermore, significant gender differences in throwing performance have been identified, with males throwing more accurately, with higher velocity, and more advanced developmental technique than females (e.g., Beseler et al., 2021; Ehl et al., 2005; Halverson et al., 1982; Johnson et al., 2020; Lorson et al., 2013; Williams et al., 1996b). This study will examine the gender differences of throwing performance.

Study Aims

There were four primary aims and one secondary aim within this study. One primary aim was to examine the effect of single session peer teaching instructional approaches on improving short-term overarm throwing performance compared to a control group. A second primary aim was to ascertain whether video analysis used in a peer teaching setting impacted participants' perceived ability to perform and analyse the overarm throw. A third primary aim was to inspect participants' perceptions about the importance of video analysis in the Qualitative Movement Diagnosis (QMD) process. A fourth primary aim was to determine the impact of video analysis on participants' enjoyment. Finally, a secondary aim was to examine whether gender influenced throwing performance.

It was hypothesised that the Video Analysis Group (VAG) would throw with more advanced technique in the post and retention testing than the Verbal Group (VG), who would throw with more advanced technique than the Control Group (CG) in the post and retention testing. It was hypothesised that the VAG would have higher perceived ability to perform and analyse the overarm throw than VG after their respective interventions. It was hypothesised that the VAG and VG would both identify video analysis technology to be critical in the QMD process. It was hypothesised that the VAG would identify their intervention as more enjoyable than the VG. It was also hypothesised that males would throw with more advanced technique than females.

Method

Participants

Forty-nine university students enrolled in a Bachelor of Health and Physical Education program participated in the study. The sessions were conducted using intact classes (Sariscsany & Petrigrew, 1997) as part of each student's first year Fundamental Movement course. Participants who had experienced formal throwing training using their non-dominant hand were excluded from the study. Two participants withdrew from their university studies and did not complete the retention testing, and thus were excluded from analyses, leaving a total of 47 (M_{age}= 20.57; SD_{age} = 3.403 years) participants for all analyses. There were 24 males (M_{age}= 20.96; SD_{age} = 4.175 years) and 23 females (M_{age}= 20.09; SD_{age} = 2.334 years), who were naïve to the purposes of the study.

A sample size power analysis was based on an examination of treatment-time interactions (i.e., differences between the changes over time in the three treatment groups) in a Repeated Measures Analysis of Covariance (RMANCOVA) using the throwing score, with adjustment for potential confounders including gender and age. Based on data collected within studies in this dissertation and fundamental movement class observations, I anticipated initial value of 45 points for the adjusted mean of the throwing score at pre-test, and targets of six, three, and one point in the mean throwing score increase from pre- to post-test for the Video Analysis Group (VAG), Verbal Group (VG), and a Control Group (CG), respectively, with mean reductions of one point in each group at retention. Based on over two decades of fundamental movement class observations and the data collected from Study 1 and 2 of this dissertation, I assumed a 'within-groups' SD of four points, corresponding to a range of around 16 points due to individual differences between participants after accounting for gender and treatment differences. This resulted in an effect size of 0.24216, which is a 'medium' effect size (Cohen, 2013). Under the assumptions of constant correlation over time (sphericity), with a conservatively estimated magnitude of $r = 0.7$ (Mosher & Schutz, 1983), with a significance level of 5% and 80% power, the required sample size calculated using GPower software (Faul et al., 2007) was $N = 24$ (i.e., three groups of size 8).

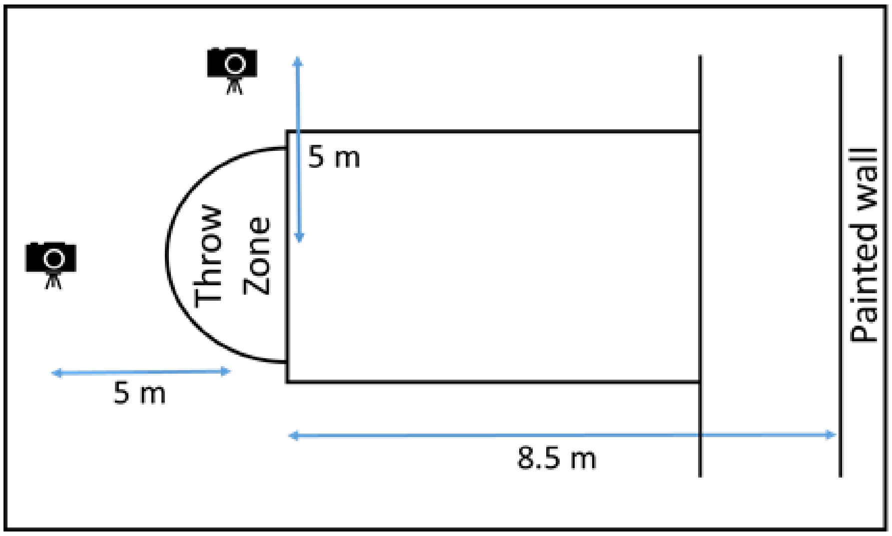
Focusing solely on the two intervention groups, but otherwise maintaining the same specifications, the mean changes over time postulated for these two treatments correspond to an effect size of 0.169251, which is a 'small' to 'medium' effect size (Cohen, 2013). In order to have 80% power to detect a mean difference of this magnitude in a post hoc pairwise comparison, the required sample size was increased to $N = 36$ (i.e., three groups of size 12).

Equipment

The venue and equipment for the experiment were identical to that used in Study 1 of this dissertation, except that the radar gun was no longer required. The throwing zone, camera positions, footage editing, and throwing assessment were also identical to Study 1 (see Figure 5.1). The throws were performed with the non-dominant hand because the task novelty would help control for past experience (Janelle et al., 1997; Southard, 2006).

Figure 5.1

Camera Positions



Participant Familiarisation Videos

A narrated video explaining the procedure of the experiment and a narrated video outlining the critical components of the throw were shown to all participants prior to the pre-testing (videos explained in Procedure section). The experimental procedures video was a narrated audio-visual recording of a PowerPoint presentation (Version 16.0.4849), developed using the Camtasia Studio screen capture software (Version 8.4.3). The critical component video was a narrated audio-visual recording developed in Adobe Premiere Pro Creative Cloud video editing software 2014 (San Jose, CA: Adobe Systems Incorporated). The videos were shown on a 102 cm Hisense TV (Model 40K220PW) (Hisense Corporation, Qingdao, Shandong Province, China) mounted on a desk behind a sliding door in an office adjacent to the basketball court (see Figure 5.2).

Figure 5.2

Television Mounted Behind Sliding Door

The large screen television was used based on Weir and Connor's (2009) recommendation that a large screen or projector is essential when teaching large groups of students. The television was positioned close by to decrease the amount of time between the viewing of videos and throwing practice, which aligns with the suggestion of researchers (Obrusnikova & Rattigan, 2016) that less time between video viewing and skill practice, leads to more retention.

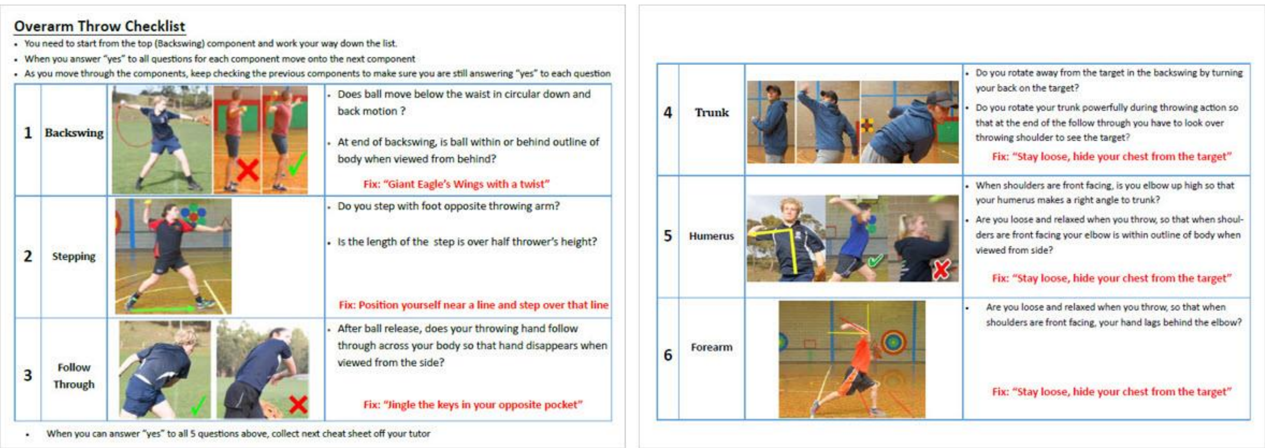
During the intervention, video analysis group participants had access to the Hudl Technique video analysis app (Version 6.1.3.2; available from https://apps.apple.com/au/app/hudl-technique/id470428362) on their "smart phones" (El-Hussein & Cronje, 2010), which allowed them to video record and analyse throwing performances. The Hudl Technique analysis app had been used by the participants on a number of occasions prior to the intervention so they were already familiar with how it worked and to ensure they were not distracted as a result of seeing themselves on screen for the first time (Darden & Shimon, 2000; Darden, 1999; Hebert et al., 1998).

Overarm Throwing Checklist

During the interventions, video analysis group and verbal group pairs used a peer teaching throwing checklist to assist them in the QMD process. The checklist shown in Figure 5.3 was identical to the hard copy checklist the pairs utilised (see Appendix L) for a more readable version). The checklist which included text, photographs, and visual annotations, helped observers analyse their partners' throwing. The checklist also helped focus observers' attention on one component at a time, guiding them as to which weaknesses to remedy first (Kernodle & Carlton, 1992). Learners were expected to benefit more from video analysis when their attention was focused on critical information (Kernodle & Carlton, 1992; Koh & Khairuddin, 2004). As it is argued that PE teachers should provide remediation to help learners improve throwing (Knudson, 2013; Lees, 2002), each component on the checklist included a remedy or "fix" that identified how common errors could be rectified. The remedies chosen for each component were based on corrections identified in the literature (e.g., Aguinaldo et al., 2007; Ciapponi, 1999; Ehl et al., 2005; Fortenbaugh et al., 2009; Langendorfer & Roberton, 2002; Langendorfer et al., 2012; Roberton & Halverson, 1984; Southard, 2006) and my personal teaching and coaching experience. In the development of the checklist, I also sought feedback from a trusted colleague who also had extensive PE teaching and baseball coaching experience, and minor changes were implemented after those discussions.

Figure 5.3

Throwing Component Checklist



Questionnaire. After completing the post-testing, participants completed a statement-based questionnaire (Figure 5.4) to identify their perceptions of their intervention and whether the respective interventions enhanced their motivation and confidence levels. Motivation and confidence are important contributing factors to learning and performance, in line with the OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016), which identifies confidence as a predictor of performance and self-efficacy. As no questionnaire had been developed or validated for this purpose, the pilot questionnaire items were based on a literature review of previously used similar questionnaires (Ferracioli et al., 2013; Koh & Khairuddin, 2004). The questionnaire consisted of 6-items. The first item identified participants' previous formal throwing training with their non-dominant hand. The second item identified the level of confidence participants had to throw with their non-dominant hand prior to the intervention. Items three, four, and five recognised their perceptions of the intervention and item six recognised participants' thoughts about the importance of video analysis in the QMD process. The participants selected a response from a 5-point Likert scale (1 = *Strongly disagree* to 5 = *Strongly agree*).

Figure 5.4

Questionnaire Statements

i) I have had no formal throwing training using my non-dominant hand
ii) I felt confident executing an overarm throw using my non-dominant hand prior to the intervention
iii) The intervention helped me improve my non-dominant hand throwing performance
iv) The intervention increased my confidence to be able to observe and provide corrective feedback to my partner
v) The intervention was an enjoyable, engaging task to complete
vi) Video replay is essential in the QMD process

Measures

Testing Assessment of Throwing Technique

Throwing technique was measured using a modified version of the developmental levels hypothesised, and validated by Roberton and Halverson (1984) and Williams et al. (1998) for the overarm throw. This modified version in Table 5.1 included the follow-through component discussed in Chapter 3. Using this body component approach, the throwing footage was examined by the same assessor as the previous studies in this dissertation.

6-Item Questionnaire

The dependent variables recorded were participants' perceptions of their intervention and whether the respective interventions enhanced participants' ability to analyse and perform the overarm throw for force, and whether video analysis improves learners' motivation to develop FMS.

Table 5.1

Modified Version of Roberton's Developmental Levels

Backswing action component	
Level 1	**No backswing.** Ball in the hand moves directly forward to release from the arm's original position.
Level 2	**Elbow and humeral flexion.** Ball moves away from the target to a position behind or alongside the head by upward flexion of the humerus and elbow.
Level 3	**Humeral lateral rotation.** Ball moves away from the target by lateral rotation of the humerus in a position of 90 degrees abduction.
Level 4	**Circular, upward backswing.** Ball moves away from the target to a position behind the head via a circular overhead movement with elbow extended, or a diagonal lift, or a vertical lift from the hip.
Level 5	**Shortcut circular, downward backswing.** Ball moves away from the target to a position behind the thrower via a circular, down and back motion, which carries the ball below waist height, followed by elbow flexion, at the end of the backswing the ball is forward of the outline of the thrower's body (when viewed from behind).
Level 6	**Circular, downward backswing.** Ball moves away from the target to a position behind the thrower via a circular, down-and-back motion, carrying the hand below the waist, at the end of the backswing the ball is within the outline of the body (when viewed from behind).
Stepping action component	
Level 1	**No step.** The thrower throws from the initial foot position.
Level 2	**Ipsilateral step.** Thrower steps with the foot on the same side as the throwing hand.
Level 3	**Short contralateral step.** The thrower's step with the opposite foot is half his or her standing height or less.
Level 4	**Long contralateral step.** The thrower's step with the opposite foot is over half his or her standing height.

Follow-through action component	
Level 1	**No follow-through.** Arm movement stops when ball is released.
Level 2	**Follow-through across the body.** Throwing hand follows through across the body so that the whole hand disappears from sight when viewed from the side.
Trunk action component	
Level 1	**No trunk rotation**. Only the arm is active in force production. Sometimes the forward thrust of the arm pulls the trunk into a passive left rotation (assuming a right-handed throw).
Level 2	**Block rotation**. The hips and shoulders rotate away from the target and then towards the target simultaneously, acting as a unit or a block.
Level 3	**Differentiated rotation,** the hips precede the shoulders in initiating forward rotation. The thrower rotates away from the target then begins forward rotation with the hips then the shoulders begin rotating slightly after.
Humerus action component	
Level 1	**Humerus oblique.** The upper arm moves forward to ball release in a plane that intersects the trunk obliquely above or below the horizontal line of the shoulders.
Level 2	**Humerus aligned but independent.** The upper arm moves forward to ball release horizontally aligned with the shoulder, forming a right angle between humerus and trunk. When shoulders are front-facing, the upper arm and elbow have moved independently ahead of the outline of the body (as seen from the side) via horizontal adduction at the shoulder.
Level 3	**Humerus lags.** The upper arm moves forward to ball release horizontally aligned, when shoulders are front-facing, the upper arm remains within the outline of the body (as seen from the side).
Forearm action component	
Level 1	**No forearm lag.** The forearm and ball move steadily forward to ball release.
Level 2	**Forearm lag.** The forearm and ball appear to 'lag' (i.e., remain stationary behind the thrower). The largest lag occurs before the shoulders reach front-facing.
Level 3	**Delayed forearm lag.** The largest lag occurs at the moment shoulders are front-facing.

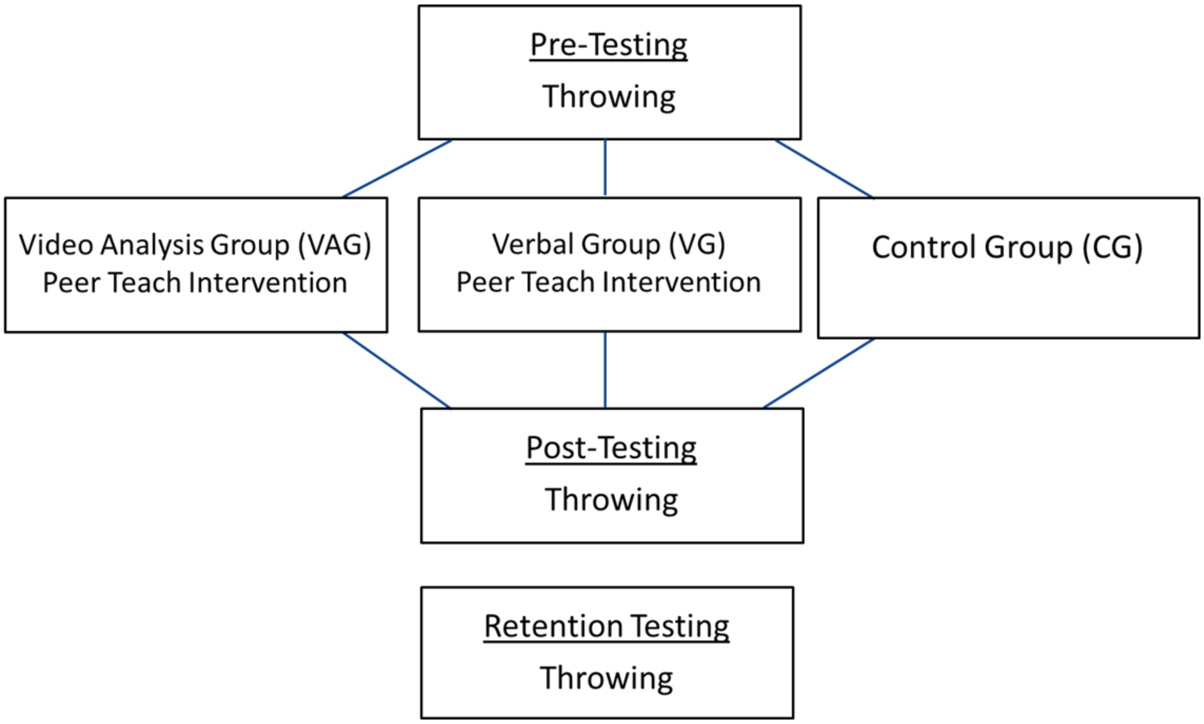
Note. These levels have been adapted from Roberton & Halverson (1984) and Williams et al. (1998), and the follow-through validation in chapter 4 of this dissertation.

Experimental Approach / Design

This study, which was conducted in an ecologically valid learning setting (Bronfenbrenner, 1977; D'Arripe-Longueville et al., 2002; Ensergueix & Lafont, 2010; Miller-Cotto & Auxter, 2021), utilised a quasi-experimental between-subjects pre-test, intervention, post-test, retention test design (Figure 5.5). The pre-testing, intervention, and post-testing sessions were conducted during one of the participants' scheduled fundamental movement classes. The retention testing occurred three weeks later in the same scheduled class.

Figure 5.5

Peer Teaching Instructional Study Experimental Approach



Procedure

All aspects of participation in the study were explained, and written consent was obtained prior to the collection of data. The study was approved by the University Human Research Ethics Committee (see Appendices I, J, and K).

Experiment Procedure Explanation

The video explaining the procedures of the experiment was shown prior to pre-testing at the start of the first session of the experiment.

Throwing Technique Component Explanation

To analyse performance, observers must have a strong knowledge of critical components of the skill and their sequence (Knudson, 2013; Morrison & Reeve, 1989). To ensure participants understood the critical components of the overarm throw for force, a throwing technique video, including footage of elite and proficient throwers accompanied by verbal narration and visual cueing outlined the six critical components of the throw. A narrated video was chosen because Janelle et al. (2003) found that those who used video modelling with verbal and visual cueing acquired and retained better technique when learning a novel skill. Another benefit of video instructions is participants in all groups receive standardised instructions (Talpey et al., 2014). The two instructional videos were shown prior to the warm-up.

Warm-up and Familiarisation

The same warm-up and throwing familiarisation used in Study 1 was implemented in this study.

Pre-Testing

In pre-testing, participants completed three overarm throws using their non-dominant hand. Participants threw a tennis ball with maximum force but were advised that accuracy and velocity of the throws would not be measured. The specific cue utilised in previous throwing studies (Halverson et al., 1977; Langendorfer & Roberton, 2002) of “crash the ball into the wall” was used in this study.

Throwing technique was selected as the primary dependent variable since it is an applied and common form of assessment used by PE teachers in a practical class setting. In addition, throwing technique, a process measure, is a more accurate measure of technique development when compared to product measures like speed and distance, which also reflect body size and strength, disadvantaging students and athletes with less size and strength (Haywood & Getchell, 2014). Additionally, the Roberton developmental sequence for forceful overarm throwing appears to relate closely to ball velocity (Roberton & Konczak, 2001). In line with the OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016), other dependent variables included: participants' perceptions of their intervention and whether the respective interventions enhanced participants' ability to analyse and perform the overarm throw for force, and whether video analysis improves learners' motivation to develop fundamental motor skills.

To reduce the influence of performance anxiety (Beseler et al., 2016), the only people present during testing were the participants' intervention partner, a research assistant and I. Prior to completing the throws, participants were given the opportunity to ask any questions.

The student number and throw stands used in Study 1 were used in this study to help the assessor identify the thrower and the throw number (see Figure 5.6).

Figure 5.6

Participant Identification

Experimental Interventions

Participants were allocated to one of three experimental groups, Video Analysis Group (VAG), Verbal Group (VG), and a Control Group (CG), based on the tutorial group in which they were enrolled. All sessions were completed during the participants' normal scheduled classes, decreasing the likelihood of feedback crossover (Jennings et al., 2013). VAG and VG participants worked with a partner of their choice in a Reciprocal style of peer teaching (Mosston & Ashworth, 2002) with the aim of improving each other's throwing technique. Selecting their own partners was expected to support performance success (Mosston & Ashworth, 2002), and make learners more comfortable receiving feedback from friends (Byra & Marks, 1993). VAG and VG peer teach interventions (which involved the observers providing feedback to the throwers) were identical except the VAG had access to video analysis technology. The CG participants completed unrelated course work that involved no overarm throwing or QMD activities.

During the 20-minute intervention period, each pair found a space in the gym and a wall at which they could throw; one of the pair threw (thrower) for the first five minutes and their partner (observer) provided feedback. The roles were then reversed for the next five minutes. This process was repeated twice; in total each participant threw for 10 minutes. Pilot testing indicated that separating the 10 minutes throwing practice each participant had, into two blocks of five minutes, reduced the likelihood of fatigue. Due to the session logistics, I did not control for feedback that each pair in each experimental group received. The observers used the throwing component checklist (Figure 5.3) and QMD skills learnt in earlier practical and theoretical classes to develop the thrower's throwing performance. The checklist was implemented to support learners paired in a reciprocal style (Ernst & Byra, 1998), and to ensure both students were active in the learning process (Kretschmann, 2017). There were two parts to the checklist, the first page covered the backswing, stepping, and follow-through components. Once the pairs had rectified faults related to these components, they were instructed to collect from me, the second part of the checklist that covered the trunk, humerus, and forearm components. During the intervention phase, when asked for assistance by the participants from either group, I interacted with the pairs forming a triad (Byra & Marks, 1993). To avoid commandeering the observer's role, my communication was always directed to the observer, never the thrower (Mosston & Ashworth, 2002).

Post-Testing and Retention Testing

At the completion of the interventions, participants rested for 10 minutes, then completed post-testing, identical to the pre-testing. No feedback was provided in the post-testing. At the completion of the post-testing, participants completed the questionnaire and were instructed to refrain from any further non-dominant hand overarm throwing practice. A retention test identical to the pre- and post-testing was conducted three weeks after the post-testing. The retention testing examined whether the interventions were effective by determining the durability of the throwing technique improvements (Giannousi et al., 2017).

Statistical Analysis

To compare the effectiveness of the three interventions on throwing technique, the throwing footage was analysed according to Roberton's (Roberton & Halverson, 1984) developmental levels (Table 5.1). The assessment of the six components were used to derive a summated scale ranging from six to 21 for each throw. The dependent variable, "throwing score", was the total score of the three throws, which ranged from 18 to 63. Two factors were considered: group (video analysis, verbal and control group), and test (pre, post and retention). The Statistical Package for Social Sciences (SPSS for Windows, version 24.0.) was used to perform a 3-factor (Group x Gender x Test) repeated measures analysis of covariance (3-way ANCOVA), with test as a within-subjects factor, gender and intervention group as between-subjects factors, with adjustment for the between-subjects covariate age. Adjustment for covariate age was incorporated into the analyses in response to findings of previous throwing research that identified the impact age can have on throwing performance (Lorson et al., 2013; Williams et al., 1998). To investigate the nature of the changes over time in the three groups and by gender, interactions between group, gender and test were also included in the model. Independent sample t-tests were conducted to examine the difference between male and female throwing scores at various points in the experiment. All analyses had a *p* value of 0.05 for significance.

To examine the responses to the six survey questions, the responses were each cross tabulated against intervention group (video, verbal, control) and chi-squared tests of association were performed to identify differences in the profiles of responses in the three groups. Because of small cell sizes which threatened the validity of the tests, the five categories for the questionnaire items were collapsed, first into three categories (*Disagree, Not sure, Agree*), and then into two categories (*Disagree or Not sure, Agree*). Some expected cell sizes were still < 5, and so Fisher's exact tests were conducted instead of chi-squared tests. Because the CG had not experienced the intervention, this group was excluded from the intervention analysis statements.

Results

Assumptions

The assumptions underlying the following analyses of covariance were tested, Box tests were conducted to check the equality of covariance. Results showed the observed covariance matrices of the component totals were equal across the intervention groups (Box's M=11.557, F=.737, p = .716), indicating the variances were similar.

Group Difference Check

To ensure homogeneity of groups at pre-test, pre-test throwing scores for the three groups were analysed by a one-way ANOVA (see Table 5.3). No significant intervention group differences were found for pre-test throwing score, $F(2,15) = 0.30$, $p = 0.970$, partial $\eta^2 = .001$. The groups had equal throwing ability at pre-test.

The questionnaire results that were related to participants' formal throwing training and confidence to throw with the non-dominant hand prior to the intervention were also analysed to ensure homogeneity. The first statement survey item was, *I have had no formal throwing training using my non-dominant hand.* Every participant in every group agreed with this statement so homogeneity of prior training in all groups can be assumed.

One participant in each group (see Table 5.2) identified themselves as being confident throwing with their non-dominant hand prior to the intervention. When the three levels were collapsed into two by combining the *Disagree* and *Not sure* responses, the Fisher's exact test revealed no significant group effect, $p = 1.00$, indicating the three groups were equally confident throwing with their non-dominant hand at pre-testing.

Table 5.2

Prior Throwing Confidence

			Disagree or Not sure	Agree
Group	VAG	Count	16	1
		% Within Group	94.1%	5.9%
	VG	Count	18	1
		% Within Group	94.7%	5.3%
	CG	Count	10	1
		% Within Group	90.9%	9.1%

Throwing Score

The descriptive statistics of throwing score are provided in Table 5.3. The results of the repeated measures ANCOVA, after adjusting for age, are as follows. The within-subjects results approached significance, $F(2,80) = 2.825$, $p = .065$, partial $\eta^2 = .066$. The analysis revealed the combined post-test throwing score for all three groups was higher than the pre-test throwing scores and the retention test throwing scores higher than the post-test scores, indicating throwing technique improved with each testing session.

Table 5.3

Throwing Score: Total Means (M) ± Standard Deviation (SD)

Intervention Group	Gender	*n*	Pre *M* ± *SD*	Post *M* ± *SD*	Retention *M* ± *SD*
VAG	Male	8	45.0 ± 4.1	50.1 ± 3.5	50.1 ± 4.8
	Female	9	45.0 ± 4.2	48.3 ± 3.8	48.1 ± 5.3
	Total	17	45.0 ± 4.0	49.2 ± 3.7	49.1 ± 5.0
VG	Male	11	47.0 ± 5.6	48.7 ± 6.3	49.5 ± 6.2
	Female	8	42.6 ± 2.9	44.6 ± 3.9	45.9 ± 3.7
	Total	19	45.2 ± 5.0	47.0 ± 5.7	47.9 ± 5.5
CG	Male	5	46.6 ± 5.0	48.2 ± 2.8	50.2 ± 4.2
	Female	6	43.2 ± 4.4	44.2 ± 4.2	45.0 ± 5.4
	Total	11	44.7 ± 4.8	46.0 ± 4.1	47.4 ± 5.3

The between-subjects analysis identified the only statistically significant predictor of throwing score was gender. The male mean score of 48.1 averaged across all other variables, including test, was significantly higher than the female mean score of 45.3, $F(1,40) = 4.427$, $p = .042$, partial $\eta^2 = .100$. The independent samples t-tests indicated that males were higher at all testing points, with the difference in pre-test throwing scores marginally significant, $t(45) = 2.0$, $p = .053$, the male post-test throwing significantly higher than the female throwing, $t(45) = 2.4$, $p = .022$, and male retention test throwing significantly higher than female throwing, $t(45) = 2.3$, $p = .028$.

Throwing score was not significantly affected by intervention group, F (2,40) = 0.79, p = .463, partial η^2 = .038, and there was no significant interaction effect of intervention group and gender, F(2,40) = 0.46, p = .636, partial η^2 = .022.

Group and Test Interaction Analysis

The group by test interaction plots shown without and with gender information are shown in Figures 5.7 and 5.8, respectively. The interaction effects for both genders combined were not significant, F(4,80) = 1.477, p = .217, partial η^2 = .069. The interaction effects for males, F(4,40) = 1.617, p = .19, partial η^2 = .139 and females, F(4,38) = 0.375, p = .83, partial η^2 = .038 were also not significant.

Figure 5.7

Interaction Plot: Group by Test

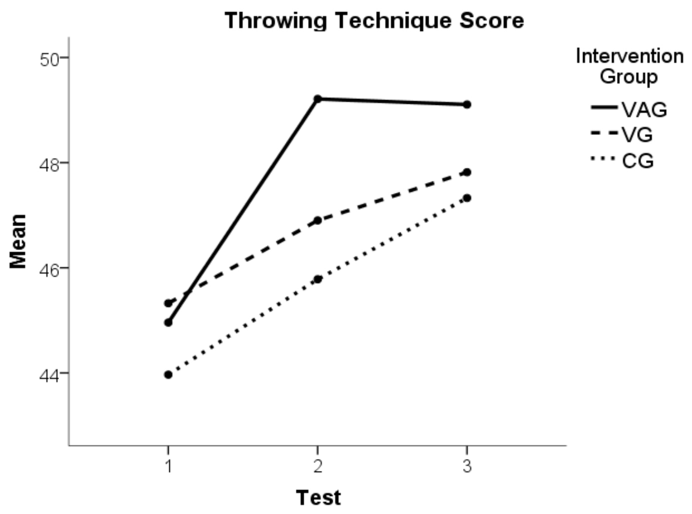
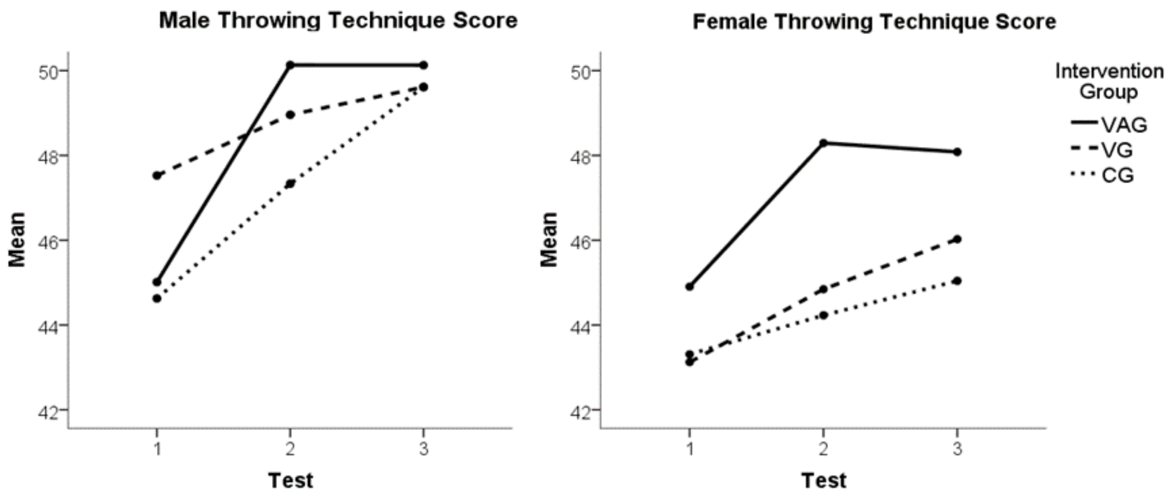


Figure 5.8

Interaction Plots: Group by Test by Gender



Although the group by test interaction was not statistically significant, an analysis of "simple effects" revealed different patterns of statistically significant changes over time within the three groups. While this may be counter-intuitive, it is not a contradiction. The two approaches address subtly different questions. The test of interaction examines whether the changes over time differ significantly between groups, while the simple effects tests indicate whether the changes within each group are significantly different from zero (Grace-Martin, n.d.). Situations can arise where two effects are not significantly different from each other, but the larger effect is significantly different from zero while the smaller one is not. As such, simple effects analysis was conducted for each group by adding Bonferroni-adjusted post-hoc analyses for the differences between test occasions. The results of the VAG showed a significant (mean difference = 4.253, $p < .0001$) change in the pre- to post-test throwing scores and a significant (mean difference = 4.147, $p < .0001$) change in pre- to retention scores. There was no significant change in the pre- to post-test scores for the VG (mean difference = 1.576, $p = .238$) or the CG (mean difference = 1.814, $p = .398$), but there was a significant change in the pre- to retention test scores in the VG (mean difference = 2.492, $p = .011$) and the CG (mean difference = 3.360, $p = .011$). There were no significant changes in throwing score from post to retention test scores in any of the intervention groups (VAG mean difference = 0.105, $p = 1.00$, VG mean difference = 0.916, $p = .981$, CG mean difference = 1.546, $p = .664$) indicating no significant changes occurred during the three weeks between post and retention testing.

Gender Impact on Group and Test Interaction

Although the 3-factor (or second order) gender by group by test interaction was not statistically significant, $F(4,80) = 0.613$, $p = .654$, partial $\eta^2 = .030$, I conducted a simple effects analysis of the effects of test within each combination of group and gender. Conducting Bonferroni-adjusted post-hoc interaction tests for group by test on each gender separately, a similar pattern of results was shown by both genders. The VAG males showed significant (mean difference = 4.910, $p < .01$) improvement from pre- to post-test scores and a significant (mean difference = 4.975, $p < .01$) change in pre- to retention test throwing scores. The VAG females showed a significant (mean difference = 3.078, $p = .035$) improvement from pre- to post-test scores and a significant (mean difference = 3.212, $p = .010$) change in pre- to retention test throwing scores. The throwing scores of VG males indicated no significant change from pre- to post-test (mean difference = .892, $p = 1.000$), or pre- to retention test (mean difference = 1.872, $p = .435$). The VG females indicated no significant change from pre- to post-test (mean difference = 2.310, $p = .195$), a significant pre- to retention test change was evident (mean difference = 3.127, $p = .019$). The male CG throwing scores indicated no significant change from pre- to post-test (mean difference = 3.782, $p = .199$), or from pre- to retention-test (mean difference = 5.122, $p = .063$). The female CG throwing scores indicated no significant change from pre- to post-test (mean difference = .971, $p = 1.000$), or from pre- to retention-test (mean difference = 1.845, $p =$

.376). There were no significant changes in throwing score from post- to retention-test in any of the male intervention groups (VAG mean difference = .065, p = 1.000, VG mean difference = .980, p = 1.000, CG mean difference = 1.340, p = 1.000), or the female intervention groups (VAG mean difference = .135, p = 1.000, VG mean difference = .818, p = 1.000, CG mean difference = .875, p = 1.000).

Levene's tests were conducted to examine the equality of error variance. Results showed no significant departures from normality or constant variance in pre-testing ($F(2,20) = .405$, p = .672), post-testing ($F(2,20) = .274$, p =.763), or retention testing ($F(2,20) = .473$, p =.630). Kolmogorov-Smirnov (K-S) and Shapiro-Wilk (S-W) test statistics were used to test assumptions of normality; the throwing scores followed a normal distribution in pre-testing (K-S p = .200, S-W p = .418), post-testing (K-S p = .200, S-W p = .448), and retention testing (K-S p = .200, S-W p = .270).

Questionnaire Results

The results of the questionnaire were examined to determine the impact interventions had on participants' perceived throwing ability, perceived QMD skills, perceptions about the importance of video analysis technology in the QMD process, and the impact video analysis had on participants' enjoyment level when learning to throw with their non-dominant hand.

Intervention Impact on Perceived Throwing Ability

The percentages (shown in Table 5.4) indicate the VAG and VG both responded positively about the impact their respective interventions had on their throwing ability. Only one VAG participant stated that she was unsure whether the intervention had improved her throwing. The Fisher's exact test revealed no significant group effect, p = .472. Both VAG and VG participants believed their respective interventions helped improve their non-dominant hand throwing.

Table 5.4

Intervention Impact on Perceived Throwing Ability

			Disagree or Not sure	Agree
Group	VAG	Count	1	16
		% Within Group	5.9%	94.1%
	VG	Count	0	19
		% Within Group	0.0%	100.0%

Intervention Impact on Perceived QMD Ability

The percentages (Table 5.5) indicate the VAG and VG responded positively about the impact that the interventions had on their confidence to perform QMD. The Fisher's exact test revealed no significant group effect, $p = .650$. Both VAG and VG participants believed their respective interventions helped them perform QMD on their partner's overarm throwing.

Table 5.5

Intervention Impact: Perceived QMD Skills

			Disagree or Not sure	Agree
Group	VAG	Count	3	14
		% Within Group	17.6%	82.4%
	VG	Count	2	17
		% Within Group	10.5%	89.5%

Video Replay Importance

Only the VAG experienced video replay in their intervention, however, all participants had experienced multiple video analysis sessions in their fundamental movement course prior to this study, as such, the VG provided experiential responses about the importance of video replay (Table 5.6). The Fisher's exact test revealed no significant group effect, $p = .264$, indicating that video replay was similarly essential for both groups.

Table 5.6

Video Replay Importance CG Removed

			Disagree or Not sure	Agree
Group	VAG	Count	3	14
		% Within Group	17.6%	82.4%
	VG	Count	7	11
		% Within Group	38.9%	61.1%

Intervention Enjoyment Level

The responses (Table 5.7) indicate more VG participants found their intervention enjoyable and engaging than VAG participants. The Fisher's exact test revealed a significant group effect, $p = .037$.

Table 5.7

Intervention Enjoyment Level

			Disagree or Not sure	Agree
Group	VAG	Count	6	11
		% Within Group	35.3%	64.7%
	VG	Count	1	18
		% Within Group	5.3%	94.7%

Discussion

The purposes of this study were to determine whether a single session peer teaching intervention could improve short-term non-dominant hand overarm throwing performance and to examine what perception students had of the interventions. Important findings from the current study were the immediate improvements made by those with access to video analysis during their intervention, and the perceived improvements both peer teaching interventions had on participants' throwing and QMD skills.

Throwing Performance

One primary aim was to determine whether a single session peer teaching intervention could improve short-term non-dominant hand overarm throwing performance. Results indicated that throwing technique improved for all three groups, with the VAG being the only group to show significant pre- to post-test improvement. Although the VAG was the only group to show significant pre- to post-test improvement, there was no significant difference in the scores of the three groups at post- and retention testing, as such, the hypothesis that the VAG would throw with more advanced technique in the post- and retention testing than the VG, who would throw with more advanced technique than the CG was proven incorrect. The immediate VAG improvements are similar to Robles' finding (2013) that the presentation of verbal and video feedback to students learning the grab start swimming dive was more effective than receiving verbal feedback alone. Robles' study did not include retention testing. The retention results of the current study expand on Robles' findings, indicating that while there was an immediate advantage of video analysis, this advantage was no longer present at retention testing.

A prominent explanation that could explain the immediate improvements in Robles' (2013) study and the present study, is that video feedback provides learners with visual movement information to compare to correct form, which can be used to detect errors and modify ensuing performances (Menickelli et al., 2000). The video feedback may have increased observers' and throwers' observational powers and qualitative analysis abilities (Koh & Khairuddin, 2004), enhancing the feedback provided to the thrower, facilitating adaptations during practice (Potdevin et al., 2018), allowing efficient skill acquisition.

A second, somewhat speculative, explanation for the "faster" acquisition is that the VAG intervention involved more explicit motor learning that led to higher conscious awareness of how the throw should be performed (Kleynen et al., 2014). More opportunity to visually critique another thrower's technique may have led the VAG to generate additional explicit knowledge during the intervention period, which usually is more robust for skill acquisition, but also has been shown to deteriorate under psychological stress (Masters, 1992). Explicit approaches, encourage learners to increase attentional control to their movements; this more internal focus of attention (Kal et al., 2018) may result in rapid improvements in performance (Rendell et al., 2011).

Acquiring skills efficiently is important in most motor learning settings, as there is often limited time to practice a skill before needing to transfer it to a new context (Horn et al., 2007).

PE classrooms are an example where crowded curriculum often only allows teachers to teach units or topics for one or two weeks before the class begins the next topic. At the same time, it is important that performance improvements are persistent, which is assessed during the retention (Lee et al., 1994; Magill & Anderson, 2021; Spittle, 2021). If the group cannot maintain the performance advantage at retention, the value of improvements decreases considerably. The only group to improve significantly from pre- to post-testing was the VAG, importantly the improvements were persistent at retention. The VG and CG did not achieve the same throwing technique improvement from pre- to post-testing, however, all groups were similar in throwing technique during the post and retention testing, which means the intervention had minimal effects on persistence. One explanation for these results is the intervention only included one 20-minute practice session, and multiple practice sessions may lead to more persistent improvements.

Gender Difference

The results of the current study demonstrated that males had more advanced throwing technique than females initially and throughout the study, irrespective of their group, as such, the hypothesis that males would throw with more advanced technique than females was proven correct. These findings are consistent with studies that examined gender differences in throwing both quantitatively (e.g., throwing velocity and distance) and qualitatively (Ehl et al., 2005; Lorson & Goodway, 2008; Schott & Getchell, 2021; Thomas & French, 1985; Williams et al., 1996b). Thomas and French's (1985) early meta-analysis examined gender differences in motor performance of children and adolescents with results indicating males as early as 4 years were throwing faster and farther (distance) than females and this difference increased rapidly as these children approached adolescence. This pattern continued linearly through puberty to 17 years of age, males throwing three standard deviations further than females the same age. The results of more recent throwing studies (e.g., Ehl et al., 2005; Lorson & Goodway, 2008; Lorson et al., 2013) have substantiated Thomas and French's findings, with males throwing with more accuracy, more velocity, and more advanced technique than females at all ages. In the context of the current study, the two genders were not influenced differently by the respective interventions. Males did not show greater performance improvements than females, they simply demonstrated higher throwing performance in pre, post and retention testing.

Impact on Perceived Throwing Ability

While peer teaching is not new, only minimal research has examined its effectiveness (Townsend & Mohr, 2002). To my knowledge no research has examined whether access to video analysis during a peer teaching intervention influences actual and perceived motor skill performance. As a result, direct comparisons between the findings of the current study and similar studies were not possible, instead comparisons were made to other studies that have examined the effectiveness of peer teaching and video analysis separately.

This study indicated the VAG and VG both believed their respective interventions helped improve non-dominant hand throwing, as such the hypothesis that the VAG would have higher perceived ability to perform the overarm throw was proven incorrect. The positive attitudes are similar to the findings of studies on the effectiveness of peer teaching (Ensergueix & Lafont, 2010; Johnson & Ward, 2001). A meta-analysis on 65 independent evaluations of peer teaching programs conducted in elementary or secondary schools (Cohen et al., 1982), identified that students who had experienced peer teaching had more positive attitudes to the subject than students who had not experienced peer teaching. Dyson (2001) also found similar results with students indicating peer teaching helped improve their volleyball and basketball skills. Furthermore, Ensergueix and Lafont (2010) found similar results to the present study when participants who experienced peer tutoring during their intervention had higher self-efficacy about table tennis skills compared to participants who practiced individually without peer tutoring.

Comparing the current study findings with video analysis research was problematic because studies that compared video analysis interventions to no video technology often neglected to question the non-technology participants about their perceptions on the intervention they experienced. Nevertheless, similar to the current throwing study, Ferracioli et al. (2013) found that the VAG and VG thought their respective interventions were effective in helping improve swimming performance. Furthermore, Ferracioli et al.'s questionnaire results showed video feedback (video group) and verbal feedback (verbal group) had similar motivational effects during the five-day breaststroke learning process.

Impact on Perceived QMD Ability

Questionnaire results indicated participants' perceived ability to analyse the overarm throw was similar for the VAG and VG, highlighting verbal feedback was perceived as effective as video and verbal feedback combined. As such, the hypothesis that the VAG would have higher perceived ability to analyse the overarm throw than VG was proven incorrect. These findings contrasted the findings of two studies that examined the integration of video analysis into a PE setting (Koh & Khairuddin, 2004; O'Loughlin et al., 2013). O'Loughlin et al. (2013) found primary school children's performance assessment perspectives were aided by video footage in PE compared to traditional teacher feedback. Koh, and Khairuddin (2004) also contrasted the current study's findings, identifying video analysis as a means of improving learners' observational powers. One possible explanation for this contradictory finding is the length of the intervention. The current throwing study involved one 20-minute intervention / practice period, in comparison to the gymnastics study (Koh & Khairuddin, 2004) intervention, which was conducted over 9 weeks and the basketball skills study (O'Loughlin et al., 2013), which lasted 10 weeks. Perhaps the perceived QMD benefits of video analysis may not be evident unless the students are provided the opportunity to experience the use of the technology over several sessions.

Importance of Video Analysis

Both VAG and VG participants indicated that they believed video analysis to be essential in the QMD process, as such the hypothesis that the VAG and VG would both identify video analysis technology to be critical in the QMD process was proven correct. These findings are congruent with the findings of other research where learners acknowledged that video analysis assisted them to identify strengths and weaknesses (Weir & Connor, 2009), helped them understand cues (Kretschmann, 2017), made performance assessment possible (O'Loughlin et al., 2013), and enhanced observational powers and QMD skills (Koh & Khairuddin, 2004).

Enjoyment Level

Participants who experienced the verbal intervention enjoyed and engaged with it more than those in the video analysis intervention, as such the hypothesis that the VAG would identify their intervention as more enjoyable than the VG was proven incorrect. These findings contradict video analysis research that found learners enjoy and are motivated by watching video replays of their performances (Darden, 1999; Ferracioli et al., 2013; Hamlin, 2005; Koh & Khairuddin, 2004). Researchers have also identified that video analysis enhances learners' engagement (Casey & Jones, 2011; Heynen, 2008; O'Loughlin et al., 2013; Palao et al., 2013; Weir & Connor, 2009). The number of intervention sessions involved in the respective studies may be a reason. Unlike this study, other studies included between five (e.g., Ferracioli et al., 2013; Palao et al., 2013) and 16 sessions (e.g., Casey & Jones, 2011), which may have enabled participants to become accustomed to the technology, allowing them to enjoy the sessions more than participants in the current study who may have felt overwhelmed (Obrusnikova & Rattigan, 2016). The VAG in this study may have experienced time pressures trying to film, analyse the video footage, and then provide feedback to their partner in the single 20-minute session, which may have affected enjoyment levels. If this was the case, it would be beneficial to remind students that while the quantity of throws may decrease when using video analysis, the rich visual information (Robles, 2013) available will enhance observational powers (Koh & Khairuddin, 2004).

Future Research

Researchers have identified that students who improved performance because of video analysis are more motivated and engaged by the feedback, often leading to more practice inside and outside of PE classes (O'Loughlin et al., 2013). Although speculative, the immediate performance improvements shown in the current study for the VAG could lead to motivational benefits, which may enhance learner's perceived success and continued practice (Knudson, 2013). There is scope for further research to examine whether video analysis improves students' motivation levels. Future research could also explore whether benefits of video analysis in a peer teaching setting applies to primary and secondary aged learners. If school aged learners are able to show immediate motor skill improvements after a single 20-minute session, it could allow the transfer of these newly acquired skills to a different context, such as game based activities in their PE classes, recreational activities with their friends or more formal, organised sporting activities (Horn et al., 2007). PE teachers may be taught how to effectively implement the accessible and affordable technology into their classes. Ultimately, we may be able to help these learners develop their fundamental motor skills, in the process increasing the likelihood of them being healthy, physically active members of society (Barnett et al., 2013). Given the single 20-minute session did not lead to strong group differences at retention testing, future research could extend the number of peer teaching sessions to determine if more robust improvements can be achieved.

Limitations

Despite the valuable findings, there are potential limitations that need to be acknowledged. Due to the logistics associated with completing the data collection within scheduled classes, the questionnaire was completed after the post-testing. This is a potential limitation; in identifying how confident they were to execute a non-dominant hand throw prior to the intervention, the participants may have been relying on memory recall and there is a possible bias from the intervention. Due to the session logistics, I did not control for feedback that each pair in each experimental group received, whereby the amount of feedback provided could be a confounding variable. These limitations were an unavoidable result of conducting an ecologically valid study. Finally, the questionnaire was developed based on a literature review of similar questionnaires, yet it was not yet validated. Future use of these questionnaire statements should seek further validation with other studies. It was my intention to find a balance between scientific rigour and ecological validity of this type of study.

Summary

The findings of the current study have identified pre-service PE teachers working in a peer teaching setting for 20-minutes can show immediate improvements to non-dominant hand overarm throwing technique if video analysis feedback is used during practice. Nevertheless, the CG and VG eventually performed similarly to the VAG group at retention. In light of the immediate improvements that can be made when using video analysis technology, it is recommended that Physical Education Teacher Education (PETE) programs should consider incorporating peer teaching / video analysis sessions into fundamental movement courses to help pre-service PE teachers develop their fundamental motor skills (FMS). Much like primary and secondary PE, the crowded curriculum of PETE programs makes it difficult for pre-service teachers to fully develop all FMS. Video analysis sessions could facilitate pre-service PE teachers developing FMS proficiency more quickly, thus, making them more effective teachers through their ability to proficiently demonstrate the skills they are teaching (Baghurst et al., 2015; Gabbei, 2011; Pulling & Allen, 2014). During these peer teaching / video analysis sessions, it is recommended pairs be presented with checklists to guide them. The checklists will help focus attention on one component at a time, guiding them as to which weakness to rectify first, and will provide them with an appropriate remediation for each performance error.

The questionnaire responses identified that participants in the VAG and VG both believed their respective interventions helped improve their non-dominant hand throwing. Furthermore, both VAG, and VG participants identified video analysis to be essential in the QMD process. Finally, the VG found their intervention more enjoyable and engaging than the VAG, possibly because of time pressures experienced as a result of video analysis being used in a single 20-minute session.

The peer teaching activities carried out in this study were ecologically valid and can be completed in a single practical PETE class. These affordable, easy to implement activities could shape the future of PETE training, potentially altering pre-service teachers beliefs that they do not get adequate hands on opportunities to experience the use of information and communication technology in the PETE programs (Casey et al., 2017; Tearle & Golder, 2008).

CHAPTER 6

STUDY 4: INVESTIGATING THE AFFECT OF PEER TEACHING INSTRUCTIONAL APPROACHES ON IMPROVING THROWING TECHNIQUE PERFORMANCE AND INTERVENTION PERCEPTIONS IN AN EXTENDED PEER TEACH SETTING

In Study 3, pre-service Physical Education (PE) teachers participated in a study to examine the effect of single session peer teaching instructional approaches on improving overarm throwing performance. The Video Analysis Group (VAG) and the Verbal Group (VG) worked in a peer teaching setting for 20-minutes, trying to improve their overarm throwing technique. The VAG had access to video analysis technology, the VG did not. The Control Group (CG) completed unrelated course work that involved no overarm throwing or QMD activities. Throwing technique improved for all three groups, the only group to show significant improvement from pre- to post-test was the VAG, even though there was no significant difference in the post-test scores of the three groups. The retention results indicated no significant group difference in the retention test scores.

There is a well-recognised relationship between the amount of appropriate practice and learning (Ashy et al., 1988; Crossman, 1959; Silverman, 1985, 2011; Spittle, 2021), according to the power of law of practice (Crossman, 1959; Snoddy, 1926), all things being equal, the more a skill is practiced by a learner the more they will learn the skill. A study (Silverman, 1985) conducted in an ecological physical education setting found the number and quality of trials were a positive indicator of achievement. Silverman investigated the learning of the survival float swimming skill, with 102 university students enrolled in five intermediate swimming classes participating in the study. Instruction time consisted of two 15-minute classes, with video footage from the classes assessed by two assessors. Results showed the number of practice trials performed by learners at an appropriate level had a positive relationship to learning the survival float.

Studies such as that conducted by Silverman (1985), and the findings of Study 3 in the current dissertation, raise the question, would the throwing performance improvements be more 'robust' (Bertram et al., 2007) and a group effect be revealed, if extra practice sessions were included in the peer teaching interventions? Learners have demonstrated significant improvements in non-dominant hand throwing (Janelle et al., 1997) in as few as two practice sessions over 100 throws per session. Learners have also demonstrated significant improvements in a novel "soccer kick up" skill after practicing for two 20-minute sessions (Ashy et al., 1988). There is a common notion that, usually, the more practice a learner performs, the more they will learn (Spittle, 2021). This chapter includes a study that examined the effect of two peer teaching instructional approaches on improving overarm throwing performance in a three-session peer teaching intervention. Extending on Study 3, this study aimed to identify if there is a dose-response relationship (Robinson et al., 2017) that would justify additional peer teaching sessions and if gender differences of throwing performance occurs.

Study Aims

There were four primary aims and one secondary aim within this study. One primary aim was to determine whether a three-session video analysis peer teaching intervention effected overarm throwing performance compared to a verbal or control group. A second primary aim was to establish whether video analysis impacted the participants' perceived ability to perform and analyse the overarm throw. A third primary aim was to examine participants' perceptions about the importance of video analysis in the Qualitative Movement Diagnosis (QMD) process. A fourth primary aim was to determine the impact that video analysis has on participants' enjoyment. Finally, a secondary aim was to examine whether gender influenced throwing performance.

It was hypothesised that the Video Analysis Group (VAG) would throw with more advanced technique in the post and retention testing than the Verbal Group (VG), who would throw with more advanced technique than the Control Group (CG) in the post and retention testing. It was hypothesised that the VAG would have higher perceived ability to perform and analyse the overarm throw than VG after their respective interventions. It was hypothesised that the VAG and VG would both identify video analysis technology to be critical in the QMD process. It was hypothesised that the VAG would identify their intervention as more enjoyable than the VG. It was also hypothesised that the males would throw with more advanced technique than females.

Method

Participants

Fifty-four university (M_{age}= 20.65; SD_{age} = 4.464 years) students enrolled in a Bachelor of Health and Physical Education program participated in the study; none of these participants were involved in any of the other throwing studies in this dissertation. The recruitment of participants and participant requirements were identical to Study 3. There were 25 males (M_{age}= 20.28; SD_{age} = 2.151 years) and 29 females (M_{age}= 20.97; SD_{age} = 5.791 years), who were naïve to the purposes of the study. Study 3 and Study 4 were identical except for the intervention. Since the intervention details were not a part of the previous power analysis, the number of participants required for this study was identical to Study 3.

Equipment

The venue and equipment for the experiment were identical to that used in Study 3 of this dissertation. The participant familiarisation videos, throwing zone, camera positions, and footage editing were also identical to Study 3.

Measures

The measures in the current study were identical to the measures used in Study 3, (i.e., testing assessment of throwing technique, and 6-item questionnaire).

Experimental Approach / Design

The current study design was identical to Study 3 except there were three practice sessions occurring on consecutive weeks. I wanted to be as experimentally robust as possible but had to consider the ecological validity of the study, therefor the duration of the first session was 20 minutes, while the second and third were 10 minutes each. This study was conducted in an ecologically valid learning setting (Bronfenbrenner, 1977; D'Arripe-Longueville et al., 2002; Ensergueix & Lafont, 2010; Miller-Cotto & Auxter, 2021), utilising a quasi-experimental between-subjects pre-test, intervention, post-test, retention test design. All testing and intervention sessions occurred during one of the participants' scheduled fundamental movement classes.

Procedure

All aspects of participation in the study were explained, and written consent was obtained prior to the collection of data. The study was approved by the University Human Research Ethics Committee (see Appendices M, N, and O).

Experiment Procedure Explanation

A similar video as shown in Study 3 was used to explain the procedures of the experiment. The video was shown to participants prior to pre-testing at the start of the first session of the experiment.

Throwing Technique Component Explanation

The same video as shown in Study 3 was shown to participants prior to pre-testing to outline the critical components of the throw.

Warm-up and Familiarisation

The same warm-up and throwing familiarisation used in Study 3 was implemented.

Testing and Interventions

Participants completed the same testing and intervention sessions as conducted in Study 3. The same dependent variable (throwing technique) was recorded, and participants received the same instructions on how to throw the ball (i.e., "crash the ball into the wall").

At the completion of the pre-testing, the first 20-minute intervention session was conducted. Identical to Study 3, participants were allocated to one of three experimental groups based on the tutorial group in which they were enrolled: Video Analysis Group (VAG), Verbal Group (VG), or Control Group (CG). The first, second and third intervention sessions, which followed the same format as the intervention session in Study 3, were completed one week apart. The post-testing was completed immediately after the third intervention session and the retention testing completed one week later.

Questionnaire

At the completion of the post-testing, participants completed the same 6-item questionnaire that was completed in Study 3.

Statistical Analysis

The same statistical analyses of throwing technique scores and survey responses conducted in Study 3 were completed in the present study.

Results

Assumptions

The assumptions underlying the following analyses of covariance were tested, Box tests were conducted to check the equality of covariance. Results showed the observed covariance matrices of the component totals were marginally significant (Box's M=11.557, F=1.480, p = .045).

Group Difference Check

To ensure homogeneity of groups at pre-test, pre-test throwing scores for the three groups were analysed by a one-way ANOVA (see Table 6.3). No significant intervention group differences were found for pre-test throwing scores, $F(2,51) = 0.086$, $p = 0.917$, partial $\eta^2 = .003$, indicating the groups had equal throwing performance at pre-testing.

The questionnaire responses related to participants' prior formal throwing training and confidence to throw with the non-dominant hand prior to the intervention were also analysed to ensure homogeneity. The responses to the first survey statement *I have had no formal throwing training using my non-dominant hand* are shown in Table 6.1. The Fisher's exact test revealed no significant differences in the responses of the groups, $p = 1.00$, indicating the three groups self-reported equal experience at non-dominant hand throwing at pre-testing.

Table 6.1

Prior Formal Throwing Training

			Not sure	Agree
Group	VAG	Count	2	20
		% Within Group	9.1%	90.9%
	VG	Count	2	14
		% Within Group	12.5%	87.5%
	CG	Count	1	15
		% Within Group	6.3%	93.8%

The responses to the second survey statement *I felt confident executing an overarm throw using my non-dominant hand prior to the intervention* were analysed, results are shown in Table 6.2. When the three levels were collapsed into two by combining the *Disagree* and *Not sure* responses, the results were similar, the Fisher's exact test revealed no significant group effect, $p = .758$, indicating the three groups self-reported equal confidence in throwing with their non-dominant hand at pre-testing.

Table 6.2

Prior Throwing Confidence

			Disagree or Not sure	Agree
Group	VAG	Count	17	5
		% Within Group	77.2%	22.7%
	VG	Count	12	4
		% Within Group	75.0%	25.0%
	CG	Count	14	2
		% Within Group	87.5%	12.5%

Throwing Score

The descriptive statistics of throwing technique score are shown in Table 6.3.

Table 6.3

Throwing Score: Total Means (M) ± Standard Deviation (SD)

Intervention Group	Gender	*n*	Pre *M* ± *SD*	Post *M* ± *SD*	Retention *M* ± *SD*
VAG	Male	10	45.1 ± 7.7	49.4 ± 5.6	50.8 ± 7.3
	Female	12	42.8 ± 5.6	47.4 ± 4.7	47.3 ± 5.8
	Total	22	43.9 ± 6.6	48.3 ± 5.1	48.9 ± 6.6
VG	Male	9	45.0 ± 4.7	48.6 ± 1.8	48.2 ± 2.4
	Female	7	41.7 ± 3.6	48.4 ± 4.8	48.6 ± 3.7
	Total	16	43.6 ± 4.5	48.5 ± 3.3	48.4 ± 3.0
CG	Male	6	47.7 ± 6.4	48.8 ± 3.7	49.2 ± 2.8
	Female	10	40.3 ± 4.1	42.9 ± 6.0	43.2 ± 3.3
	Total	16	43.1 ± 6.1	45.1 ± 5.9	45.4 ± 4.2

The repeated measures ANCOVA results, after adjusting for age indicated a significant test main effect, $F(2,46) = 7.088$, $p = .002$, partial $\eta^2 = .236$, with the post-test throwing scores for all three groups higher than the pre-test throwing scores and retention test scores higher than the post-test scores. This indicates throwing technique improved with each session for everyone collectively.

The between-subjects analysis identified the only statistically significant predictor of throwing technique score was gender. The male mean score of 48.0 averaged across all other variables, including time, was significantly higher than the female mean score of 44.8, $F(1,47) = 6.816$, $p = .012$, partial $\eta^2 = .127$. The independent samples t-tests indicated that males were higher at all testing points, with the difference in pre-test throwing scores significant, $t(52) = 2.7$, $p = .010$, the male post-test throwing significantly higher than female post-test throwing, $t(52) = 2.1$, $p = .037$, and the male retention test throwing significantly higher than the female retention test throwing, $t(52) = 2.4$, $p = .018$.

There was no group main effect, $F(2,47) = 0.666$, $p = .518$, partial $\eta^2 = .028$, and there was no significant group by gender interaction effect, $F(2,47) = 1.361$, $p = .266$, partial $\eta^2 = .055$.

Group and Test Interaction Analysis

The group by test interaction effect for both genders combined were not significant, $F(4,94) = 1.454$, $p = .223$, partial $\eta^2 = .058$ (Figure 6.1). The separate group by test interaction effects for males, $F(4,42) = 1.228$, $p = .313$, partial $\eta^2 = .105$ and females, $F(4,50) = 1.182$, $p = .330$, partial $\eta^2 = .086$ were also not significant (see Figure 6.2).

Figure 6.1

Interaction Plot: Group by Test

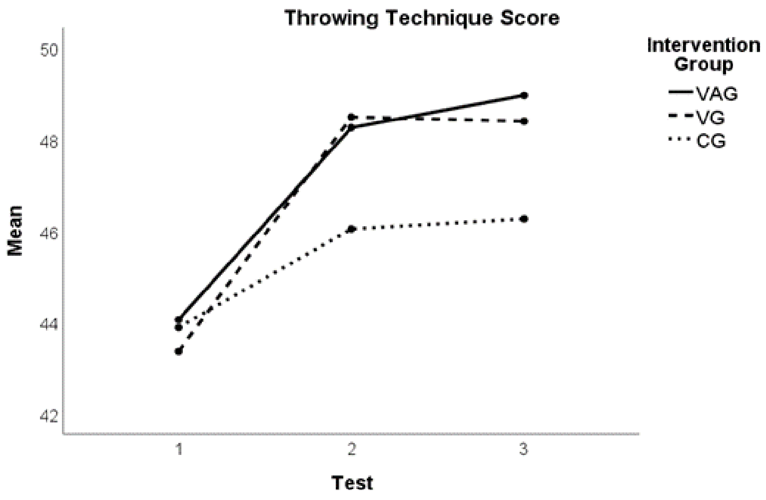
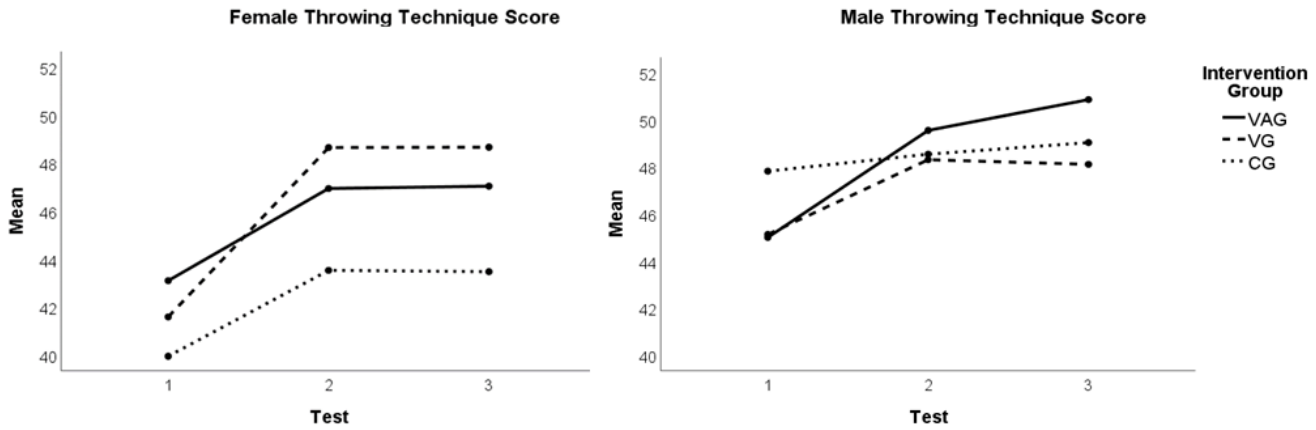


Figure 6.2

Interaction Plot: Group by Test and Gender



While the group by test interaction was not statistically significant, an analysis of "simple effects" revealed different group patterns of statistically significant changes over time. Like Study 3, simple effects analysis was conducted for each group by adding Bonferroni-adjusted post-hoc analyses for the differences between test occasions. The results of the VAG indicated a significant (mean difference = 4.201, $p < .001$) change in the pre- to post-test throwing scores and a significant (mean difference = 4.904, $p < .0001$) change in pre- to retention test throwing scores. The VG results revealed a significant change in the pre- to post-test (mean difference = 5.124, $p < .001$), and pre- to retention test (mean difference = 5.032, $p < .001$), throwing scores. There was no significant change in the pre- to post-test (mean difference = 2.155, $p = .207$) or the pre- to retention test (mean difference = 2.374, $p = .164$) throwing scores for the CG. There were no significant changes in throwing scores from post- to retention test in any of the intervention groups (VAG mean difference = 0.703, $p = .860$, VG mean difference = 0.091, $p = 1.00$, CG mean difference = 0.219, $p = 1.00$), indicating no significant changes during the 1-week retention period.

Gender Impact on Group and Test Interaction

The 3-factor (or second order) gender by group by test interaction was not statistically significant, $F(4, 94) = 1.378$, $p = .247$, partial $\eta^2 = .055$. Like Study 3, I conducted a simple effects analysis of test within each combination of group and gender, conducting Bonferroni-adjusted post-hoc interaction tests for group by test on each gender separately. The VAG males showed a significant (mean difference = 4.984, $p = .014$) improvement from pre- to post-test, and pre- to retention test (mean difference = 5.699, $p < .01$) throwing scores. The VAG females showed a significant (mean difference = 3.798, $p = .021$) improvement from pre- to post-test scores, and pre- to retention test (mean difference = 3.806, $p = .023$) throwing scores. The throwing performance of VG males indicated no significant change from pre- to post-test (mean difference = 3.144, $p = .187$), or pre- to retention test (mean difference = 3.223, $p = .216$). In contrast to the male VG throwing, the VG females showed significant improvement from pre- to post-test (mean difference = 6.929, $p < .001$), and pre- to retention (mean difference = 7.024, $p <$

.001) throwing scores. The male CG throwing scores indicated no significant change from pre- to post-test (mean difference = 0.644, p =1.00), or pre- to retention test (mean difference = 1.501, p = 1.00). The female CG throwing scores indicated no significant change from pre- to post (mean difference = 3.392, p = .07), or pre- to retention test(mean difference = 3.516, p = .063). There were no significant changes in throwing scores from post- to retention test in any of the male intervention groups (VAG mean difference = .716, p = .899, VG mean difference = .078, p = 1.000, CG mean difference = .857, p = .958), or the female intervention groups (VAG mean difference = .008, p = 1.000, VG mean difference = .095, p = 1.000, CG mean difference = .124, p = 1.000).

Levene's tests were conducted to examine the equality of error variance. Results showed no significant departures from normality or constant variance in the pre-testing (F(5,48) = 1.041, p = .405), post-testing (F(5,48) = 1.389, p =.245), or the retention testing (F(5,48) = 2.133, p = .077). Kolmogorov-Smirnov (K-S) and Shapiro-Wilk (S-W) test statistics were used to test assumptions of normality; the throwing performance followed a normal distribution in pre-testing (K-S p = .200, S-W p = .776), and post-testing (K-S p = .200, S-W p = .840); at retention testing, two low outliers led to a significant Shapiro-Wilk result (K-S p = .200, S-W p = .007). Given the sample size and the otherwise symmetrical shape of the histogram of residuals, this was not considered to represent a serious violation of the assumption of normality.

Questionnaire Results

The questionnaire results were examined to determine the impact interventions had on participants' perceived throwing ability, perceived QMD skills, perceptions about the importance of video analysis technology in the QMD process, and the impact video analysis had on participants' enjoyment level when learning to throw with the non-dominant hand.

Intervention Impact on Perceived Throwing Performance

The perceived throwing percentages (shown in Table 6.4) indicated that the VAG and VG both responded positively about the impact the respective interventions had on throwing performance. The Fisher's exact test revealed no significant group effect, $p = .124$. Both VAG and VG participants believed the respective interventions helped improve their non-dominant hand throwing.

Table 6.4

Intervention Impact on Perceived Throwing Performance

			Disagree or Not sure	Agree
Group	VAG	Count	4	18
		% Within Group	18.1%	81.9%
	VG	Count	0	16
		% Within Group	0.0%	100.0%

Intervention Impact on Perceived QMD Skill

The Fisher's exact test revealed no significant group effect for perceive QMD ability, $p = .249$. Both VAG and VG participants believed the respective interventions helped them perform QMD on their partner's overarm throwing (Table 6.5).

Table 6.5

Intervention Impact: Perceived QMD Skill

			Disagree or Not sure	Agree
Group	VAG	Count	3	19
		% Within Group	13.6%	86.4%
	VG	Count	0	16
		% Within Group	0.0%	100.0%

Video Replay Importance

Only VAG participants experienced video replay during the intervention, however, all participants had experienced multiple video analysis technology familiarisation sessions (via the Hudl "app") in the fundamental movement course prior to this study. The Fisher's exact test revealed no significant group effect, $p = .108$, indicating that video replay was similarly essential for both groups.

Table 6.6

Video Replay Importance CG Removed

			Disagree or Not sure	Agree
Group	VAG	Count	2	20
		% Within Group	9.1%	90.9%
	VG	Count	5	11
		% Within Group	31.3%	68.8%

Intervention Enjoyment Level

The Fisher's exact test revealed no significant group effect for enjoyment levels, $p = .698$, indicating VAG and VG participants both found the interventions enjoyable and engaging (Table 6.7).

Table 6.7

Intervention Enjoyment Level

			Disagree or Not sure	Agree
Group	VAG	Count	4	18
		% Within Group	18.2%	81.8%
	VG	Count	4	12
		% Within Group	25.0%	75.0%

Discussion

The purposes of this study were to determine whether a three-session peer teaching intervention could improve non-dominant hand overarm throwing performance and to examine the perception students had of the interventions. Important findings from the current study were significant throwing improvements made by the VAG and VG, and the perceived improvements both peer teaching interventions had on participants' throwing and QMD skills.

Throwing Performance

One primary aim of this study was to determine whether a three-session peer teaching intervention could improve non-dominant hand overarm throwing performance. Results indicated that throwing technique improved for all three groups, however, the VAG and VG participants, working in reciprocal pairs, were the only groups to make significant pre- to post-test throwing improvements. As such, the hypothesis that the VAG would throw with more advanced technique in the post- and retention testing than the VG, who would throw with more advanced technique than the CG, was only partially supported. The VAG and VG retention test scores were also significantly higher than the pre-test scores, this indicates the persistence characteristic of the improved performance (Lee et al., 1994; Magill & Anderson, 2021; Spittle, 2021). The CG who completed unrelated course work that involved no overarm throwing practice, revealed no significant change in pre- to post-test or pre- to retention test throwing performance.

In Study 3, when only one intervention session was completed, the VAG were the only group to achieve significant pre- to post-test throwing improvement, signifying it was advantageous to have video analysis feedback. In the current study, which involved three intervention sessions, both VAG and VG participants achieved significant throwing improvement in post-testing. This indicates that access to video analysis was not essential because both peer teaching interventions achieved similar improvements. Nevertheless, given the finite learning time within PETE programs (Nielsen & Beauchamp, 1992; Reeve, 2000), and the understanding that QMD is an essential skill PE teachers need in order to help improve their students' motor skills (Gangstead & Beveridge, 1984; Hoffman, 1983; Kelly & Melograno, 2004; Overdorf & Coker, 2013; Pinheiro & Simon, 1992; Ward et al., 2020), these findings are an important consideration for university coordinators of Fundamental Movement courses. If video analysis technology is not available, additional practice sessions may be required for significant improvements to occur, thus, more practical classes are required, making it more difficult for a variety of FMS to be taught in these courses. The availability of video analysis technology appears to decrease the time required to learn to perform and analyse fundamental motor skills.

Gender Difference

The results of the current study indicated males had more advanced throwing technique than females at pre, post and retention testing, regardless of their group, as such, the hypothesis that the males would throw with more advanced technique than females was proven correct. These findings are consistent with the findings of Study 3 and a large number of studies that have examined throwing gender differences (e.g., Ehl et al., 2005; Halverson et al., 1982; Lorson & Goodway, 2008; Lorson et al., 2013; Schott & Getchell, 2021; Thomas & French, 1985; Williams et al., 1996b). The two genders were not influenced differently by the respective interventions - male participants did not show greater performance improvements than the females, they simply demonstrated higher throwing performance throughout the study.

Gender Impact on Group and Test

Examining the group by test interactions for each gender separately, consistent with the Study 3 findings, both VAG males and females showed significant pre- to post-test and pre- to retention test throwing improvements when video analysis was available and utilised. When video analysis was not available, however, the results revealed a group by test interaction for gender. The VG males showed no throwing improvement from pre- to post-test or from pre- to retention test. In contrast, VG females demonstrated a significant improvement in pre- to post-test and pre- to retention test throwing, indicating the ability to improve throwing even when video analysis was not available. These results both resembled and contrasted the findings of a swimming study that examined the impact technology-enhanced feedback had on 5th grade students learning the front-crawl (Kretschmann, 2017). Like the current study, Kretschmann's male and female swimmers who received video analysis feedback improved their swimming times over 25 m. When video analysis was not available in the swimming study, there was a gender impact that contrasted the present study's findings; the males demonstrated significant pre- to post-test improvements and the females showed no improvement. Kretschmann suggested the male swimmers might have been more "prone" to verbal feedback, but the results needed to be treated with caution because the number of males and females in the study groups were not equal. In the current study it was the VG females that appeared to be more "prone" to verbal feedback. A possible explanation for VG females outperforming VG males is the proposed advantages females have in the verbal domain (Burman et al., 2008; Hyde & Linn, 1988; Maccoby & Jacklin, 1974; Parsons et al., 2005; Roberts & Bell, 2002). As early as three years of age, females outperform males on verbal tasks (Hyde & Linn, 1988; Roberts & Bell, 2002). Working in reciprocal pairs, these verbal skills may have assisted VG females more than males in that form of teaching. Furthermore, after the intervention sessions, the VG females also demonstrated greater improvement than the VAG females, which may indirectly indicate the VG females benefited most. At pre-testing the VG females recorded lower throwing scores than both the VG males and the VAG females. It was an unexpected result to see the VG females outscore the VAG females at post and retention testing. It was also unexpected to see the VG females outscoring the VG males at retention. The sample size, however, for males and females in the intervention groups were not even, similar to Kretschmann's (2017) swimming study, thus, these results should be treated with caution.

Intervention Perceptions

The questionnaire responses indicated the VAG and VG both believed their respective interventions helped improve non-dominant hand throwing, as such, the hypothesis that the VAG would have higher perceived ability to perform the overarm throw than VG was proven incorrect. The positive attitudes of the VAG and VG groups are similar to the findings of Study 3 in this dissertation and a previous peer teaching study (Ensergueix & Lafont, 2010) who found ninth-graders working in peer teaching pairs had higher post-testing self-efficacy scores than those who practiced individually to improve table tennis skills. Apparently, participants in all three studies collectively believed the peer teaching had improved their performance.

Questionnaire responses indicated no group effect on the participants' perceived ability to analyse the overarm throw. Verbal feedback was as effective as video and verbal feedback combined, as such, the hypothesis that the VAG would have higher perceived ability to analyse the overarm throw than VG was proven incorrect. While these results were consistent with the findings of Study 3, they contrasted previous research that examined the integration of video replay when learning gymnastic skills (Koh & Khairuddin, 2004), and basketball skills (O'Loughlin et al., 2013). The gymnastic and basketball skills studies both identified video feedback to be critical to the QMD process. A possible explanation for the contrasting results may be previous learners' video analysis experience in past research studies (e.g., Koh & Khairuddin; O'Loughlin et al., 2013). There is an 'oohah' (i.e., exclaim in wonder) status that occurs when learners use video analysis for the first time that produces a level of credibility for the intervention (Casey & Jones, 2011). The university students in the present study had all used the Hudl app before, therefore the novelty had likely worn off and this status would be very improbable. The 9 and 10 year old participants in the O'Loughlin et al. (2013) study were experiencing the technology for the first time. From reading their interview statements, the young learners clearly valued this novel learning approach. The Koh and Khairuddin (2004) study was conducted almost 20 years ago at a different technological time period where video analysis technology was new and more likely a novelty to the participants.

Questionnaire results suggested both VAG and VG participants acknowledged video replay was essential in the QMD process. As such, the hypothesis that the VAG and VG would both identify video analysis technology to be critical in the QMD process was proven correct. While only the VAG participants experienced video analysis in the intervention, all participants had completed familiarisation sessions during their fundamental movement course to ensure they were not distracted as a result of viewing video footage of themselves on screen for the first time (Darden & Shimon, 2000; Darden, 1999). The percentage difference of participants agreeing that video replay is essential (VAG = 90.9%, VG = 68.8%) may relate to the limited exposure that the VG had to the technology in the fundamental movement classes. The fewer video analysis sessions may have resulted in the VG not developing as clear a conceptualisation of whether they agreed with this statement. The overall value placed on video analysis in the current study is congruent with the results of Study 3 and previous research that has identified video analysis can help learners identify the strengths and weaknesses of their performances (Weir & Connor, 2009), help learners understand cues (Kretschmann, 2017), and enhance learner's observational and QMD skills (Koh & Khairuddin, 2004). The VG females identified video analysis was essential even though they demonstrated larger throwing improvements than the VAG females at post and retention testing and completed intervention sessions without video analysis feedback.

Enjoyment Level

VAG and VG participants identified their interventions were equally engaging and enjoyable, as such, the hypothesis that the VAG would identify their intervention as more enjoyable than the VG was proven incorrect. These results contrasted the results from Study 3, where VG participants identified their intervention to be more enjoyable and engaging than the VAG. The contrasting responses may be a result of the additional intervention sessions in the current study. The additional 20 minutes may have decreased the time pressures experienced by the VAG as they filmed and analysed the video footage, making these tasks less daunting (Obrusnikova & Rattigan, 2016; Palao et al., 2013), and the interventions more relaxed and enjoyable. The potential discomfort experienced by the VAG in Study 3 when they observed themselves performing a novel skill on video for the first time may have been less confronting in the current study. Viewing footage of themselves for three sessions may have allowed them to become more comfortable watching the replay footage, therefore making the intervention more enjoyable (Darden, 1999; Jambor & Weekes, 1995).

Limitations

When interpreting the findings of the current study, there are potential limitations that should be considered. First, participants were from a PETE program from one university, therefore the results cannot be generalised to all universities and university courses. Second, due to the logistical challenges of the ecological peer teaching sessions, the type and amount of feedback provided during the peer teaching sessions was not experimentally and systematically monitored. Future research could examine this ecological setting in more detail and monitor the type and amount of feedback provided in the reciprocal pairs and the impact these variables have on performance.

Future Research

Future research could examine whether video analysis can improve other FMS and whether there are wider applications in sport and the practice of sport specific skills that coaches, and teachers could utilise to facilitate learner and athlete development. Future research could also examine whether a student working individually with a tripod, mobile phone and video analysis app can achieve the same overarm throwing improvements. The recording and analysis options within apps like Hudl would allow learners to practice their FMS individually outside of scheduled classes, which could mean less sessions are required during the semester, helping alleviate some of the pressures associated with the crowded PETE curriculum. Finally, future research could also examine whether implementing a peer teaching / throwing technique training program prior to the peer teaching sessions would increase participant achievement. A training program that improves pre-service teachers' understanding of how to effectively provide throwing technique feedback, may increase the performance improvements achievable during the reciprocal intervention sessions.

Summary

The findings of the current study have outlined the potential performance improvements when peer teaching is used for a novel skill. Pre-service PE teachers working in a peer teaching setting for three sessions made significant overarm throwing improvements. These durable improvements were made with and without video analysis.

Questionnaire responses revealed access to video analysis had no significant impact on the pre-service PE teachers' perceived ability to perform the overarm throw. Both the VAG and VG suggested the three session interventions helped improve their non-dominant hand throwing. Both groups responded positively that their respective interventions increased their confidence to observe and analyse their partner's overarm throwing. Correspondingly, both groups suggested video replay to be essential in the QMD process. Finally, in contrast to the findings from Study 3, both VAG and VG participants found their respective interventions to be equally enjoyable and engaging.

While improvements can be made without video analysis if at least three sessions are completed, the three sessions required may not be feasible in already crowded PETE program curriculum. Thus, video analysis should be included in the peer teaching sessions to accelerate the skill development, a bonus is the technology allows learners to review their video footage and practice further outside of class.

CHAPTER 7

GENERAL DISCUSSION

An integral focus of Physical Education (PE) is for primary and secondary school students to develop proficiency in Fundamental Motor Skills (FMS), such as overarm throwing (Lander et al., 2017). Fundamental movement courses within Physical Education Teacher Education (PETE) programs are responsible for ensuring graduate PE teachers have the necessary skills to help their students develop these FMS (Baghurst et al., 2015). Within these fundamental movement courses, pre-service teachers learn how to teach and assess FMS, they also learn how to perform these skills so that they can effectively demonstrate the critical components of the skills during the teaching process. Ashford et al. (2006) revealing motor skill acquisition is greatly increased when observation of a skill occurs prior to practicing it, highlighting the need of physical educators to correctly demonstrate proper skill technique (Baghurst et al., 2015). The overall purpose of this dissertation was to examine the process of assessing and developing the FMS of overarm throwing. One of the primary aims of the current dissertation was to provide more rigorous validation for the Haywood et al. (1991) sequence for the backswing component in Roberton's levels (Roberton & Halverson, 1984), and also to validate the follow-through component, which is not currently included in Roberton's levels. The second primary aim of this dissertation was to examine the impact of video analysis feedback in the skill acquisition process (in a peer teach setting).

To select the most appropriate method of assessing throwing technique for the video analysis studies (Studies 3 and 4), in Studies 1 and 2 I attempted to use Roberton's levels (Roberton & Halverson, 1984) assessment system to measure throwing performance. Roberton's assessment system uses a component approach that breaks the throwing action into body components. Based on my teaching experience and the research I have conducted on this topic, it seems Roberton's levels is the most precise and effective system for assessing throwing performance development, however, there is likely scope for Roberton's levels to be improved.

Despite the common use of video analysis technology in the process of developing motor skills, research findings examining the effectiveness of video analysis technology have been inconclusive (e.g., Magill & Anderson, 2021; Phillips et al., 2013; Potdevin et al., 2018; Spittle, 2021; Weir & Connor, 2009). Some researchers have shown that video analysis can assist the skill acquisition process (Oñate et al., 2005; Robles, 2013), whereas other researchers have found video feedback has no impact (Ferracioli et al., 2013; Rothstein & Arnold, 1976; Van Wieringen et al., 1989), and yet video analysis feedback in some situations can impede the learning process (Kernodle et al., 2001). To contribute to video analysis research, this dissertation also sought to examine the impact of video analysis on male and female pre-service PE teachers' overarm throwing performance in a peer teaching setting. It further examined the impact of video analysis on participants' perceptions about their ability to perform and analyse the throw, the importance of this technology for skill acquisition, and how engaging and enjoyable participants felt about their respective interventions.

The current dissertation included four studies. Study 1 and 2 explored Roberton's (Roberton & Halverson, 1984) levels assessment system to determine suitability of the Haywood et al. (1991) backswing sequence for assessing the backswings of university-aged throwers, and the impact the follow-through had on throwing velocity. Study 3 and 4 investigated the impact of video analysis feedback on overarm throwing performance in a peer teaching setting. This general discussion chapter will summarise the general findings of the four interrelated studies and then elaborate on the theoretical and practical implications, limitations, and the potential for future research stemming from the four studies. The two qualitative assessment studies that attempted to refine Roberton's levels will be discussed first, followed by the two video analysis feedback studies.

Study 1 Findings

Study 1 examined whether the Haywood et al. (1991) six-level sequence was suitable for assessing the backswing of university-aged throwers. The results showed the two new backswing movements suggested by Haywood et al. were demonstrated by university-aged throwers and were not confined to older throwers, supporting the hypothesis that the six-level sequence was suitable for assessing university-aged throwing technique. Like the Haywood et al. findings, the backswing technique of nearly half the university-aged throwers were categorised into one of the two new levels.

The velocity results supported the Haywood et al. (1991) findings; those with more advanced backswing actions generally threw at a higher velocity, providing support for the hypothesis that there is a positive relationship between backswing levels and throwing velocity. Also consistent with results from the Haywood et al. study, was that participants with a Level 3 backswing threw faster than those with a Level 4 backswing. While the difference was not significant, there is partial support for the hypothesis that Level 3 throwers would throw faster than Level 4 throwers, which may call into question whether Level 3 and 4 have been incorrectly ordered.

Roberton's (Roberton & Halverson, 1984) levels currently consists of five critical components. The follow-through component, identified as critical to both throwing injury prevention (Dillman et al., 1993; McCaig & Young, 2015; Whiteley, 2007) and overarm throwing performance (Braatz & Gogia, 1987; Hands & McIntyre, 2015; Leme, 1978; McCaig & Young, 2015; NSW Department of Education and Training, 2000; Ulrich, 2000; Werner et al., 2008), is not currently one of those five components. Thus, Study 2 investigated the effect of the follow-through component on throwing velocity to further ascertain whether this component should be added to Roberton's (Roberton & Halverson, 1984) five critical components.

Study 2 Findings

Assessment results showed that, after accounting for the effects of gender, throwing experience, and age, the more advanced the follow-through technique, the faster the velocity. The analyses showed throwers exhibiting Level 2 and 3 follow-throughs threw significantly faster than Level 1 throwers. Further analyses indicated collapsing the follow-through levels into two levels added extra predictive power of throwing velocity over and above the composite score of the five existing components. Thus, the first hypothesis that there would be a significant difference among follow-through developmental levels and throwing velocity was partially supported.

Researchers have argued that the follow-through cannot impact velocity because the ball has left the hand (Dillman et al., 1993) and the follow-through is a by-product of the preceding throwing components. The results of Study 2 questions this contention, indicating the follow-through still affected throwing velocity even after adjusting for the effects of the other five critical components and had the second largest impact on throwing velocity of all six components.

Theoretical Implications for Qualitative Assessment of Movement

There are several theoretical implications stemming from these two qualitative analysis studies (Study 1 and 2). First, the results revealed that the Haywood et al. (1991) six-level sequence should not be confined to assessing older throwers. Considering the two new backswing movements were frequently demonstrated by male and female university-aged throwers, and higher velocities were achieved with more advanced backswing technique, it appears the six-level sequence is suitable for assessing throwing technique of university-aged throwers. The two additional backswing levels of humeral lateral rotation (Level 3) and shortcut downward backswing (Level 5) have improved Langendorfer's (1980) initial backswing sequence, which may make backswing assessment more accurate and comprehensive. The findings of Study 1 provide preliminary support that backswing development should be assessed with the Haywood et al. backswing sequence, regardless of the thrower's age.

Second, Study 1 results raised a question about whether the six levels have been ordered correctly. The Level 3 backswing, which is closer to the desired circular, downward Level 6 backswing than all three versions of the Level 4 backswings, allows forearm pronation (Langendorfer et al., 2012) and increased trunk rotation away from the target, enhancing the backswing length. This increased trunk rotation and longer backswing provides a greater range of movement allowing more time and space to accelerate forward (Langendorfer et al., 2012). The increased acceleration is likely to result in more advanced humerus and forearm movements (Langendorfer & Roberton, 2002). Thus, results showing Level 3 throwers threw faster than Level 4 throwers indicate the need for further research to determine whether Level 4 should come before Level 3.

Third, from an assessment perspective, the Study 2 findings provide preliminary support for the addition of the follow-through component to Roberton's (Roberton & Halverson, 1984) five existing components. One strength of adding the follow-through to the existing five components is the simplicity of its assessment. Standing side on to the thrower, the assessor simply decides on whether the throwing hand disappears. This simplicity will make throwing performance assessment simple, reliable, and practical, a positive for motor developmentalists assessing throwing research footage, and learners assessing their partners when working in reciprocal pairs (Mosher & Schutz, 1983).

The findings of Study 1 and 2 contribute to and strengthen the existing Roberton's (Roberton & Halverson, 1984) levels research. Based on a more rigorous analysis of Roberton's levels assessment system, in Study 3 and 4, I then used Roberton's levels to assess the throwing technique of participants in a peer teaching setting. One notable gap in video analysis and peer teaching research is the limited studies conducted in ecologically valid PE settings. To my knowledge, researchers have not yet examined the effect of peer teaching instructional approaches on improving overarm throwing performance compared to a control group. Study 3 and 4 in this dissertation aimed to fill this gap by conducting two studies involving realistic teacher to student ratios in authentic class settings, conducted over appropriate time frames.

Study 3 and 4 Findings

The results of Studies 3 and 4 revealed the impact of video analysis in a peer teaching setting may be dependent on the number of intervention sessions conducted. In Study 3, a comparison between video analysis, verbal instruction, and a control group in a single peer teaching session on the pre-test, post-test, and retention test throwing technique were investigated. The post-test scores revealed non-dominant hand throwing technique improved compared to the pre-test scores for the Video Analysis Group (VAG), Verbal Group (VG), and Control Group (CG), however, video analysis during the single 20-minute intervention allowed the VAG to significantly improve their short-term throwing technique. The VG and CG did not show the same level of improvement. Access to video analysis technology potentially enhanced the augmented feedback being provided to the throwers (Potdevin et al., 2018), conveying immediate movement solutions (Horn et al., 2007), and ultimately speeding up the acquisition of the novel skill. The retention test results indicated the pre- to post-test improvements achieved by the VAG were persistent at retention. The VG and CG participants did not achieve the same pre-to post-test improvements, yet all three groups were similar in their throwing technique at retention.

Study 4, an extension from Study 3 because it included three intervention sessions, was conducted to examine if there may be a dose-response relationship (Robinson et al., 2017) for instructional groups. The post-test results revealed throwing technique improved for all three groups, however, the VAG and VG who experienced the peer teach interventions, were the only groups to make significant throwing improvements after the three intervention sessions. The VAG and VG improvements were shown to be persistent when the retention test scores were significantly higher than the pre-test scores. The results identified that access to video analysis was not essential over the course of the three sessions because both peer teaching interventions achieved similar throwing improvement. In comparison to the CG, when it was possible for three separate sessions to be conducted, both peer teaching instructional approaches were effective in improving overarm throwing technique.

When the pre- to retention test improvements of Study 3 and 4 are compared, the benefits of the additional sessions can be identified. The throwing score improvements in Study 4 (VAG, VG, and CG mean differences were 4.904, 5.032, 2.374, respectively) were larger than the improvements in Study 3 (VAG, VG, and CG mean differences were 4.147, 2.492, and 1.814, respectively). The larger improvements at retention highlight the benefit in extending the practice time. It could be argued that the additional 20-minutes of practice resulted in "overlearning" where the participants' improvements were reinforced (Driskell et al., 1992).

Study 3 and 4 Critical Discussion

Study 3 and 4 are unique because they are the first studies to examine the effect of verbal and video analysis peer teaching instructional approaches on improving overarm throwing performance in an ecologically valid learning setting. Previous research has separately examined video analysis interventions or peer teaching interventions, but to the best of my knowledge, no studies have examined both in conjunction. As these studies are unique, it is difficult to make direct comparisons between the findings of these studies and previous research. It is possible, however, to compare the findings of Study 3, which involved a single intervention session, and Study 4, which involved three intervention sessions.

The post-test throwing technique results from Study 3 showed the single 20-minute intervention revealed all three groups (VAG, VG, and CG) had improved on their pre-test throwing. While there was no significant group difference in the post-test scores of the three groups, the VAG group achieved significant pre- to post-test improvement. The video analysis may have enhanced observers' and throwers' observational powers and qualitative analysis abilities (Koh & Khairuddin, 2004), enhancing the feedback provided to the thrower, facilitating adaptations during practice (Potdevin et al., 2018), allowing accelerated technique improvement. Like Study 3, the post-test results from Study 4 showed that all three groups achieved throwing technique improvement after the three intervention sessions, however, the VAG and VG who experienced the peer teaching interventions, were the only groups to make significant improvement. The CG, who did not experience the peer teaching intervention, showed no significant improvement.

The retention test scores from Study 3 revealed all three groups had achieved pre- to retention test improvement, however, there was no group difference in the retention test scores. The Study 4 retention test results identified significantly higher scores for the VAG and VG than the pre-test scores. The CG, conversely, showed no improvement from their pre-test scores. These results revealed that, if there was only one 20-minute intervention session, the only group to demonstrate significant pre- to post-test improvement were the VAG. However, when there was 40 minutes of practice completed over three sessions, unlike the CG, both peer instructional approaches allowed learners to achieve significant throwing technique improvement. The theoretical and practical implications of these findings will be discussed later.

Study 3 and 4 Intervention Perceptions

At the completion of the post-testing in Study 3 and 4, VAG and VG participants completed a short questionnaire to examine the impact their interventions had on perceived throwing ability, perceived QMD skills, perceptions about the importance of video analysis technology in the QMD process, and the impact video analysis had on participants' enjoyment level when learning to throw with their non-dominant hand. The questionnaire responses from Study 3 and 4 revealed VAG and VG participants both believed their throwing technique had been improved by their respective interventions. The positive perceptions about their peer interventions indicated the verbal feedback experienced by the VG was equally effective as the video analysis and verbal feedback experienced by the VAG (irrespective of the intervention length). These findings are congruent with those of Ensergueix and Lafont (2010) who reported that participants who experienced peer tutoring during their intervention had higher self-efficacy about table tennis skills compared to participants who practiced individually. Learners who believe in the learning process they are involved in is important, considering high self-efficacy has been associated with successful performance (Moritz et al., 2000; Pascua et al., 2015). According to Pascua et al., a learner's self-efficacy may act as a self-fulfilling prophecy, confidence to perform well enables them to perform well.

Questionnaire responses from Study 3 and 4 indicated that verbal feedback was just as effective as video analysis and verbal feedback combined when learning to observe and then provide corrective feedback on their partner's throwing performances (again irrespective of the intervention length). The positive responses from the VG would suggest video analysis technology was not necessary in the peer teaching sessions. Study 3 and 4 responses contrast suggestions that video analysis is critical when learning gymnastic skills (Koh & Khairuddin, 2004), and basketball skills (O'Loughlin et al., 2013). According to O'Loughlin et al., performance assessment is easier when video footage can be viewed. Koh and Khairuddin also believed video analysis to be important in the assessment process, suggesting it improved learners' observational powers. Three factors that may explain the contrasting results are the number of skills, types of skills being learned, and length of the intervention. The three gymnastic skills (i.e., handspring, headspring, and vault skills) assessed in the Koh and Khairuddin study and the six basketball skills (i.e., free throw, chest pass, dribble, bounce pass, jump shot, and lay up) assessed in the O'Loughlin et al. study are arguably more novel and complex than the overarm throw being learned in the current dissertation. The complexity and number of skills the participants were learning may have resulted in the learners becoming more reliant on the video analysis when trying to provide corrective feedback to their partners. The length of the interventions may also explain the differing results, with the 9-session gymnastics, and 10-session basketball interventions, considerably longer than the single session and three session throwing interventions in Study 3 and 4 of this dissertation, respectively. The extra sessions may have resulted in participants implementing video analysis more effectively with less time pressures, and as a result, participants may have assigned greater value to video analysis when helping their partners improve the gymnastics and basketball skills.

When questioned about how enjoyable and engaging participants found their respective interventions, responses revealed when there was only one 20-minute practice session (Study 3), the VG found their peer teach intervention more enjoyable than VAG participants. However, when there were three practice sessions (Study 4), the VG and VAG found the practice sessions equally enjoyable and engaging. A possible interpretation of the contrasting responses between Study 3 and Study 4 is that video analysis feedback can be time consuming and can decrease the number of skill performances learners get to attempt, which may decrease their enjoyment of the session (Guadagnoli et al., 2002; Palao et al., 2013; Weir & Connor, 2009). For example, Guadagnoli et al. conducted a study that included four 90-minute practice sessions that compared verbal feedback with video analysis feedback for experienced golfers trying to improve their ability to hit a 7-iron and found that the provision of video analysis feedback increased instruction time and decreased practice time. Notably, the decreased practice time and decreased number of practice shots did not impede the video analysis group's performance, and in the 2-week retention test, the video analysis group outperformed the verbal group. In Study 3 in the current dissertation, although speculative, the VAG may have noticed the increased instruction and decreased practice time during the single 20-minute session and the decreased number of throws performed may have produced feelings of being 'rushed'. Yet, in Study 4, the additional 20 minutes (2 x 10-min sessions) may have decreased the time pressures experienced by the VAG during their sessions, which may have allowed them to film, analyse, and provide feedback to their partner, in a more relaxed and enjoyable setting.

Gender (All Studies Combined)

Collective throwing results of all four studies in this dissertation identified a significant gender effect, with males consistently outperforming females. These results corroborate much of the empirical throwing research (Beseler et al., 2021; Halverson et al., 1982; Lorson & Goodway, 2008; Lorson et al., 2013; Petranek & Barton, 2011; Williams et al., 1993, 1996a). In Study 1 and 2, significant gender differences were revealed, with males generally categorised at higher developmental levels than females. Throwing velocities also revealed males threw with significantly higher velocities than females. The follow-through and backswing development levels had the same impact on thrown ball velocity for males and females. The findings of Study 3 and 4 also revealed significant gender differences, with the males demonstrating more advanced throwing technique at pre, post, and retention testing, irrespective of their group. The Study 4 results support previous suggestions that male throwing performance is superior to females because males practice more than females (Johnson et al., 2019; Roberton & Konczak, 2001). The demographics information from Study 4 revealed a positive relationship between involvement in organised throwing sports and throwing performance. Those with more years' experience in throwing sports were able to throw with higher velocity.

Theoretical Implications for Peer Teaching

The findings from Study 3 and 4 have several theoretical implications. First, immediate performance improvements can be achieved in 20 minutes of practice if learners have access to video analysis technology in a peer teaching setting. Access to video analysis technology appears to decrease the time required to learn to perform the overarm throw. Combining video analysis and the peer teaching pedagogical approach can not only help accelerate pre-service teacher FMS development, but it can also increase pre-service teachers' confidence to implement this technology in their teaching when they graduate. The practical hands-on experience using this technology will increase the likelihood these graduate PE teachers will have better pedagogical-technology competence (Potdevin et al., 2018) to implement into classes. Second, in contrast to the single session intervention, overarm throwing technique can be significantly improved when university-aged throwers work in reciprocal pairs for three sessions totalling 40 minutes, regardless of whether video analysis technology is available. The additional 20 minutes of practice (2 x 10-minute sessions) in Study 4 may have allowed the VG pairs to overcome the absence of video analysis and achieve similar improvement to the VAG pairs, who in Study 3 were the only group to show significant pre- to post-test throwing improvement. Study 4 results showed the VAG and VG both achieved better throwing technique than the CG in post and retention testing, demonstrating both VAG and VG peer teaching instructional approaches were more effective than the CG intervention which involved no peer teaching.

Persistence is one of the performance characteristics used to assess motor learning (Magill & Anderson, 2021; Spittle, 2021). If a learner acquires a skill, they will be able to perform it in the future, in accordance with this characteristic. Study 3 and 4 results revealed multiple peer instructional sessions are required for the significant verbal and video analysis improvements to become persistent.

Practical Implications

There are several practical implications emerging from Study 1 and 2 of this dissertation. From a motor learning and teaching perspective, students and athletes learning to throw should be encouraged to follow-through effectively after ball release to increase throw velocity and improve technique. This focus will encourage hip to shoulder rotation, leading to increased rotational velocity of the torso, ultimately inducing a lag effect on the humerus and forearm (Langendorfer et al., 2012; Stodden et al., 2006b). Focussing on the follow-through will also decrease the likelihood of throwers experiencing shoulder injuries (McCaig & Young, 2015; Whiteley, 2007). The results revealed no gender differences in the relative contribution of the six components to the velocity of the throw, as such the feedback emphasising follow-through technique should be the same regardless of gender. From an assessment perspective, the addition of the follow-through to Roberton's (Roberton & Halverson, 1984) existing five components could improve the accuracy of throwing development assessment. The additional component adds predictive power of throwing velocity over the other five components and makes Roberton's assessment system more precise, which may allow researchers and PE teachers to identify throwing development more accurately, and coaches to identify talented throwers more effectively.

There are numerous practical implications emerging from Study 3 and 4 of this dissertation. Immediate improvement can lead to motivational benefits for the learner, which may enhance learner's perceived success and continued practice (Knudson, 2013). According to Wulf and Lewthwaite (2016), motivation and confidence are important contributing factors for learning and performance. Based on the immediate improvement achieved by the VAG in Study 3, video analysis should be included in the peer teach instructional approach if only one session is possible. However, considering the motor learning characteristic of persistence, the results of Study 4 indicated that the overarm throw requires multiple sessions of video analysis or verbal peer teach instruction for significant, durable improvements to occur. Although it is challenging, considering the small number of practical classes within fundamental movement courses, it is recommended that Physical Education Teacher Education (PETE) programs incorporate multiple video analysis peer teaching sessions (for each skill) into fundamental movement courses to help pre-service PE teachers develop motor competence. This competence will allow pre-service PE teachers to demonstrate FMS to their students (Gabbei, 2011; Pulling & Allen, 2014), assisting them to develop their motor competence. While video analysis did not result in the VAG improving more than the VG in the three sessions in Study 4, speculatively, the video analysis may have improved the essential QMD skills of these pre-service teachers, which may be beneficial in the future. Considering the questionnaire response indicated VAG and VG participants identified video analysis as essential in the QMD process, video technology should be included, even if it is for a 'placebo' effect to ensure the learners have confidence in the learning process.

PE teacher educators incorporating video analysis into single session peer teaching settings need to understand the time pressures that may occur when this technology is used, which may affect enjoyment. The VAG participants in the single session intervention (Study 3) may have associated the number of throws they performed with chances to improve (hence reducing enjoyment perceptions). Spending more time watching footage and receiving feedback would have decreased the number of throws they performed in their session. As a result, they may feel they were missing out on chances to improve, possibly a factor that contributed to them not enjoying their respective intervention. When implementing video analysis into a single peer teaching session, it is important to explain to learners, even though video feedback will increase instruction time and decrease practice time, the quality of the instructional feedback they are receiving will likely make up for the decreased quantity of practice attempts (Guadagnoli et al., 2002). In contrast to Study 3, the questionnaire results from Study 4 indicated the VAG and VG both enjoyed their interventions equally when there were three separate peer teach sessions. The additional sessions, arguably allowed the VAG participants to enjoy their sessions as much as the VG because they were able to practice their throwing with high repetitions, meaning they did not experience the time pressures experienced by the VAG in the single 20-minute session (Study 3).

To bridge the throwing performance gap between males and females, parents and PE teachers should encourage girls to participate in sports and activities that involve overarm throwing from an early age. Early participation and the increased experience they get from these throwing activities can lead to improved throwing performance, potentially increasing the enjoyment in these activities. This enjoyment will increase the likelihood they stay involved in these activities as they get older (Bott & Mitchell, 2015).

Limitations

Although I attempted to use methodologically rigorous designs, there may have been some limitations in a combination of the studies that could have affected the results. Study 1 and 2 participants were randomly invited to partake, and those with lower levels of overarm throwing development may have been less inclined to participate. As such, the participants must be identified as a self-selected sample and results cannot be generalised to all university-aged throwers. The Study 1 and 2 participants were also from one regional university; therefore, the results cannot be generalised to all universities.

Due to the logistics associated with completing the data collection within scheduled classes, Study 3 and 4 questionnaires were completed after the post-test. This is a potential limitation; in completing a questionnaire *after* the intervention on how confident they were executing a non-dominant hand throw *prior to* the intervention, participants may have been relying on memory recall, allowing a possible intervention bias. Another possible limitation of Study 3 and 4 was that the questionnaire was developed based on a literature review of similar questionnaires, but it was not yet validated. Future use of these questionnaire statements requires further validation with other studies.

The ecological peer teaching sessions in Study 3 and 4 also provided logistical challenges. As such, the type and amount of feedback provided during the peer teaching sessions was not experimentally and systematically monitored, which may have affected the results of the studies. Future research could monitor the type and amount of feedback provided in the reciprocal pairs and the impact these variables have on throwing performance.

Future Research

The results from studies in this dissertation, which have extended current literature on the process of assessing and developing the overarm throw, have revealed the need for future research in this field. Taking into consideration the findings from Study 1, more research is warranted to further validate the six-level backswing sequence for assessing throwers of all ages. This future research requires examination of primary and secondary school aged participants to determine whether the six-level sequence is suitable for assessing backswing actions of throwers throughout the lifespan. If this sequence is found to be suitable for assessing primary and secondary school aged throwers, it would simplify backswing assessment, allowing throwers of all ages to be assessed with one sequence. Future research should also investigate whether the Level 3 and Level 4 categories need re-ordering. Those categorised with a Level 3 humeral lateral rotation backswing achieved higher throwing velocity than those categorised with a Level 4 backswing. While the difference was not significant, these repeated results (Haywood et al., 1991) justify a discussion as to whether Levels 3 and 4 have been incorrectly ordered.

The findings of Study 2 have provided preliminary support for the addition of the follow-through component to Roberton's (Roberton & Halverson, 1984) five existing components. However, a study involving a larger sample of randomly selected participants, representative of all age groups should investigate whether the proposed follow-through levels are appropriate for assessing primary and secondary aged throwers and older adult throwers. If suitable, the inclusion of the follow-through component could improve the accuracy of throwing development assessment and it could assist teachers and coaches to facilitate learner and athlete development.

Acquiring skills efficiently is important in most motor learning settings; primary and secondary school PE classrooms are no exception. Crowded curriculums often place pressure on PE and generalist teachers to help their students develop FMS efficiently. For generalist (i.e., who are not specialist PE) primary teachers responsible for delivering PE in primary schools (Callea et al., 2008), future research should examine whether the peer teaching approaches used in Study 3 and 4 can be used in PE courses with pre-service primary generalist teachers to equip them to better teach FMS. Future research could also examine whether the improvements made through peer teaching can also be achieved by primary and secondary school aged learners. If the same skill acquisition is possible for primary and secondary students, PE teachers can assist their students to develop FMS that will allow them to participate in physical activities with competence and confidence throughout their lives. These future studies could also investigate whether the two peer teaching interventions impact students' enjoyment and motivation levels.

The "faster" throwing acquisition achieved by the VAG in Study 3 would allow pre-service PE teachers to develop their FMS more efficiently. If video analysis can assist primary and secondary students to develop their FMS more efficiently, less face-to-face class time would be required. Long-term performance changes are the benchmark for skill acquisition (Horn et al., 2007), as such the durability of this learning must also be considered. Future research could explore longer term retention testing to ensure the persistence of the performance improvements. Learners transferring the performance improvements into game situations also needs to be considered. Future research could determine whether the "faster" acquisition allows learners to be better prepared for the constraint changes associated with constraints-based learning (e.g., minor games and games-sense activities; Horn et al., 2007).

Future research could explore whether the two peer teaching interventions can improve other FMS. This research could examine whether there are wider applications in sport and the practice of sport specific skills that coaches, and teachers could implement with their learners and athletes. Speculatively, acquisition of more complex, novel skills could be improved if video analysis technology is available. Video analysis could assist athletes and learners identify strengths and weaknesses of their performances (Weir & Connor, 2009), and help them plan a strategy for improvement (Robles, 2013). Future research could also examine whether the benefits of video analysis used in reciprocal pairs can benefit a student working individually with a tripod, mobile phone and video analysis app. Using recording and analysis options within apps, like Hudl, allows learners to practice their FMS individually. If individual practice can achieve the same progress, PETE programs could facilitate the development of more motor skills outside of scheduled classes. This would mean fewer practical classes are required during the semester, helping alleviate some crowded PETE curriculum time pressures. Future research could also examine the impact of a peer teaching / throwing training program prior to the reciprocal sessions. If pre-service teachers' understanding of providing throwing component feedback to a peer can be increased through a peer teaching program, potential performance improvements in a reciprocal intervention may also increase.

Final Comments

This dissertation sought to determine whether the Haywood et al. (1991) backswing sequence is suitable for qualitatively assessing the backswing of university-aged throwers. With male and female university-aged students frequently demonstrating one of the two new backswing levels, and more advanced backswing movements achieving higher velocities, it seems that the six-level sequence is suitable for assessing the backswing of university-aged throwers. This dissertation also sought to authenticate the inclusion of the follow-through component to Roberton's (Roberton & Halverson, 1984) existing five components. The results revealed the two follow-through levels were shown to add extra predictive power of throwing velocity over the five existing components. When combined to Roberton's existing components, of the six components, the follow-through had the second largest impact on throwing velocity. These findings provide preliminary support for the addition of the follow-through component to Roberton's (Roberton & Halverson, 1984) five existing components. This addition could make this qualitative assessment system more accurate and more comprehensive, which could assist teachers and coaches to facilitate student and athlete development. Emphasising effective follow-through technique could also help reduce the prevalence of throwing injuries in sports like baseball.

These findings were then used to examine the impact of video analysis on male and female pre-service PE teachers' overarm throwing performance in a peer teaching setting. The results indicated significant throwing improvements can be made without video analysis if at least three sessions are completed. If crowded PETE program curriculum dictate that three sessions are not feasible, single session peer teaching sessions that include video analysis feedback should be conducted to accelerate the skill development.

The overall purpose of this dissertation was to examine the process of assessing and developing the FMS of overarm throwing. I hope future researchers will benefit from this research and be encouraged to expand further on Roberton's (Roberton & Halverson, 1984) levels and video analysis research. This dissertation and future research could make overarm throwing assessment more accurate and more comprehensive. It could also lead to pre-service PE teachers achieving greater overarm throwing performance improvements, ultimately equipping them with the necessary skills to teach this FMS more effectively to their future students.

References

Aguinaldo, A. L., Buttermore, J., & Chambers, H. (2007). Effects of upper trunk rotation on shoulder joint torque among baseball pitchers of various levels. *Journal of Applied Biomechanics*, *23*(1), 42-51.

Angell, R. M., Butterfield, S. A., Tu, S., Loovis, E. M., Mason, C. A., & Nightingale, C. J. (2018). Children's throwing and striking: a longitudinal study. *Journal of Motor Learning and Development*, *6*(2), 315-332.

Ashford, D., Bennett, S. J., & Davids, K. (2006). Observational modeling effects for movement dynamics and movement outcome measures across differing task constraints: A meta-analysis. *Journal of Motor Behavior*, *38*(3), 185-205.

Ashy, M. H., Lee, A. M., & Landin, D. K. (1988). Relationship of practice using correct technique to achievement in a motor skill. *Journal of Teaching in Physical Education*, *7*(2), 115-120.

Australian Institute of Health and Welfare. (2019). *Insufficient physical activity*. https://www.aihw.gov.au/reports/risk-factors/insufficient-physical-activity

Ayvazo, S., & Ward, P. (2009). Effects of classwide peer tutoring on the performance of sixth grade students during a volleyball unit. *Physical Educator*, *66*(1), 12-22.

Baghurst, T., Richard, K., Mwavita, M., & Ramos, N. (2015). Procedures and reasoning for skill proficiency testing in physical education teacher education programs. *Cogent Education*, *2*(1), https://doi.org/10.1080/2331186X.2015.1111716.

Barnett, L. M., Hardy, L. L., Lubans, D. R., Cliff, D. P., Okely, A. D., Hills, A. P., & Morgan, P. J. (2013). Australian children lack the basic movement skills to be active and healthy. *Health Promotion Journal of Australia*, *24*(2), 82-84.

Barnett, L. M., Van Beurden, E., Morgan, P. J., Brooks, L. O., & Beard, J. R. (2009). Childhood motor skill proficiency as a predictor of adolescent physical activity. *Journal of Adolescent Health*, *44*(3), 252-259.

Barrett, D. D., & Burton, A. W. (2002). Throwing patterns used by collegiate baseball players in actual games. *Research Quarterly for Exercise and Sport*, *73*(1), 19-27.

Bayless, M. A. (1981). Effect of exposure to prototypic skill and experience in identification of performance error. *Perceptual and Motor Skills*, *52*(2), 667-670.

Bertram, C. P., Marteniuk, R. G., & Guadagnoli, M. A. (2007). On the use and misuse of video analysis. *International Journal of Sports Science and Coaching*, *2*(0), 37-46. https://doi.org/10.1260/174795407789705406

Beseler, B., Mesagno, C., Young, W., & Harvey, J. (2016). Igniting the pressure acclimatization training debate: Contradictory pilot-study evidence from Australian football. *Journal of Sport Behavior*, *39*(1).

Beseler, B., & Plumb, M. S. (2019). 10 Tips to Using Video Analysis More Effectively in Physical Education: Editor: Brian Mosier. *Journal of Physical Education, Recreation & Dance*, *90*(1), 52-56.

Beseler, B., Williams, K., & Plumb, M. S. (2021). Validation of a backswing developmental sequence for the Overarm Throw for Force. *Journal of Motor Learning and Development*, *9*(3), 383-399. https://doi.org/10.1123/jmld.2020-0064

Bilodeau, E. A., & Bilodeau, I. M. (1969). *Principles of skill acquisition*. Academic Press.

Bott, T. S., & Mitchell, M. (2015). Battling obesity with quality elementary physical education: From exposure to competence. *Journal of Physical Education, Recreation & Dance*, *86*(6), 24-28.

Boyce, B. A., Markos, N. J., Jenkins, D. W., & Loftus, J. R. (1996). How should feedback be delivered? *Journal of Physical Education, Recreation & Dance*, *67*(1), 18-22.

Braatz, J. H., & Gogia, P. P. (1987). The mechanics of pitching. *Journal of Orthopaedic & Sports Physical Therapy*, *9*(2), 56-69.

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. *American Psychologist*, *32*(7), 513.

Burman, D. D., Bitan, T., & Booth, J. R. (2008). Sex differences in neural processing of language among children. *Neuropsychologia*, *46*(5), 1349-1362.

Butterfield, S. A., Angell, R. M., & Mason, C. A. (2012). Age and sex differences in object control skills by children ages 5 to 14. *Perceptual and Motor Skills*, *114*(1), 261-274.

Byra, M., & Marks, M. C. (1993). The effect of two pairing techniques on specific feedback and comfort levels of learners in the reciprocal style of teaching. *Journal of Teaching in Physical Education*, *12*(3), 286-300.

Callea, M. B., Spittle, M., O'Meara, J., & Casey, M. (2008). Primary school teacher perceived self-efficacy to teach fundamental motor skills. *Research in Education*, *79*(1), 67-75.

Casey, A., Goodyear, V. A., & Armour, K. M. (2017). Rethinking the relationship between pedagogy, technology and learning in health and physical education. *Sport, Education and Society*, *22*(2), 288-304.

Casey, A., & Jones, B. (2011). Using digital technology to enhance student engagement in physical education. *Asia-Pacific Journal of Health, Sport and Physical Education*, *2*(2), 51-66.

Cattuzzo, M. T., dos Santos Henrique, R., Ré, A. H. N., de Oliveira, I. S., Melo, B. M., de Sousa Moura, M., de Araújo, R. C., & Stodden, D. (2016). Motor competence and health related physical fitness in youth: A systematic review. *Journal of Science and Medicine in Sport*, *19*(2), 123-129.

Cervantes, C. M., Lieberman, L. J., Magnesio, B., & Wood, J. (2013). Peer tutoring: Meeting the demands of inclusion in physical education today. *Journal of Physical Education, Recreation & Dance*, *84*(3), 43-48.

Chiviacowsky, S., & Wulf, G. (2007). Feedback after good trials enhances learning. *Research Quarterly for Exercise and Sport*, *78*(2), 40-47. http://www.tandfonline.com/doi/pdf/10.1080/02701367.2007.10599402

Chu, Y., Fleisig, G. S., Simpson, K. J., & Andrews, J. R. (2009). Biomechanical comparison between elite female and male baseball pitchers. *Journal of Applied Biomechanics*, 25(1), 22-31.

Ciapponi, T. (1999). Skill analysis. *Strategies*, *12*(5), 13-16. http://dx.doi.org/10.1080/08924562.1999.10591408

Cliff, D. P., Okely, A. D., Smith, L. M., & McKeen, K. (2009). Relationships between fundamental movement skills and objectively measured physical activity in preschool children. *Pediatric Exercise Science*, *21*(4), 436-449.

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Academic press.

Cohen, P. A., Kulik, J. A., & Kulik, C.-L. C. (1982). Educational outcomes of tutoring: A meta-analysis of findings. *American Educational Research Journal*, *19*(2), 237-248.

Coker, C. A. (1998). Observation strategies for skill analysis. *Strategies*, *11*(4), 17-19.

Crossman, E. R. (1959). A theory of the acquisition of speed-skill∗. *Ergonomics*, *2*(2), 153-166.

D'Arripe-Longueville, F., Gernigon, C., Huet, M., Cadopi, M., & Winnykamen, F. (2002). Peer tutoring in a physical education setting: Influence of tutor skill level on novice learners' motivation and performance. *Journal of Teaching in Physical Education*, *22*(1), 105-123.

Darden, G. F., & Shimon, J. (2000). Revisit an " Old" technology videotape feedback for Motor skill learning end performance. *Strategies*, *13*(4), 17-21. https://doi.org/10.1080/08924562.2000.11000324

Darden, G. F. (1999). Videotape feedback for student learning and performance: A learning-stages approach. *Journal of Physical Education, Recreation & Dance*, *70*(9), 40-45.

Department of Education Victoria. (1996). *Fundamental motor skills : A manual for classroom teachers*. Department of Education Victoria.

Dillman, C. J., Fleisig, G. S., & Andrews, J. R. (1993). Biomechanics of pitching with emphasis upon shoulder kinematics. *Journal of Orthopaedic & Sports Physical Therapy*, *18*(2), 402-408. http://www.jospt.org/doi/pdfplus/10.2519/jospt.1993.18.2.402

Dobre, A., & Gheorghe, C. (2021). The optimization of the running technique using video analysis method. Journal of Physics: Conference Series.

Driskell, J. E., Willis, R. P., & Cooper, C. (1992). Effect of overlearning on retention. *Journal of Applied Psychology*. *77*(5), 615-622

Dyson, B. (2001). Cooperative learning in an elementary physical education program. *Journal of Teaching in Physical Education*, *20*(3), 264-281.

Ehl, T., Roberton, M. A., & Langendorfer, S. J. (2005). Does the throwing "gender gap" occur in Germany? *Research Quarterly for Exercise and Sport*, *76*(4), 488-493.

El-Hussein, M. O. M., & Cronje, J. C. (2010). Defining mobile learning in the higher education landscape. *Journal of Educational Technology & Society*, *13*(3), 12-21.

Ensergueix, P. J., & Lafont, L. (2010). Reciprocal peer tutoring in a physical education setting: influence of peer tutor training and gender on motor performance and self-efficacy outcomes. *European Journal of Psychology of Education, 25*(2), 222-242.

Ernst, M., & Byra, M. (1998). Pairing learners in the reciprocal style of teaching: Influence on student skill, knowledge, and socialization. *Physical Educator*, *55*(1), 24. http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=652512&site=ehost-live&scope=site

Escamilla, R. F., Fleisig, G. S., Yamashiro, K., Mikla, T., Dunning, R., Paulos, L., & Andrews, J. R. (2010). Effects of a 4-week youth baseball conditioning program on throwing velocity. *Journal of Strength & Conditioning Research, 24*(12), 3247-3254.

Escamilla, R. F., Slowik, J. S., Diffendaffer, A. Z., & Fleisig, G. S. (2018). Differences among overhand, 3-quarter, and sidearm pitching biomechanics in professional baseball players. *Journal of Applied Biomechanics, 34*(5), 377-385.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175-191.

Fleisig, G. S., Bolt, B., Fortenbaugh, D., Wilk, K. E., & Andrews, J. R. (2011). Biomechanical comparison of baseball pitching and long-toss: implications for training and rehabilitation. *Journal of Orthopaedic & Sports Physical Therapy*, *41*(5), 296-303.

Fleisig, G. S., Diffendaffer, A. Z., Ivey, B., & Oi, T. (2018). Do mound height and pitching distance affect youth baseball pitching biomechanics? *The American Journal of Sports Medicine*, *46*(12), 2996-3001.

Ferracioli, I. J. d. C., Ferracioli, M. d. C., & Castro, I. J. d. (2013). Breaststroke learning through the use of videotape feedback. *Brazilian Journal of Kinanthropometry and Human Performance*, *15*(2), 204-214.

Fortenbaugh, D., Fleisig, G. S., & Andrews, J. R. (2009). Baseball pitching biomechanics in relation to injury risk and performance. *Sports Health*, *1*(4), 314-320.

Fradkin, J. A., Zazryn, R. T., & Smoliga, M. J. (2010). Effects of warming-up on physical performance: A systematic review with meta-analysis. *Journal of Strength and Conditioning Research*, *24*(1), 140-148. https://doi.org/10.1519/JSC.0b013e3181c643a0

Gabbei, R. C. (2011). To be skilled or not to be skilled-That is the question. *Journal of Physical Education, Recreation & Dance, 82*(4), 7-56. https://doi.org/10.1080/07303084.2011.10598604

Gangstead, S. K., & Beveridge, S. K. (1984). The implementation and evaluation of a methodological approach to qualitative sport skill analysis instruction. *Journal of Teaching in Physical Education*, *3*(2), 60-70.

Giannousi, M., Mountaki, F., & Kioumourtzoglou, E. (2017). The effects of verbal and visual feedback on performance and learning freestyle swimming in novice swimmers. *Kinesiology*, *49*(1), 0-0.

Grace-Martin, K. (n.d.). *Interpreting interactions: When the F test and the simple effects disagree.* The Analysis Factor. Retrieved January 21, 2021, from https://www.theanalysisfactor.com/interpreting-interactions-when-the-f-test-and-the-simple-effects-disagree/

Gromeier, M., Koester, D., & Schack, T. (2017). Gender differences in motor skills of the overarm throw. *Frontiers in Psychology*, *8*, 212.

Gu, X., Zhang, T., Lun Chu, T., Zhang, X., & Thomas Thomas, K. (2019). Do physically literate adolescents have better academic performance? *Perceptual and Motor Skills*, *126*(4), 585-602.

Guadagnoli, M., Holcomb, W., & Davis, M. (2002). The efficacy of video feedback for learning the golf swing. *Journal of Sports Sciences*, *20*(8), 615-622. https://doi.org/10.1080/026404102320183176

Halverson, L. E., Roberton, M. A., & Langendorfer, S. (1982). Development of the overarm throw: Movement and ball velocity changes by seventh grade. *Research Quarterly for Exercise and Sport*, *53*(3), 198-205.

Halverson, L. E., Roberton, M. A., Safrit, M. J., & Roberts, T. W. (1977). Effect of guided practice on overhand-throw ball velocities of kindergarten children. *Research Quarterly of the American Association for Health, Physical Education, & Recreation*, *48*(2), 311-318.

Hamlin, B. (2005). Motor competency and video analysis. *Teaching Elementary Physical Education*, *16*(5), 8-13.

Hands, B. (2002). *How can we best measure fundamental movement skills?*[Paper Presentation] 23rd Biennial National/International Conference.

Hands, B., & McIntyre, F. (2015). Assessment of fundamental movement skills in Australian children: the validation of a Fundamental Motor Skills Quotient (FMSQ). *Malaysian Journal of Sport Science and Recreation*, *11*(1).

Harris, F. (2009). Visual technology in physical education. *Physical & Health Education Journal*, *74*(4), 24.

Haywood, K. (2012). *Advanced analysis of motor development*. Human Kinetics.

Haywood, K., & Getchell, N. (2014). *Life span motor development* (6th ed ed.). Human Kinetics.

Haywood, K., Williams, K., & VanSant, A. (1991). Qualitative assessment of the backswing in older adult throwing. *Research Quarterly for Exercise and Sport*, *62*(3), 340-343. http://www.tandfonline.com/doi/abs/10.1080/02701367.1991.10608732

Hebert, E., & Landin, D. (1997). Videotape feedback in skill acquisition [Paper Presentation]. Southern District AHPERD conference, New Orleans, LA, February,

Hebert, E., Landin, D., & Menickelli, J. (1998). Videotape feedback: What learners see and how they use it. *Journal of Sport Pedagogy*, *4*, 12-28.

Heynen, C. (2008). Viewing and visual representation in the physical education classroom. *Strategies*, *22*(1), 25-30. https://doi.org/10.1080/08924562.2008.10590805

Hodges, N., Chua, R., & Franks, I. (2003). The role of video in facilitating perception and action of a novel coordination movement. *Journal of Motor Behavior*, *35*(3), 247-260. https://doi.org/10.1080/00222890309602138

Hoffman, S. J. (1983). *Clinical diagnosis as a pedagogical skill*. Human Kinetics

Horn, R. R., Williams, A. M., Hayes, S. J., Hodges, N. J., & Scott, M. A. (2007). Demonstration as a rate enhancer to changes in coordination during early skill acquisition. *Journal of Sports Sciences*, *25*(5), 599-614.

Horn, R. R., Williams, A. M., & Scott, M. A. (2002). Learning from demonstrations: the role of visual search during observational learning from video and point- light models. *Journal of Sports Sciences*, *20*(3), 253-269. https://doi.org/10.1080/026404102317284808

Huijbregts, P. (1998). Biomechanics and pathology of the overhead throwing motion: a literature review. *Journal of Manual & Manipulative Therapy*, *6*(1), 17-23.

Hyde, J. S., & Linn, M. C. (1988). Gender differences in verbal ability: A meta-analysis. *Psychological Bulletin*, *104*(1), 53.

Jambor, E. A., & Weekes, E. M. (1995). Videotape feedback: Make it more effective. *Journal of Physical Education, Recreation & Dance*, *66*(2), 48-50.

Janelle, C. M., Barba, D. A., Frehlich, S. G., Tennant, L. K., & Cauraugh, J. H. (1997). Maximizing performance feedback effectiveness through videotape replay and a self-controlled learning environment. *Research Quarterly for Exercise and Sport*, *68*(4), 269-279.

Janelle, C. M., Champenoy, J., Coombes, S., & Mousseau, M. (2003). Mechanisms of attentional cueing during observational learning to facilitate motor skill acquisition. *Journal of Sports Sciences*, *21*(10), 825-838. https://doi.org/10.1080/0264041031000140310

Jarvis, S., Williams, M., Rainer, P., Jones, E. S., Saunders, J., & Mullen, R. (2018). Interpreting measures of fundamental movement skills and their relationship with health-related physical activity and self-concept. *Measurement in Physical Education and Exercise Science*, *22*(1), 88-100.

Jennings, C. T., Reaburn, P., & Rynne, S. B. (2013). The effect of a self-modelling video intervention on motor skill acquisition and retention of a novice track cyclist's standing start performance. *International Journal of Sports Science & Coaching*, *8*(3), 467-480.

Johnson, J. L., Hastie, P. A., Rudisill, M. E., & Wadsworth, D. (2020). Differences in Preschool Boys’ and Girls’ Overhand Throwing Practice Behaviors During a Mastery Motivational Climate. *Journal of Motor Learning and Development*, *8*(3), 580-588.

Johnson, J. L., Rudisill, M. E., Hastie, P. A., & Sassi, J. (2019). The influence of guided practice on overhand throwing competence in preschool children in a mastery motivational climate. *Journal of Motor Learning and Development*, *7*(1), 64-83.

Johnson, M., & Ward, P. (2001). Effects of classwide peer tutoring on correct performance of striking skills in 3rd grade physical education. *Journal of Teaching in Physical Education*, *20*(3), 247-263.

Kal, E., Prosée, R., Winters, M., & Van Der Kamp, J. (2018). Does implicit motor learning lead to greater automatization of motor skills compared to explicit motor learning? A systematic review. *PLoS One*, *13*(9), e0203591.

Kelly, L. E., & Melograno, V. (2004). *Developing the physical education curriculum: An achievement-based approach*. Human kinetics.

Kelly, L. E., & Moran, J. (2010). The Effectiveness of a Web-Based Motor Skill Assessment Training Program. *The Journal of Research in Health, Physical Education, Recreation, Sport & Dance*, *5*(2), 48.

Kelly, L. E., Reuschlein, P., & Haubenstricker, J. (1989). Qualitative analysis of overhand throw and catch motor skills: Implications for assessing and teaching. *International Journal of Physical Education, Recreation and Dance*, *25*, 14-18.

Kenney, W. L., Wilmore, J. H., & Costill, D. L. (2019). *Physiology of sport and exercise*. Human kinetics.

Kernodle, M. W., & Carlton, L. G. (1992). Information feedback and the learning of multiple-degree-of-freedom activities. *Journal of Motor Behavior*, *24*(2), 187-195. http://www.tandfonline.com/doi/abs/10.1080/00222895.1992.9941614

Kernodle, M. W., Johnson, R., & Arnold, D. R. (2001). Verbal instruction for correcting errors versus such instructions plus videotape replay on learning the overhand throw. *Perceptual and Motor Skills*, *92*(3c), 1039-1051.

Kernodle, M. W., McKethan, R. N., Brantz, D., & Bridges, L. (2002). The effects of a distance learning computer program on error detection of the overhand throw by preservice elementary education teachers. *Journal of Sport Pedagogy*, *8*, 1-19.

Kleynen, M., Braun, S. M., Bleijlevens, M. H., Lexis, M. A., Rasquin, S. M., Halfens, J., Wilson, M. R., Beurskens, A. J., & Masters, R. S. W. (2014). Using a Delphi technique to seek consensus regarding definitions, descriptions and classification of terms related to implicit and explicit forms of motor learning. *PLoS One*, *9*(6), e100227.

Knudson, D. (1997). *Qualitative analysis of human movement*. Human Kinetics.

Knudson, D. (2013). *Qualitative diagnosis of human movement: improving performance in sport and exercise* (3rd ed.). Human Kinetics.

Koh, M., & Khairuddin, A. (2004). Integrating video and computer technology in teaching. *British Journal of Teaching Physical Education*, *35*(3), 43-46.

Kretschmann, R. (2017). Employing tablet technology for video feedback in physical education swimming class. *Journal of e-Learning and Knowledge Society*, *13*(2).

Lander, N., Eather, N., Morgan, P. J., Salmon, J., & Barnett, L. M. (2017). Characteristics of teacher training in school-based physical education interventions to improve fundamental movement skills and/or physical activity: A systematic review. *Sports Medicine*, *47*(1), 135-161.

Langendorfer, S. J. (1980). *Longitudinal evidence for development changes in preparatory phase of the overarm throw for force* [Paper presentation]. National Convention of the American Alliance for Health, Physical Education, Recreation and Dance.

Langendorfer, S. J., & Roberton, M. A. (2002). Individual pathways in the development of forceful throwing. *Research Quarterly for Exercise and Sport*, *73*(3), 245-256. http://www.tandfonline.com/doi/pdf/10.1080/02701367.2002.10609018

Langendorfer, S. J., Roberton, M. A., & Stodden, D. F. (2012). Biomechanical aspects of the development of object projection skills. *Paediatric Biomechanics and Motor Control: Theory and Application* (pp. 180-206). Routledge.

Laughlin, M. K., Hodges, M., & Iraggi, T. (2019). Deploying video analysis to boost instruction and assessment in physical education. *Journal of Physical Education, Recreation & Dance*, *90*(5), 23-29.

Lee, T. D., Swinnen, S. P., & Serrien, D. J. (1994). Cognitive effort and motor learning. *Quest*, *46*(3), 328-344.

Lees, A. (2002). Technique analysis in sports: A critical review. *Journal of Sports Sciences*, *20*(10), 813-828. http://www.tandfonline.com/doi/pdf/10.1080/026404102320675657

Leight, J., Banville, D., & Polifko, M. (2009). Using digital video recorders in physical education. *Journal of Physical Education, Recreation & Dance*, *80*(1), 17-21. https://doi.org/10.1080/07303084.2009.10598262

Leme, S. A. (1978). Immature thuowing patterns in normal adult women. *Journal of Human Movement Studies*, *4*, 85-93.

Lieberman, D. G., & Franks, M. (2008). Video feedback and information technologies. In I. Franks (Ed.), *The essentials of performance analysis: an introduction* (pp. 40-50). Routledge.

Liebermann, D. G., Katz, L., Hughes, M. D., Bartlett, R. M., McClements, J., & Franks, I. M. (2002). Advances in the application of information technology to sport performance. *Journal of Sports Sciences*, *20*(10), 755-769.

Logan, S. W., Barnett, L. M., Goodway, J. D., & Stodden, D. F. (2017). Comparison of performance on process-and product-oriented assessments of fundamental motor skills across childhood. *Journal of Sports Sciences*, *35*(7), 634-641.

Logan, S. W., Ross, S. M., Chee, K., Stodden, D. F., & Robinson, L. E. (2018). Fundamental motor skills: A systematic review of terminology. *Journal of Sports Sciences*, *36*(7), 781-796. https://doi.org/10.1080/02640414.2017.1340660

Lorson, K. M., & Goodway, J. D. (2008). Gender Differences in Throwing Form of Children Ages 6–8 Years During a Throwing Game. *Research Quarterly for Exercise and Sport*, *79*(2), 174-182. https://doi.org/10.1080/02701367.2008.10599481

Lorson, K. M., Stodden, D. F., Langendorfer, S. J., & Goodway, J. D. (2013). Age and Gender Differences in Adolescent and Adult Overarm Throwing. *Research Quarterly for Exercise and Sport*, *84*(2), 239-244.

Lounsbery, M., & Coker, C. (2008). Developing skill-analysis competency in physical education teachers. *Quest*, *60*(2), 255-267.

Maccoby, E. E., & Jacklin, C. N. (1974). *The psychology of sex differences* (Vol. 2). Stanford University Press.

MacNamara, A., Collins, D., Bailey, R., Toms, M., Ford, P., & Pearce, G. (2011). Promoting lifelong physical activity and high level performance: realising an achievable aim for physical education. *Physical Education & Sport Pedagogy*, *16*(3), 265-278.

Magill, R. A., & Anderson, D. I. (2021). *Motor learning and control: Concepts and applications* (12th ed.). McGraw-Hill.

Masters, R. S. W. (1992). Knowledge, knerves and know-how: The role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure. *British Journal of Psychology*, *83*(3), 343-358.

Matsuo, T., Matsumoto, T., Mochizuki, Y., Takada, Y., & Saito, K. (2002). Optimal shoulder abduction angles during baseball pitching from maximal wrist velocity and minimal kinetics viewpoints. *Journal of Applied Biomechanics*, *18*(4), 306-320.

McCaig, S., & Young, M. (2015). Throwing mechanics in injury prevention and performance rehabilitation (Steve McCaig and Mark Young). In D. Joyce & D. Lewindon (Eds.), *Sports Injury Prevention and Rehabilitation* (pp. 151-164). Routledge.

Melville, D. S. (1993). Videotaping: An assist for large classes. *Strategies*, *6*(4), 26-28.

Metzler, M. W. (2005). *Instructional models for physical education*. Holcomb Hathaway Pubs.

Michael, W., Lanisa, H., Jason, M., Ashley, D., & Emilio, J. P. (2013). The Acute Effects of Upper Extremity Stretching on Throwing Velocity in Baseball Throwers. *Journal of Sports Medicine*, *2013*. https://doi.org/10.1155/2013/481490

Miller-Cotto, D., & Auxter, A. E. (2021). Testing the ecological validity of faded worked examples in algebra. *Educational Psychology*, *41*(2), 191-205.

Mohnsen, B., & Bolt, B. (2000). Using computers for qualitative analysis of movement. *Journal of Physical Education, Recreation & Dance, 71*(3), 15-18. https://doi.org/10.1080/07303084.2000.10605104

Morgan, P. J., Barnett, L. M., Cliff, D. P., Okely, A. D., Scott, H. A., Cohen, K. E., & Lubans, D. R. (2013). Fundamental movement skill interventions in youth: a systematic review and meta-analysis. *Pediatrics*, *132*(5) 1361-1383.

Moritz, S. E., Feltz, D. L., Fahrbach, K. R., & Mack, D. E. (2000). The relation of self-efficacy measures to sport performance: A meta-analytic review. *Research Quarterly for Exercise and Sport*, *71*(3), 280-294.

Morrison, C., & Reeve, J. (1986). Effect of instructional units on the analysis of related and unrelated skills. *Perceptual and Motor Skills*, *62*(2), 563-566.

Morrison, C., & Reeve, J. (1989). Effect of different videotape instructional units on undergraduate physical education majors' qualitative analysis of skill. *Perceptual and Motor Skills*, *69*(1), 111-114.

Mosher, R. E., & Schutz, R. W. (1983). The development of a test of overarm throwing: an application of generalizability theory. *Canadian Journal of Applied Sport Sciences, 8*(1), 1-8.

Mosston, M., & Ashworth, S. (2002). *Teaching physical education*. B. Cummings.

Nielsen, A. B., & Beauchamp, L. (1992). The effect of training in conceptual kinesiology on feedback provision patterns. *Journal of Teaching in Physical Education*, *11*(2), 126-138.

NSW Department of Education and Training. (2000). *Get skilled: Get active. A K-6 resource to support the teaching of fundamental movement skills*.

O'Loughlin, J., Chroinin, D. N., & O'Grady, D. (2013). Digital Video: The Impact on Children's Learning Experiences in Primary Physical Education. *European Physical Education Review*, *19*(2), 165-182. https://doi.org/10.1177/1356336X13486050

Obrusnikova, I., & Rattigan, P. J. (2016). Using video-based modeling to promote acquisition of fundamental motor skills. *Journal of Physical Education, Recreation & Dance*, *87*(4), 24-29.

Okely, A. D., Booth, M. L., & Chey, T. (2004). Relationships between body composition and fundamental movement skills among children and adolescents. *Research Quarterly for Exercise and Sport*, *75*(3), 238-247.

Oñate, J. A., Guskiewicz, K. M., Marshall, S. W., Giuliani, C., Yu, B., & Garrett, W. E. (2005). Instruction of jump- landing technique using videotape feedback: altering lower extremity motion patterns. *The American Journal of Sports Medicine*, *33*(6), 831-842.

Overdorf, V. G., & Coker, C. A. (2013). Efficacy of movement analysis and intervention skills. *Physical Educator*, *70*(2), 195.

Palao, J. M., Hastie, P. A., Cruz, P. G., & Ortega, E. (2013). The impact of video technology on student performance in physical education. *Technology, Pedagogy and Education*, *24*(1), 51-63. https://doi.org/10.1080/1475939X.2013.813404

Palmer, H. A., Newell, K. M., Gordon, D., Smith, L., & Williams, G. K. (2018). Qualitative and quantitative change in the kinematics of learning a non-dominant overarm throw. *Human Movement Science*, *62*, 134-142.

Palmer, H. A., Newell, K. M., Mulloy, F., Gordon, D., Smith, L., & Williams, G. K. (2020). Movement form of the overarm throw for children at 6, 10 and 14 years of age. *European Journal of Sport Science*, 1-9.

Parsons, T. D., Rizzo, A. R., Zaag, C. v. d., McGee, J. S., & Buckwalter, J. G. (2005). Gender differences and cognition among older adults. *Aging, Neuropsychology, and Cognition*, *12*(1), 78-88.

Pascua, L. A., Wulf, G., & Lewthwaite, R. (2015). Additive benefits of external focus and enhanced performance expectancy for motor learning. *Journal of Sports Sciences*, *33*(1), 58-66.

Pedegana, L. R., Elsner, R. C., Roberts, D., Lang, J., & Farewell, V. (1982). The relationship of upper extremity strength to throwing speed. *The American Journal of Sports Medicine*, *10*(6), 352-354.

Petranek, L. J., & Barton, G. V. (2011). The overarm-throwing pattern among U-14 ASA female softball players: a comparative study of gender, culture, and experience. *Research Quarterly for Exercise and Sport*, *82*(2), 220-228.

Phillips, E., Farrow, D., Ball, K., & Helmer, R. (2013). Harnessing and understanding feedback technology in applied settings. *Sports Medicine*, *43*(10), 919-925.

Pinheiro, V., & Simon, H. (1992). An operational model of motor skill diagnosis. *Journal of Teaching in Physical Education*, *11*(3), 288-302.

Potdevin, F., Vors, O., Huchez, A., Lamour, M., Davids, K., & Schnitzler, C. (2018). How can video feedback be used in physical education to support novice learning in gymnastics? Effects on motor learning, self-assessment and motivation. *Physical Education and Sport Pedagogy*, *23*(6), 559-574.

Pulling, A. R., & Allen, R. (2014). Impact of a peer-tutoring course on skill performance, assessment, and instruction. *Physical Educator*, *71*(2), 344-362.

Reeve, J. (2000). Qualitative analysis: Putting it all together. *Journal of Physical Education, Recreation & Dance*, *71*(1), 16. http://www.tandfonline.com/doi/pdf/10.1080/07303084.2000.10605978

Rendell, M. A., Farrow, D., Masters, R., & Plummer, N. (2011). Implicit practice for technique adaptation in expert performers. *International Journal of Sports Science & Coaching*, *6*(4), 553-566.

Rikli, R., & Smith, G. (1980). Videotape feedback effects on tennis serving form. *Perceptual and Motor Skills*, *50*(3), 895-901.

Rink, J. (2003). Effective instruction in physical education. In S. J. Silverman & C. D. Ennis (Eds.), *Student learning in physical education: Applying research to enhance the instruction* (pp. 165-186). Human Kinetics.

Roberton, M. A. (1977). Stability of stage categorizations across trials: Implications for the" stage theory" of overarm throw development. *Journal of Human Movement Studies*, 3, 49-59.

Roberton, M. A. (1978). Longitudinal evidence for developmental stages in the forceful overarm throw. *Journal of Human Movement Studies*, *4*(2), 167-175.

Roberton, M. A., & Halverson, L. E. (1984). *Developing children-Their changing movement: A guide for teachers*. Lea and Febiger.

Roberton, M. A., & Konczak, J. (2001). Predicting children's overarm throw ball velocities from their developmental levels in throwing. *Research Quarterly for Exercise and Sport*, *72*(2), 91-103.

Roberton, M. A., & Langendorfer, S. J. (1979). Testing motor development sequences across 9-14 years. In C. Nadeau, W. Halliwell, K. Newell, & G. Roberts (Eds.), *Psychology of motor behavior and sport* (pp. 269-279).

Roberts, J. E., & Bell, M. A. (2002). The effects of age and sex on mental rotation performance, verbal performance, and brain electrical activity. *Developmental Psychobiology: The Journal of the International Society for Developmental Psychobiology*, *40*(4), 391-407.

Roberts, T., & Brown, L. (2008). Learn More in Less Time: Fundamental Aquatic Skill Acquisition via Video Technology. *Strategies*, *21*(4), 29-31.

Robinson, L. E., Palmer, K. K., & Meehan, S. K. (2017). Dose-response relationship: The effect of motor skill intervention duration on motor performance. *Journal of Motor Learning and Development*, *5*(2), 280-290. https://doi.org/10.1123/jmld.2016-0004

Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Medicine*, *45*(9), 1273-1284.

Robles, S. C. (2013). Improving Diving Skill through Verbal Feedback and Video Feedback. *IAMURE International Journal of Education*, *7*(1), 85-102.

Rothstein, A. L. (1980). Effective use of videotape replay in learning motor skills. *Journal of Physical Education and Recreation*, *51*(2), 59-60.

Rothstein, A. L., & Arnold, R. K. (1976). Bridging the gap: Application of research on video-tape feedback and bowling. *Motor skills: Theory into practice*, 35-62.

Runion, B. P., Roberton, M. A., & Langendorfer, S. J. (2003). Forceful overarm throwing: A comparison of two cohorts measured 20 years apart. *Research Quarterly for Exercise and Sport*, *74*(3), 324-330.

Schott, N., & Getchell, N. (2021). Qualitative and quantitative assessment of overarm throwing in children with and without developmental coordination disorder. *Journal of Motor Learning and Development*, *9*(2), 266-285. https://doi.org/10.1123/jmld.2020-0056

Seroyer, S. T., Nho, S. J., Bach, B. R., Bush-Joseph, C. A., Nicholson, G. P., & Romeo, A. A. (2010). The kinetic chain in overhand pitching: Its potential role for performance enhancement and injury prevention. *Sports Health*, *2*(2), 135-146.

Shepard, L. A. (2000). The role of assessment in a learning culture. *Educational Researcher*, *29*(7), 4-14.

Sidaway, B., & Hand, M. J. (1993). Frequency of modeling effects on the acquisition and retention of a motor skill. *Research Quarterly for Exercise and Sport*, *64*(1), 122-126. http://www.tandfonline.com/doi/abs/10.1080/02701367.1993.10608786

Siedentop, D., & Tannehill, D. (2000). *Developing teaching skills in physical education*. Mayfield Pub. Co.

Silverman, S. (1985). Relationship of engagement and practice trials to student achievement. *Journal of Teaching in Physical Education*, *5*(1), 13-21.

Silverman, S. (2011). Teaching for student learning in physical education. *Journal of Physical Education, Recreation & Dance*, *82*(6), 29-34. https://doi.org/10.1080/07303084.2011.10598642

Snoddy, G. S. (1926). Learning and stability: A psychophysical analysis of a case of motor learning with clinical applications. *Journal of Applied Psychology*, *10*, 1-36.

Southard, D. (2002). Change in throwing pattern: Critical values for control parameter of velocity. *Research Quarterly for Exercise and Sport*, *73*(4), 396-407.

Southard, D. (2006). Changing throwing pattern: Instruction and control parameter. *Research Quarterly for Exercise and Sport*, *77*(3), 316-325. http://www.tandfonline.com/doi/pdf/10.1080/02701367.2006.10599366

Southard, D. (2009). Throwing pattern: Changes in timing of joint lag according to age between and within skill level. *Research Quarterly for Exercise and Sport*, *80*(2), 213-222. http://www.tandfonline.com/doi/pdf/10.1080/02701367.2009.10599555

Spittle, M. (2021). *Motor learning and skill acquisition: Applications for physical education and sport*. Bloomsbury Publishing.

Stodden, D. F., Fleisig, G. S., McLean, S. P., & Andrews, J. R. (2005). Relationship of biomechanical factors to baseball pitching velocity: within pitcher variation. *Journal of Applied Biomechanics*, *21*(1), 44-56.

Stodden, D. F., Fleisig, G. S., McLean, S. P., Lyman, S. L., & Andrews, J. R. (2001). Relationship of pelvis and upper torso kinematics to pitched baseball velocity. *Journal of Applied Biomechanics*, *17*(2), 164-172. http://www.humankinetics.com/acucustom/sitename/Documents/DocumentItem/2294.pdf

Stodden, D. F., Goodway, J. D., Langendorfer, S. J., Roberton, M. A., Rudisill, M. E., Garcia, C., & Garcia, L. E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest*, *60*(2), 290-306.

Stodden, D. F., Langendorfer, S., & Roberton, M. A. (2009). The association between motor skill competence and physical fitness in young adults. *Research Quarterly for Exercise and Sport*, *80*(2), 223-229. http://www.tandfonline.com/doi/pdf/10.1080/02701367.2009.10599556

Stodden, D. F., Langendorfer, S. J., Fleisig, G. S., & Andrews, J. R. (2006a). Kinematic constraints associated with the acquisition of overarm throwing Part I: Step and trunk actions. *Research Quarterly for Exercise and Sport*, *77*(4), 417-427.

Stodden, D. F., Langendorfer, S. J., Fleisig, G. S., & Andrews, J. R. (2006b). Kinematic constraints associated with the acquisition of overarm throwing Part II: Upper extremity actions. *Research Quarterly for Exercise and Sport*, *77*(4), 428-436. http://www.tandfonline.com/doi/pdf/10.1080/02701367.2006.10599378

Talpey, S., Young, W., & Beseler, B. (2014). Effect of instructions on selected jump squat variables. *Journal of Strength and Conditioning Research*. https://doi.org/10.1519/JSC.0000000000000435

Tearle, P., & Golder, G. (2008). The use of ICT in the teaching and learning of physical education in compulsory education: how do we prepare the workforce of the future? *European Journal of Teacher Education*, *31*(1), 55-72.

Thomas, J. R., & French, K. E. (1985). Gender differences across age in motor performance: A meta-analysis. *Psychological Bulletin*, *98*(2), 260.

Todd, T. A., Ahrold, K., Jarvis, D. N., & Mache, M. A. (2020). Evaluation of overhand throwing among college students with and without autism spectrum disorder. *Adapted Physical Activity Quarterly*, *38*(1), 43-61.

Townsend, J. S., & Mohr, D. J. (2002). Review and implications of peer teaching research. *Teaching Elementary Physical Education*, *13*(6), 28-31.

Truedson, T. N., Sexton, P. J., & Pettitt, R. W. (2012). Unconventional baseball pitching styles, part 1: Biomechanics and pathology. *International Journal of Athletic Therapy and Training*, *17*(4), 35-39.

Ulrich, D. A. (2000). *Test of gross motor development: Profile/examiner record form*. Pro-Ed.

Umek, A., & Kos, A. (2018). Smart equipment design challenges for real time feedback support in sport. *Facta Universitatis, Series: Mechanical Engineering*, *16*(3), 389-403.

US Physical Activity Guidelines Advisory Committee. (2018). *2018 physical activity guidelines advisory committee scientific report*. Retrieved December 15, 2021, from https://health.gov/sites/default/files/2019-09/PAG_Advisory_Committee_Report.pdf

van den Tillaar, R., & Ettema, G. (2004). Effect of body size and gender in overarm throwing performance. *European Journal of Applied Physiology, 91*(4), 413-418.

Van Wieringen, P. C. W., Emmen, H. H., Bootsma, R. J., Hoogesteger, M., & Whiting, H. T. A. (1989). The effect of video- feedback on the learning of the tennis service by intermediate players. *Journal of Sports Sciences*, *7*(2), 153-162. https://doi.org/10.1080/02640418908729833

Victorian Curriculum and Assessment Authority. (2020). *Health and Physical Education: Rationale and Aims*. Retrieved September 25, 2020, from https://victoriancurriculum.vcaa.vic.edu.au/health-and-physical-education/introduction/rationale-and-aims

Walkley, J. W., & Kelly, L. E. (1989). The effectiveness of an interactive videodisc qualitative assessment training program. *Research Quarterly for Exercise and Sport*, *60*(3), 280-285. http://www.tandfonline.com/doi/abs/10.1080/02701367.1989.10607451

Warburton, D. E., & Bredin, S. S. (2017). Health benefits of physical activity: a systematic review of current systematic reviews. *Current Opinion in Cardiology*, *32*(5), 541-556.

Ward, P., Ayvazo, S., Dervent, F., Iserbyt, P., Kim, I., & Li, W. (2020). Skill analysis for teachers: Considerations for physical education teacher education. *Journal of Physical Education, Recreation & Dance, 92*(2), 15-21.

Weir, T., & Connor, S. (2009). The use of digital video in physical education. *Technology, Pedagogy and Education*, *18*(2), 155-171. https://doi.org/10.1080/14759390902992642

Werner, S. L., Fleisig, G. S., Dillman, C. J., & Andrews, J. R. (1993). Biomechanics of the elbow during baseball pitching. *Journal of Orthopaedic & Sports Physical Therapy*, *17*(6), 274-278. http://www.jospt.org/doi/pdfplus/10.2519/jospt.1993.17.6.274

Werner, S. L., Suri, M., Guido Jr, J. A., Meister, K., & Jones, D. G. (2008). Relationships between ball velocity and throwing mechanics in collegiate baseball pitchers. *Journal of Shoulder and Elbow Surgery*, *17*(6), 905-908.

Whiteley, R. (2007). Baseball throwing mechanics as they relate to pathology and performance-a review. *Journal of Sports Science & Medicine*, *6*(1), 1.

Wild, M. R. (1938). The behavior pattern of throwing and some observations concerning its course of development in children. *Research Quarterly. American Association for Health and Physical Education*, *9*(3), 20-24.

Williams, K., Haywood, K., & VanSant, A. (1990). Movement characteristics of older adult throwers. In J. E. C. Humphrey (Ed.), *Advances in Motor Development Research* (Vol. 3, pp. 29-44). AMS Press.

Williams, K., Haywood, K., & VanSant, A. (1991). Throwing patterns of older adults: A follow-up investigation. *International Journal of Aging and Human Development*, *33*(4), 279-294.

Williams, K., Haywood, K., & VanSant, A. (1993). Force and accuracy throws by older adult performers. *Journal of Aging and Physical Activity*, *1*(1), 2-12.

Williams, K., Haywood, K., & VanSant, A. (1996a). Force and accuracy throws by older adults: II. *Journal of Aging and Physical Activity*, *4*(2), 194-202.

Williams, K., Haywood, K., & Vansant, A. (1998). Changes in throwing by older adults: A longitudinal investigation. *Research Quarterly for Exercise and Sport*, *69*(1), 1-10. http://www.tandfonline.com/doi/pdf/10.1080/02701367.1998.10607721

Williams, K., Haywood, K. M., & Painter, M. A. (1996b). Environmental versus biological influences on gender differences in the overarm throw for force: Dominant and nondominant arm throws. *Women in Sport and Physical Activity Journal*, *5*(2), 29-48.

Wilson, B. D. (2008). Development in video technology for coaching. *Sports Technology*, *1*(1), 34-35-40.

Wulf, G., & Lewthwaite, R. (2016). Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. *Psychonomic Bulletin & Review*, *23*(5), 1382-1414.

Young, W., Grace, S., & Talpey, S. (2014). Association between Leg Power and Sprinting Technique with 20-m Sprint Performance in Elite Junior Australian Football Players. *International Journal of Sports Science and Coaching*, *9*(5), 1153-1160.

Appendix A- Plain Language Information Statement

SCHOOL OF HEALTH SCIENCES AND PSYCHOLOGY

PROJECT TITLE:	**Validation of revised developmental levels of the overarm throw in University, High School and Primary School students**
PRINCIPAL RESEARCHER:	Dr Mandy Plumb
OTHER/STUDENT RESEARCHERS:	Brad Beseler

Dear Participant,

You are invited to participate in the research project described below.

The Project:

You are invited to participate in a research project titled **"**Validation of revised developmental levels of the overarm throw in University, High School and Primary School students' being conducted by Dr Mandy Plumb and Brad Beseler.

Aim of the Project:

My current project is looking at the overarm throw and attempting to validate a revised developmental sequence in a younger population. Currently it has only been validated in an older and pre-school population. By validating the sequence, it will allow us to reliably use this across the lifespan. It will also have implications for any staff who are involved in teaching physical education, in particular the overarm throw.

The aim of this study is to validate the revised developmental levels of the overarm throw in University students and School aged children.

What You Will Be Asked to Do:

If you agree to participate, you will be asked to complete an informed consent form, and a demographics form (asking you about your age, height and weight and throwing experience). You will then complete an overarm throwing test that will involve throwing a tennis ball with maximum force five times. The velocity of the throws will be recorded by a radar gun positioned directly behind you. The throws will be video recorded from the side and also behind and the footage will be later assessed by an experienced throwing panel who will assess the quality of your throwing technique.

The only people who will have access to the video footage will be the researchers involved in the study. At all other times the videotape footage will be located on a password protected desktop hard drive, located in a locked Federation University Australia staff office. After final analysis, the footage will be kept indefinitely and may be used for teaching purposes, if individuals consent to this. The testing should take no longer than 15 minutes.

Your participation in the project is entirely voluntary and you can opt out of the study at any time up until data is processed. You are not required to provide an explanation as to why you are choosing not to be involved. If you are worried about any aspect of your involvement you can ask questions of the researchers at any time. If you choose to be involved in the study you will print your name on and sign the consent form. Some students may be enrolled in a course that is coordinated by one of the researchers. Those students should not feel pressured to be involved in the study, as refusal to be involved in the study will not result in any discrimination or penalty.

If participants wish to make a complaint regarding the conduct of the research they should direct these complaints to the Ethics Officer for attention (this information is contained in the footer of this form).

Are there any risks?

As is the case in any practical setting where fundamental movement skills are being completed there is a risk of injury. The following steps will be taken to minimise this risk; the researcher administering the study has extensive physical education teaching experience, and holds current a first aid qualification, risk management procedures that are implemented with Human Movement and Sport Sciences (HMSS) classes will be implemented and appropriate warm up activities will be completed prior to the testing activities. The level of risk will not be greater than that to which participants will be exposed within HMSS practical classes.

Your results are confidential (subject to legal limitations), and no one, other than the research team, will have access to your individual results. All data will be stored indefinitely and with your consent may be used as a teaching resource. In the unlikely event that you might experience any distress resulting from participation in this project you can phone Lifeline, a confidential crisis support service available to everyone 24 hours a day on 13 11 14.

The findings of the study may be published in a journal and presented at conferences, there will be no information included in an article or these presentations that identifies individual participants.

If you have any questions, or you would like further information regarding the project titled "**Validation of revised developmental levels of the overarm throw in University, High School and Primary School students"** please contact the Principal Researcher **Dr Mandy Plumb** of the School of Health Sciences and Psychology PH: 53276664

EMAIL: a.plumb@federation.edu.au

Should you (i.e. the participant) have any concerns about the ethical conduct of this research project, please contact the Federation University Ethics Officers, Research Services, Federation University Australia,
P O Box 663 Mt Helen Vic 3353 or Northways Rd, Churchill Vic 3842.
Telephone: (03) 5327 9765, (03) 5122 6446
Email: research.ethics@federation.edu.au

CRICOS Provider Number 00103D

Appendix B - Consent Form

PROJECT TITLE:	**Validation study of revised developmental levels in the overarm throw in University, High and Primary School Students.**
RESEARCHERS:	Dr Mandy Plumb and Brad Beseler

Code number allocated to the participant:	

Informed Consent For University Students:

I, (participants name) ____ hereby agree to being a participant in the above research project

- I have read and understood the Information Sheet and any questions have been answered to my satisfaction.
- I understand that I may withdraw from participating in the project at any time without prejudice.
- I understand that all information gathered by the researcher will be treated as strictly confidential, except in instances of legal requirements, such as court subpoenas, freedom of information requests, or mandated by some professionals.
- I understand that the protocol adopted by Federation University Australia Human Research Ethics Committee for the protection of privacy will be adhered to and the relevant sections of the Privacy Act are available at http://www.nhmrc.gov.au
- I agree that any research data gathered for the study may be published provided my name or other identifying information is not disclosed.
- I understand that I will be videotaped.
- I understand that the video footage may be used for teaching purposes in the Exercise and Sports Science Program at Federation University, if I consent to this.

☐ Yes, I consent to video footage being used for teaching purposes in the Exercise and Sports Science Program at Federation University

☐ No, I do not consent to video footage being used for teaching purposes in the Exercise and Sports Science Program at Federation University

PARTICIPANTS SIGNATURE:_______________________________**DATE:** ___________________

RESERACHER'S FULL NAME's: Dr Mandy Plumb/Brad Beseler

RESEARCHER'S SIGNATURE:____**DATE:**

Appendix C - Ethics Approval

Human Research Ethics Committee

Principal Researcher:	Dr Mandy Plumb
Other/Student Researcher/s:	Mr Brad Beseler
School/Section:	**School of Health Science and Psychology**
Project Number:	**A17-005**
Project Title:	**Validation of revised developmental levels of the overarm throw in University, High School and Primary School students.**
For the period:	22/02/2017 **to** 30/12/2019

Quote the Project No: A17-005 in all correspondence regarding this application.

Please note: Ethics Approval is contingent upon the submission of annual Progress reports when applicable and a Final report upon completion of the project. It is the responsibility of researchers to make a note of the following dates and submit these reports in a timely manner, as reminders may not be sent out. Failure to submit reports will result in your ethics approval lapsing

REPORTS TO HREC:

Annual reports for this project must be submitted to the Ethics Officer by:
22 February 2018
22 February 2019

A final report for this project must be submitted to the Ethics Officer by:
30 January 2020

Report templates can be found at:
http://federation.edu.au/research-and-innovation/research-support/ethics/human-ethics/human-ethics3

Fiona Koop
Ethics Officer
22 February 2017

Please see attached 'Conditions of Approval'.

CONDITIONS OF APPROVAL

1. The project must be conducted in accordance with the approved application, including any conditions and amendments that have been approved. You must comply with all of the conditions imposed by the HREC, and any subsequent conditions that the HREC may require.

2. You must report immediately anything which might affect ethical acceptance of your project, including:

   - Adverse effects on participants;
   - Significant unforeseen events;
   - Other matters that might affect continued ethical acceptability of the project.

3. Where approval has been given subject to the submission of copies of documents such as letters of support or approvals from third parties, these must be provided to the Ethics Office before the research may commence at each relevant location.

4. Proposed changes or amendments to the research must be applied for, using a '**Request for Amendments**' form, and approved by the HREC before these may be implemented.

5. If an extension is required beyond the approved end date of the project, a '**Request for Extension**' should be submitted, allowing sufficient time for its consideration by the committee. Extensions cannot be granted retrospectively.

6. If changes are to be made to the project's personnel, a '**Changes to Personnel**' form should be submitted for approval.

7. An '**Annual Report**' must be provided by the due date specified each year for the project to have continuing approval.

8. A '**Final Report**' must be provided at the conclusion of the project.

9. If, for any reason, the project does not proceed or is discontinued, you must advise the committee in writing, using a '**Final Report**' form.

10. You must advise the HREC immediately, in writing, if any complaint is made about the conduct of the project.

11. You must notify the Ethics Office of any changes in contact details including address, phone number and email address.

12. The HREC may conduct random audits and / or require additional reports concerning the research project.

Failure to comply with the *National Statement on Ethical Conduct in Human Research* (2007) and with the conditions of approval will result in suspension or withdrawal of approval.

Appendix D - Demographic Questionnaire

Validation of Revised Developmental Levels of the Overarm Throw in University, High School and Primary School Students

Questionnaire:

Name: ______________________ **Student ID:** ___________________

Gender: Male ☐ Female ☐

Age: ______

Weight: ______ kg

Height: ______ cm

For University students: Program of Study (eg. Nursing, Psychology etc…)

____

1. How many years' experience have you had involvement in an organised sport/s that involves overarm throwing? ___________ Please name the sport _______________ ____

2. Are you currently involved in organised sport/s that involve overarm throwing? Yes ☐ No ☐. If yes, name the sport ____________________________________ ____ ____

3. How many times a week are you (current) / were you involved in this organised sport/s (previous)?

   Current _______ per week.

   Previous _______ per week.

Appendix E - Plain Language Information Statement

SCHOOL OF HEALTH SCIENCES AND PSYCHOLOGY

PROJECT TITLE:	**Examining the effect of the critical components of the overarm throw on throwing velocity**
PRINCIPAL RESEARCHER:	Dr Mandy Plumb
OTHER/STUDENT RESEARCHERS:	Brad Beseler and Associate Professor Michael Spittle

The Project:

You are invited to participate in a research project titled **"**Examining the effect of the critical components of the overarm throw on throwing velocity**"** being conducted by Dr Mandy Plumb and Brad Beseler.

Aim of the Project:

The aim of this study is to examine the effect of the critical components of the overarm throw on throwing velocity. The study will determine whether or not there is a significant correlation between throwing components and throwing velocity.

What You Will Be Asked to Do:

If you agree to participate, you will be asked to complete an informed consent form, and a demographics form (asking you about your age, height and weight and throwing experience. You will then complete an overarm throwing test that will involve throwing a tennis ball with maximum force five times. The velocity of the throws will be recorded by a radar gun positioned directly behind you. The throws will be video recorded from the side and also behind and the footage will be later assessed by an experienced throwing panel who will assess the quality of your throwing technique.

The only people who will have access to the video footage will be the researchers involved in the study. At all other times the videotape footage will be located on a password protected desktop hard drive, located in a locked Federation University Australia staff office. After final analysis, and following the period of time that research data must be stored, the footage will be erased. The testing should take the class no longer than 15 minutes.

Your participation in the project is entirely voluntary and you can opt out of the study at any time up until data is processed, you are not required to provide an explanation as to why you are choosing not to be involved. If you are worried about any aspect of your involvement you can ask questions of the researchers at any time. If you choose to be involved in the study you will print your name on and sign the consent form. If you do not want to be involved in the study you can simply inform the researcher and you are free to leave the venue. Some students may be enrolled in a course that is coordinated by one of the researchers. Those students should not feel pressured to be involved in the study as refusal to be involved in the study will not result in any discrimination or penalty.

If participants wish to make a complaint regarding the conduct of the research they should direct these complaints to the Ethics Officer for attention (this information is contained in the footer of this form).

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Are there any risks?

As is the case in any practical setting where fundamental movement skills are being completed there is a risk of injury. The following steps will be taken to minimise this risk; the researcher administering the study has extensive physical education teaching experience, and holds current a first aid qualification, risk management procedures that are implemented with HMSS classes will be implemented and appropriate warm up activities will be completed prior to the testing activities. The level of risk will not be greater than that to which participants will be exposed within HMSS practical classes.

Your results are confidential (subject to legal limitations), and no one, other than the research team, will have access to your individual results. All data will be destroyed after 5 years. In the unlikely event that you might experience any distress resulting from participation in this project you can phone Mandy Plumb (the Principal Researcher) on 5327 6664 or alternatively you can phone Brad Beseler on 5327 9063 or alternatively you can phone Lifeline, a confidential crisis support service available to everyone 24 hours a day on 13 11 14, and the Federation University Counselling services 53279470.

Those enrolled in courses that are coordinated by the researchers are assured that the results of the testing completed as part of this study will have no impact on the assessment tasks in those courses.

The findings of the study may be published in a journal and presented at conferences, there will be no information included in an article or these presentations that identifies individual participants.

If you have any questions, or you would like further information regarding the project titled "Examining the effect of the critical components of the overarm throw on throwing velocity" please contact the Principal Researcher **Dr Mandy Plumb** of the School of Health Sciences and Psychology
PH: 53276664

EMAIL: a.plumb@federation.edu.au

Should you (i.e. the participant) have any concerns about the ethical conduct of this research project, please contact the Federation University Ethics Officers, Research Services, Federation University Australia,
P O Box 663 Mt Helen Vic 3353 or Northways Rd, Churchill Vic 3842.
Telephone: (03) 5327 9765, (03) 5122 6446
Email: research.ethics@federation.edu.au

CRICOS Provider Number 00103D

Appendix F - Consent Form

PROJECT TITLE:	**Examining the effect of the critical components of the overarm throw on throwing velocity**
RESEARCHERS:	Dr Mandy Plumb, Brad Beseler and Associate Professor Michael Spittle

Code number allocated to the participant:	

<u>Consent – Please complete the following information:</u>

I ____ of

____+

hereby consent to participate as a subject in the above research study.

The research program in which I am being asked to participate has been explained fully to me, verbally and in writing, and any matters on which I have sought information have been answered to my satisfaction.

I understand that: all information I provide (including questionnaires and video footage) will be treated with the strictest confidence and data will be stored separately from any listing that includes my name and address.

- Aggregated results will be used for research purposes and may be reported in scientific and academic journals.
- I am free to withdraw my consent at any time during the study in which event my participation in the research study will immediately cease and information/data obtained from it will not be used.
- I understand the exception to this is if I withdraw after information has been aggregated - it is unable to be individually identified - so from this point it is not possible to withdraw my information/data, although I may still withdraw my consent to participate.

SIGNATURE:__________________________________ **DATE:** ____________________.

Appendix G - Ethics Approval

Human Research Ethics Committee

Principal Researcher:	Dr Mandy Plumb
Other/Student Researcher/s:	Mr Brad Beseler
School/Section:	**School of Health Sciences and Psychology**
Project Number:	**A16-151**
Project Title:	**Examining the effect of the critical components of the overarm throw on throwing velocity.**
For the period:	21/10/2016 **to** 30/12/2021

Quote the Project No: A*16-151 in all correspondence regarding this application.*

Please note: Ethics Approval is contingent upon the submission of Annual Progress reports and a Final report upon completion of the project. It is the responsibility of researchers to make a note of the following dates and submit these reports in a timely manner, as reminders may not be sent out. Failure to submit reports will result in your ethics approval lapsing

REPORTS TO HREC:

Annual reports for this project must be submitted to the Ethics Officer on:
21 October 2017
21 October 2018
21 October 2019
21 October 2020
21 October 2021

A Final report for this project must be submitted to the Ethics Officer on:
30 January 2022

These report forms can be found at:
http://federation.edu.au/research-and-innovation/research-support/ethics/human-ethics/human-ethics3

Fiona Koop
Ethics Officer
21 October 2016

Please see attached 'Conditions of Approval'.

<u>**CONDITIONS OF APPROVAL**</u>

1. The project must be conducted in accordance with the approved application, including any conditions and amendments that have been approved. You must comply with all of the conditions imposed by the HREC, and any subsequent conditions that the HREC may require.

2. You must report immediately anything which might affect ethical acceptance of your project, including:

   - Adverse effects on participants;
   - Significant unforeseen events;
   - Other matters that might affect continued ethical acceptability of the project.

3. Where approval has been given subject to the submission of copies of documents such as letters of support or approvals from third parties, these must be provided to the Ethics Office before the research may commence at each relevant location.

4. Proposed changes or amendments to the research must be applied for, using a '**Request for Amendments**' form, and approved by the HREC before these may be implemented.

5. If an extension is required beyond the approved end date of the project, a '**Request for Extension**' should be submitted, allowing sufficient time for its consideration by the committee. Extensions cannot be granted retrospectively.

6. If changes are to be made to the project's personnel, a '**Changes to Personnel**' form should be submitted for approval.

7. An '**Annual Report**' must be provided by the due date specified each year for the project to have continuing approval.

8. A '**Final Report**' must be provided at the conclusion of the project.

9. If, for any reason, the project does not proceed or is discontinued, you must advise the committee in writing, using a '**Final Report**' form.

10. You must advise the HREC immediately, in writing, if any complaint is made about the conduct of the project.

11. You must notify the Ethics Office of any changes in contact details including address, phone number and email address.

12. The HREC may conduct random audits and / or require additional reports concerning the research project.

Failure to comply with the *National Statement on Ethical Conduct in Human Research* (2007) and with the conditions of approval will result in suspension or withdrawal of approval.

Appendix H - Demographic Questionnaire

Examining the effect of the critical components of the overarm throw on throwing velocity

Questionnaire:

Name: ______________________

Students Number: ________________

Gender: Male ☐ Female ☐

Age: ______

Weight: ______ kg (height and weight will be measured and recorded by researcher)

Height: ______ cm

1. How many years of experience have you had involvement in an organised sport that involves overarm throwing? ___________ Please name the sport/s ______________
____
2. How many years of experience have you had involvement in unorganised / recreational throwing practice? ______. Please explain the activity ______________
____
____
3. Are you currently involved in organised or recreational activities that involve overarm throwing? Yes ☐ No ☐ . If yes, explain the sport / activity _________
____
____
4. How many times a week are you / were you involved in this organised or recreational activity? __________ (previously), ___________ (currently).

Video files _______________ (participants ignore this section)

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SCHOOL OF HEALTH SCIENCES AND PSYCHOLOGY

PROJECT TITLE:	Can video technology help students improve throwing technique in a peer teaching setting?
PRINCIPAL RESEARCHER:	Dr Mandy Plumb
OTHER/STUDENT RESEARCHERS:	Brad Beseler, Dr Nicola Johnson and Dr Michael Spittle

The Project:

You are invited to participate in a research project titled **"Can video technology help students improve throwing technique in a peer teaching setting?"** being conducted by Dr Mandy Plumb, Brad Beseler Johnson.

Aim of the Project:

The aim of the study is to examine whether or not overarm throwing performance with the non-preferred hand can be improved as a result of a peer teaching intervention. The study will also examine whether students who have access to personal mobile electronic devices ("smart phones" or portable tablets) during the intervention display greater improvement in throwing performance than students who do not have access to the same technology.

What You Will Be Asked to Do:

If you agree to participate, you will be asked to complete an informed consent form, and a demographics form (asking you about your age, experience level of overarm throwing with opposite hand and coaching experience in relation to overarm throwing prior to participation. At the start of the study and at the end of the study you will complete a throwing test with your non-preferred hand. Each test will include throwing the ball with your opposite hand with maximum force, towards a target 3 times. The throws will be video recorded from the side and also behind and the footage will be later assessed by an expert throwing panel who will assess the quality of your throwing technique.

The only people who will have access to the video footage will be the researchers involved in the study. At all other times the videotape footage will be located on a password protected desktop hard drive, located in a locked Federation University Australia staff office. After final analysis, and following the period of time that research data must be stored, the footage will be erased. The testing at the start and at the end of the study should take the class no longer than 10 minutes.

In between the pre- and post-tests you will complete a 20 minute throwing intervention session.
At the completion of the post-testing, you will complete a survey to measure your perceptions of the intervention procedure. The survey will also measure the effect the respective interventions have had on your confidence to perform the overarm throw, and also your confidence to qualitatively diagnose the overhand throw. The survey will take five minutes.

Your participation in the project is entirely voluntary and you can opt in or out of the study at any time until data is combined. If you are worried about any aspect of your involvement you can ask questions of the researchers at any time. If you choose to have their results included in the study will print their name on and sign the consent form. Those who do not want to have their results included in the study will simply print their name on, but will not sign the consent form. All signed and unsigned forms will be placed into an envelope (one envelope per class) that will be sealed prior to the start of the study and that envelope will not be opened until the course has been completed and the results been made available to the students. As such students who do not want their results to be included in the study do not feel pressured to be involved in the study because the researcher who is also the course coordinator will not know who has chosen to be involved or chosen not to be involved in the study until the course results have been finalised. To ensure the envelope is not opened before results have been finalised, at the time the envelope is sealed, masking tape will be placed across the sealed section and a student form the class will sign his or her name across the tape. Regardless of whether or not you choose to have your results included in the study you will still complete the session as it is a required session in the course you are completing.

Are there any risks?

As is the case in any practical setting where fundamental movement skills are being completed there is a risk of injury. The following steps will be taken to minimise this risk; the researcher administering the study has extensive physical education teaching experience, and holds current a first aid qualification, risk management procedures that are implemented with HMSS classes will be implemented and appropriate warm up activities will be completed prior to the testing activities. The level of risk will not be greater than that to which participants will be exposed within HMSS practical classes.

Your results are confidential (subject to legal limitations), and no one, other than the named researchers, will have access to your individual results. All data will be destroyed after 5 years. In the unlikely event that you might experience any distress resulting from participation in this project you can phone Mandy Plumb (the Principal Researcher) on 5327 6664 or alternatively you can phone Brad Beseler on 5327 9063 or Nicola Johnson on 51226366 or alternatively you can phone Lifeline, a confidential crisis support service available to everyone 24 hours a day on 13 11 14.

The results of the testing completed as part of this study will have no impact on the assessment tasks in the course you are completing.

The findings of the study may be published in a journal and presented at conferences, there will be no information included in an article or these presentations that identifies individual participants.

If you have any questions, or you would like further information regarding the project titled (Can video technology help students improve throwing form in a peer teaching setting?), please contact the Principal Researcher **Dr Mandy Plumb** of the School of Health Sciences and Psychology
PH: 53276664

EMAIL: a.plumb@federation.edu.au

Should you (i.e. the participant) have any concerns about the ethical conduct of this research project, please contact the Federation University Ethics Officers, Research Services, Federation University Australia,
P O Box 663 Mt Helen Vic 3353 or Northways Rd, Churchill Vic 3842.
Telephone: (03) 5327 9765, (03) 5122 6446
Email: research.ethics@federation.edu.au

CRICOS Provider Number 00103D

PROJECT TITLE:	Can video technology help students improve throwing technique in a peer teaching setting?
RESEARCHERS:	Dr Mandy Plumb, Brad Beseler and Dr Nicola Johnson

Code number allocated to the participant:	

Consent – Please complete the following information:

I, ... of . . . .
. . . .
hereby consent to participate as a subject in the above research study.

The research program in which I am being asked to participate has been explained fully to me, verbally and in writing, and any matters on which I have sought information have been answered to my satisfaction.

I understand that: all information I provide (including questionnaires and video footage) will be treated with the strictest confidence and data will be stored separately from any listing that includes my name and address.

- Aggregated results will be used for research purposes and may be reported in scientific and academic journals
- ***I am free to withdraw my consent at any time during the study in which event my participation in the research study will immediately cease and any information obtained from it will not be used.***
- ***Once information has been aggregated it is unable to be identified, and from this point it is not possible to withdraw consent to participate***

SIGNATURE: . . . .   **DATE**: . . . .

Appendix K - Ethics Approval

Human Research Ethics Committee

Principal Researcher:	Dr Mandy Plumb
Other/Student Researcher/s:	Mr Brad Beseler Dr Nicola Johnson
School/Section:	**Health Sciences and Psychology / HMSS**
Project Number:	**A16-004**
Project Title:	**Can Interactive Video Technology Improve Qualitative Movement Diagnosis and Performance of the Overhand Throw?**
For the period:	11/02/2016 **to** 30/12/2021

Quote the Project No: A16-004 in all correspondence regarding this application.

Comment: The Information Protection (Data Storage and Security), page 16 in the application should have individually identifiable data crossed.

Please note: Ethics Approval is contingent upon the submission of annual Progress reports and a Final report upon completion of the project. It is the responsibility of researchers to make a note of the following dates and submit these reports in a timely manner, as reminders may not be sent out. Failure to submit reports will result in your ethics approval lapsing

REPORTS TO HREC:

An annual report for this project must be submitted to the Ethics Officer on:
11 February 2017
11 February 2018
11 February 2019
11 February 2020
11 February 2021

A final report for this project must be submitted to the Ethics Officer on:
30 01 2022

These report forms can be found at:
http://federation.edu.au/research-and-innovation/research-support/ethics/human-ethics/human-ethics3

Fiona Koop

Ethics Officer
18 February 2022

Please see attached 'Conditions of Approval'.

Office Use Only								
RM		Sig Dates		Shared Drv:		Matrix		Notes:

CONDITIONS OF APPROVAL

1. The project must be conducted in accordance with the approved application, including any conditions and amendments that have been approved. You must comply with all of the conditions imposed by the HREC, and any subsequent conditions that the HREC may require.

2. You must report immediately anything which might affect ethical acceptance of your project, including:

   - Adverse effects on participants;
   - Significant unforeseen events;
   - Other matters that might affect continued ethical acceptability of the project.

3. Where approval has been given subject to the submission of copies of documents such as letters of support or approvals from third parties, these must be provided to the Ethics Office before the research may commence at each relevant location.

4. Proposed changes or amendments to the research must be applied for, using a '**Request for Amendments**' form, and approved by the HREC before these may be implemented.

5. If an extension is required beyond the approved end date of the project, a '**Request for Extension**' should be submitted, allowing sufficient time for its consideration by the committee. Extensions cannot be granted retrospectively.

6. If changes are to be made to the project's personnel, a '**Changes to Personnel**' form should be submitted for approval.

7. An '**Annual Report**' must be provided by the due date specified each year for the project to have continuing approval.

8. A '**Final Report**' must be provided at the conclusion of the project.

9. If, for any reason, the project does not proceed or is discontinued, you must advise the committee in writing, using a '**Final Report**' form.

10. You must advise the HREC immediately, in writing, if any complaint is made about the conduct of the project.

11. You must notify the Ethics Office of any changes in contact details including address, phone number and email address.

12. The HREC may conduct random audits and / or require additional reports concerning the research project.

Failure to comply with the *National Statement on Ethical Conduct in Human Research* (2007) and with the conditions of approval will result in suspension or withdrawal of approval.

Appendix L - Overarm Throw Checklist

- You need to start from the top (Backswing) component and work your way down the list.
- When you answer "yes" to all questions for each component move onto the next component
- As you move through the components, keep checking the previous components to make sure you are still answering "yes" to each question

1	**Backswing**	 	• Does ball moves below the waist in circular down and back motion ? • At end of backswing, is ball within or behind outline of body when viewed from behind? **Fix: "Giant Eagle's Wings with a twist"**
2	**Stepping**		• Do you step with foot opposite throwing arm? • Is the length of the step is over half thrower's height? **Fix: Position yourself near a line and step over that line**
3	**Follow Through**	 	• After ball release, does your throwing hand follow through across your body so that hand disappears when viewed from the side? **Fix: "Jingle the keys in your opposite pocket"**

- When you can answer "yes" to all 5 questions above, collect next cheat sheet off your tutor

4	**Trunk**		• Do you rotate away from the target in the backswing by turning your back on the target? • Do you rotate your trunk powerfully during throwing action so that at the end of the follow through you have to look over throwing shoulder to see the target? **Fix: “Stay loose, hide your chest from the target”**
5	**Humerus**		• When shoulders are front facing, is you elbow up high so that your humerus makes a right angle to trunk? • Are you loose and relaxed when you throw, so that when shoul-ders are front facing your elbow is within outline of body when viewed from side? **Fix: “Stay loose, hide your chest from the target”**
6	**Forearm**		• Are you loose and relaxed when you throw, so that when shoulders are front facing, your hand lags behind the elbow? **Fix: “Stay loose, hide your chest from the target”**

SCHOOL OF HEALTH SCIENCES AND PSYCHOLOGY

PROJECT TITLE:	Can video technology help students improve throwing technique in a peer teaching setting?
PRINCIPAL RESEARCHER:	Dr Mandy Plumb
OTHER/STUDENT RESEARCHERS:	Brad Beseler, Dr Nicola Johnson

The Project:

You are invited to participate in a research project titled **"Can video technology help students improve throwing technique in a peer teaching setting?"** being conducted by Dr Mandy Plumb, Brad Beseler and Dr Nicola Johnson.

Aim of the Project:

The aim of the study is to examine whether or not overarm throwing performance with the non-preferred hand can be improved as a result of a peer teaching intervention. The study will also examine whether students who have access to personal mobile electronic devices ("smart phones" or portable tablets) during the intervention display greater improvement in throwing performance than students without access to the same technology.

What You Will Be Asked to Do:

If you agree to participate, you will be asked to complete an informed consent form, and a demographics form (asking you about your age, experience level of overarm throwing with opposite hand and coaching experience in relation to overarm throwing prior to participation. At the start of the study and at the end of the study you will complete a throwing test with your non-preferred hand. Each test will include throwing the ball with your opposite hand with maximum force, towards a target 3 times. The throws will be video recorded from the side and also behind and the footage will be later assessed by an expert throwing panel who will assess the quality of your throwing technique.

The only people who will have access to the video footage will be the researchers involved in the study. At all other times the videotape footage will be located on a password protected desktop hard drive, located in a locked Federation University Australia staff office. After final analysis, and following the period of time that research data must be stored, the footage will be erased. The testing at the start and at the end of the study should take the class no longer than 10 minutes.

In between the pre- and post-tests you will complete one 20 minute intervention session and another two 10 minute throwing intervention sessions. Each intervention session will occur on consecutive weeks at the end of the practical sessions.

At the completion of the post-testing, you will complete a survey to measure your perceptions of the intervention procedure. The five minute survey will also measure the effect the respective interventions have had on your confidence to perform the overarm throw, and also your confidence to qualitatively diagnose the overhand throw. Then two weeks after the post-testing you will complete a retention test identical to the pre and post-testing to see if the learning has been durable.

Your participation in the project is entirely voluntary and you can opt in or out of the study at any time until data is combined. If you are worried about any aspect of your involvement you can ask questions of the researchers at any time. If you choose to have your results included in the study will print their name on and sign the consent form. Those who do not want to have their results included in the study will simply print their name on, but will not sign the consent form. All signed and unsigned forms will be placed into an envelope (one envelope per class) that will be sealed prior to the start of the study and that envelope will not be opened until the course has been completed and the results been made available to the students. As such students who do not want their results to be included in the study do not feel pressured to be involved in the study because the researcher who is also the course coordinator will not know who has chosen to be involved or chosen not to be involved in the study until the course results have been finalised. To ensure the envelope is not opened before results have been finalised, at the time the envelope is sealed, masking tape will be placed across the sealed section and a student form the class will sign his or her name across the tape. Regardless of whether or not you choose to have your results included in the study you will still complete the session as it is a required session in the course you are completing.

Are there any risks?

As is the case in any practical setting where fundamental movement skills are being completed there is a risk of injury. The following steps will be taken to minimise this risk; the researcher administering the study has extensive physical education teaching experience, and holds current a first aid qualification, risk management procedures that are implemented with Human Movement and Sport Sciences (HMSS) classes will be implemented and appropriate warm up activities will be completed prior to the testing activities. The level of risk will not be greater than that to which participants will be exposed within HMSS practical classes.

Your results are confidential (subject to legal limitations), and no one, other than the research team, will have access to your individual results. All data will be destroyed after 5 years. In the unlikely event that you might experience any distress resulting from participation in this project you can phone Mandy Plumb (the Principal Researcher) on 5327 6664 or alternatively you can phone Brad Beseler on 5327 9063 or Nicola Johnson on 51226366 or alternatively you can phone Lifeline, a confidential crisis support service available to everyone 24 hours a day on 13 11 14.

The results of the testing completed as part of this study will have no impact on the assessment tasks in the course you are completing.

The findings of the study may be published in a journal and presented at conferences, there will be no information included in an article or these presentations that identifies individual participants.

If you have any questions, or you would like further information regarding the project titled (Can video technology help students improve throwing form in a peer teaching setting?), please contact the Principal Researcher Dr Mandy Plumb of the School of Health Sciences and Psychology PH: 53276664 EMAIL: a.plumb@federation.edu.au
Should you (i.e. the participant) have any concerns about the ethical conduct of this research project, please contact the Federation University Ethics Officers, Research Services, Federation University Australia, P O Box 663 Mt Helen Vic 3353 or Northways Rd, Churchill Vic 3842. Telephone: (03) 5327 9765, (03) 5122 6446 Email: research.ethics@federation.edu.au CRICOS Provider Number 00103D

PROJECT TITLE:	Can video technology help students improve throwing technique in a peer teaching setting?
RESEARCHERS:	Dr Mandy Plumb, Brad Beseler, Dr Nicola Johnson and Prof Michael Spittle

Code number allocated to the participant:	

Consent – Please complete the following information:

I, ... of . . . .
. . . .
hereby consent to participate as a subject in the above research study.

The research program in which I am being asked to participate has been explained fully to me, verbally and in writing, and any matters on which I have sought information have been answered to my satisfaction.

I understand that: all information I provide (including questionnaires and video footage) will be treated with the strictest confidence and data will be stored separately from any listing that includes my name and address.

- Aggregated results will be used for research purposes and may be reported in scientific and academic journals
- ***I am free to withdraw my consent at any time during the study in which event my participation in the research study will immediately cease and any information obtained from it will not be used.***
- ***Once information has been aggregated it is unable to be identified, and from this point it is not possible to withdraw consent to participate***

SIGNATURE: . . . . **DATE**: . . . .

Appendix O - Ethics Approval

Human Research Ethics Committee

Federation UNIVERSITY • AUSTRALIA

Principal Researcher:	Dr Mandy Plumb
Other/Student Researcher/s:	Mr Brad Beseler Dr Nicola Johnson
School/Section:	**Health Sciences and Psychology / HMSS**
Project Number:	**A16-004**
Project Title:	**Can Interactive Video Technology Improve Qualitative Movement Diagnosis and Performance of the Overhand Throw?**
For the period:	11/02/2016 **to** 30/12/2021

Quote the Project No: A16-004 in all correspondence regarding this application.

Comment: The Information Protection (Data Storage and Security), page 16 in the application should have individually identifiable data crossed.

Please note: Ethics Approval is contingent upon the submission of annual Progress reports and a Final report upon completion of the project. It is the responsibility of researchers to make a note of the following dates and submit these reports in a timely manner, as reminders may not be sent out. Failure to submit reports will result in your ethics approval lapsing

REPORTS TO HREC:

An annual report for this project must be submitted to the Ethics Officer on:
11 February 2017
11 February 2018
11 February 2019
11 February 2020
11 February 2021

A final report for this project must be submitted to the Ethics Officer on:
30 01 2022

These report forms can be found at:
http://federation.edu.au/research-and-innovation/research-support/ethics/human-ethics/human-ethics3

Fiona Koop

Ethics Officer
18 February 2022

Please see attached 'Conditions of Approval'.

Office Use Only								
RM		Sig Dates		Shared Drv:		Matrix		Notes:

CONDITIONS OF APPROVAL

1. The project must be conducted in accordance with the approved application, including any conditions and amendments that have been approved. You must comply with all of the conditions imposed by the HREC, and any subsequent conditions that the HREC may require.

2. You must report immediately anything which might affect ethical acceptance of your project, including:

   - Adverse effects on participants;
   - Significant unforeseen events;
   - Other matters that might affect continued ethical acceptability of the project.

3. Where approval has been given subject to the submission of copies of documents such as letters of support or approvals from third parties, these must be provided to the Ethics Office before the research may commence at each relevant location.

4. Proposed changes or amendments to the research must be applied for, using a '**Request for Amendments**' form, and approved by the HREC before these may be implemented.

5. If an extension is required beyond the approved end date of the project, a '**Request for Extension**' should be submitted, allowing sufficient time for its consideration by the committee. Extensions cannot be granted retrospectively.

6. If changes are to be made to the project's personnel, a '**Changes to Personnel**' form should be submitted for approval.

7. An '**Annual Report**' must be provided by the due date specified each year for the project to have continuing approval.

8. A '**Final Report**' must be provided at the conclusion of the project.

9. If, for any reason, the project does not proceed or is discontinued, you must advise the committee in writing, using a '**Final Report**' form.

10. You must advise the HREC immediately, in writing, if any complaint is made about the conduct of the project.

11. You must notify the Ethics Office of any changes in contact details including address, phone number and email address.

12. The HREC may conduct random audits and / or require additional reports concerning the research project.

Failure to comply with the *National Statement on Ethical Conduct in Human Research* (2007) and with the conditions of approval will result in suspension or withdrawal of approval.

Annual/Final Project Report

Human Research Ethics Committee

Please indicate the type of report	☐ Annual Report (**Omit 3b & 5b**) ☒ Final Report
Project No:	A16-004
Project Name:	Can Interactive Video Technology Improve Qualitative Movement Diagnosis and Performance of the Overhand Throw?
Principal Researcher:	Dr Christopher Mesagno
Other Researchers:	Mr Brad Beseler Dr Mandy Plumb Dr. Nicola Johnson
Date of Original Approval:	21/10/2016
School / Section:	**School of Health Science and Psychology**
Phone:	53276136
Email:	c.mesagno@federation.edu.au

Please note: For HDR candidates, this Ethics annual report is a separate requirement, in addition to your HDR Candidature annual report, which is submitted mid-year to research.degrees@federation.edu.au.

1) Please indicate the current status of the project:				
1a) Yet to start				☐
1b) Continuing				☐
1c) Data collection completed				☒
1d) Abandoned / Withdrawn:				☐
1e) If the approval was subject to certain conditions, have these conditions been met? (If not, please give details in the comments box below)			☒ Yes	☐ No
Comments:				
1f) Data Analysis	☐ Not yet commenced	☐ Proceeding	☒ Complete	☐ None
1g) Have ethical problems been encountered in any of the following areas:				

Annual/Final Project Report

Human Research Ethics Committee

Study Design	☐ Yes	☒ No
Recruitment of Subjects	☐ Yes	☒ No
Finance	☐ Yes	☒ No
Facilities, Equipment	☐ Yes	☒ No
(If yes, please give details in the comments box below)		
Comments:		

2a) Have amendments been made to the originally approved project?	
☐ No	☒ Yes
2b) If yes, was HREC approval granted for these changes?	
☒ Yes	**Provide detail:** ☐ Yes **Application for Amendment to an Existing Project** ☒ Yes **Change of Personnel** ☐ Yes **Extension Request**
☐ No	**If you have made changes, but not had HREC approval, provide detail as to why this has not yet occurred:**
2c) Do you need to submit any amendments now?	
☒ No	☐ Yes **Application for Amendment to an Existing Project** ☐ Yes **Change of Personnel** ☐ Yes **Extension Request** *** NB: If 'Yes', download & submit the appropriate request to the HREC for approval:** **Please note: Extensions will not be granted retrospectively. Apply well prior to the project end date, to ensure continuity of HRE approval.**

3a) Please indicate where you are storing the data collected during the course of this project: (Australian code for the Responsible conduct of Research Ch 2.2.2, 2.5 – 2.7)
Data will be kept in locked filing cabinets. Access to computer files will be available by password only.
3b) Final Reports: Advise when & how stored data will be destroyed (Australian code for the Responsible conduct of Research Ch 2.1.1)

Data will be destroyed after 5 years from completion of the PhD by Principal Researcher.

4) Have there been any events that might have had an adverse effect on the research participants OR unforeseen events that might affect continued ethical acceptability of the project?	
☒ No	☐ Yes *** NB: If 'yes', please provide details in the comments box below:**
Comments:	

5a) Please provide a short summary of results of the project so far (no attachments please):
Results show video analysis facilitates the performance of the overarm throw
5b) Final Reports: Provide details about how the aims of the project, as stated in the application for approval, were achieved (or not achieved). (Australian code for the Responsible conduct of Research 4.4.1)
The aims of the project were achieved because results indicated video analysis facilitated the performance of the overarm throw

6) Publications: Provide details of research dissemination outcomes for the previous year resulting from this project: eg: Community seminars; Conference attendance; Government reports and/or research publications
Research dissemination will be completed via a PhD dissertation. No other dissemination has been completed thus far.

7) The HREC welcomes any feedback on: • **Difficulties experienced with carrying out the research project; or** • **Appropriate suggestions which might lead to improvements in ethical clearance and monitoring of research.**

Annual/Final Project Report

Human Research Ethics Committee

8) Signatures			
Principal Researcher:	Print name: Dr. Christopher Mesagno	**Date:**	1/12/2020
Other/Student Researchers:	Print name: Brad Beseler	**Date:**	1/12/2020
	Print name: Dr. Mandy Plumb	**Date:**	1/12/2020
	Print name: Dr. Nicola Johnson	**Date:**	1/12/2020

Submit to the Ethics Office, Mt Helen campus, by the due date:
research.ethics@federation.edu.au