An Exploration into The Learning Process to Independent Cycling in Preschool Children

by

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A thesis submitted for the award of Doctor of Philosophy (PhD) to the School of Health and Human Performance, Dublin City University, Dublin, Ireland

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January 2020

Authors Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work, and that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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Acknowledgements

I would like to extend my sincere gratitude to the following people who helped in various ways during the completion of my thesis:

To my supervisors for providing constant encouragement and for being a great team of minds to learn, grow and work with. Kieran, thank you for believing in me all those years ago, for being patient and for pushing me to always do more. Johann, thank you for providing me with invaluable guidance, knowledge, laughs and friendship.

To my fellow postgrads/postdocs 'Alberts Legends', you guys made the office such a comfortable and happy place to be. Thank you from the bottom of my heart for all the chats and laughs and for making the last 4 years far more enjoyable than could ever have been expected.

To Ardtona House School and all the preschools, parents, teachers and especially the children who participated in the studies. The laughs and fun had while with you made up some of the best moments.

To all the students and staff of the School of Health and Human Performance who helped over the 4 years. To Ryder, who provided comfort not only to the children but also to myself and my fellow postgrads when we needed it the most.

To Yvolution Ltd. for your collaboration, generosity and for backing the project. To the Irish Research council for your funding and to South Dublin County Council and DCU Sport for providing free use of your facilities.

To all my friends and especially anyone who has ever called 33 Iveragh home, thank you for all the highs and support that made me feel like I was at no point doing this PhD alone.

Most of all to my extraordinary family, for your strength, inspiration, belief, support, comfort, kindness and love. You're the best people and dogs I know. A special mention has to go to my Mom, by just being your wonderful and optimist self you have encouraged me throughout my life to push beyond my limits and do what makes me happy, without you I wouldn't be submitting this PhD thesis at all.

Funding Sources:
This research was funded by The Irish Research Council and Yvolution Ltd. under grant number EPSG/2016/147.

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List of Abbreviations

ACI	*Ability to Cycle Independently*
AMC	*Actual Motor Competence*
BB	*Balance Bike*
BS	*Bike with Stabilisers*
FMS	*Fundamental Movement Skills*
IMU	*Inertial Measurement Unit*
MABC-2	*Movement Assessment Battery for Children – second edition*
MSE	*Motor Skill Engagement*
PMC	*Perceived Motor Competence*
RCT	*Randomised Control Trial*
TGMD	*Test of Gross Motor Development*

Publications and Public Outreach

Journal Articles

1. **Kavanagh, J. A., Issartel, J., Moran, K., 2019.** Quantifying Cycling as a Foundational Movement Skill in Early Childhood. *Journal of Science and Medicine in Sport (in press).* https://doi.org/10.1016/j.jsams.2019.08.020
2. **Kavanagh, J. A., Issartel, J., Moran, K., 2019.** How actual motor competence and perceived motor competence influence motor skill engagement of a novel cycling task. *Scandinavian Journal of Medicine and Science in Sport (in press).* https://doi.org/10.1111/sms.13492
3. **Kavanagh, J., Moran, K., Issartel, J., 2019.** Development and Reliability of the KIM Cycling Scale – A Measurement Tool for the Development Process to Cycling Independently. *Physical Education and Sport Pedagogy (in press).* https://doi.org/10.1080/17408989.2019.1700497

Conference Presentations

1. Kavanagh, J., Issartel, J., Moran, K. Methodology for Study 1. *Psychike, Co. Down, Ireland. May 2016.*
2. Kavanagh, J., Issartel, J., Moran, K. Motor control and balance bikes. *NASPSA, San Diego, USA. June 2017.*
3. Kavanagh, J., Issartel, J., Moran, K. Is Balance Predictive of Independent Cycling in Preschool Children? *NASPSA, Denver, USA. June 2018.*
4. Kavanagh, J., Issartel, J., Moran, K. Effectiveness of a five-week cycling intervention on learning to cycle independently. *UCD Child and Health. August 2018.*

Public Outreach

1. Written piece on benefits of learning to ride a bike. RTÉ Brainstorm. February 2019. https://www.rte.ie/brainstorm/2019/0220/1031672-why-cycling-is-good-for-you/
2. Video on Risky Play. RTÉ. June 2019. https://www.facebook.com/watch/?v=817137232006797.

Abstract

There is limited research exploring how children learn to cycle. The learning process to independent cycling generally occurs on an adapted bike (eg. two additional wheels, no pedals). Balance bikes have recently gained attention as a more appropriate method to learn to cycle. Currently, there is no evidence to support this argument and moreover, limited exploration into the learning process to independent cycling. Four studies in total were performed with children between 2-6 years of age. Study 1 consisted of an 8-week intervention whereby the intervention group were given balance bikes to free play on. Study 1 aimed to explore ability on a balance bike (BB) as a measure of the learning process to independent cycling and explore the relationships between ability on a BB, actual motor competence (AMC) and perceived motor competence (PMC). Furthermore, study 1 also investigated whether ability on a BB, AMC or PMC predicted how much a child would engage on the balance bike. During study 1 a cycling scale was developed to assess the children's ability to cycle independently (ACI) on a traditional bike. Study 2 and study 4 were reliability studies used to assess the reliability of this scale and usability for practitioners. Study 3 consisted of 10 cycling classes over 5 weeks and was designed in order to teach preschool children independent cycling on either balance bikes or bikes with stabilisers. ABB, AC, PC and ACI were assessed along with balance measured using inertial sensors placed on the frame of the balance bike. ACI was measured at 5 timepoints (pre, week 2, mid, week 4, post) to investigate how children progress along the cycling scale. This novel research has addressed key questions on how children learn to cycle and started the journey to greater understanding.

Chapter 1- Introduction to the Thesis

Learning to cycle independently is a milestone for most children. The beginning of this learning process generally begins between 3 and 5 years of age through practice on a constrained version of a traditional bike (i.e. balance bike, bike with stabilisers). Learning to cycle independently is an acquired skill, that is not easily attained (Åström, Klein, & Lennartsson, 2005). Cycling is a fun and a popular pastime and furthermore, it opens up more opportunities for a healthy lifestyle through physical activity and transportation. The World Health Organisation recommends that children receive 60 minutes of moderate to vigorous physical activity a day (WHO, 2010), which contributes to the primary and secondary prevention of several chronic diseases (Warburton & Bredin, 2017). While there is ample evidence supporting the importance of physical activity, more than 80% of the world's adolescent population are not meeting the recommended guidelines (WHO, 2017). Active travel (including cycling for transportation) can be an easy way for children to incorporate physical activity into their daily routine.

Childhood is a critical period as many physiological and psychological changes take place (Ortega, Ruiz, Castillo, & Sjöström, 2008). Fundamental movement skills (FMS) are generally developed in early childhood (Lubans, Morgan, Cliff, Barnett, & Okely, 2010); as they are not naturally developed they must be learned through practice (Gallahue, Ozmun, & Goodway, 2006). Having a broader experience of these fundamental movements provides a wealth of information with which children base their perceptions of themselves and the world around them (Gallahue et al., 2006). Children have the developmental potential to progress to the mature stage of most FMS by the age of six (Gallahue et al., 2006). As children progress through this phase they are able to apply their combined FMS to produce specialised skills in sports and recreational activities like cycling (Clark, 2005). Therefore, the mastering of FMS during early childhood is thought to be essential for successful participation in sports and physical activities (Stodden, Langendorfer, & Roberton, 2009). Lifestyle behaviours that are established during childhood and adolescence subsequently influence adult behaviours. Cycling is a good example of this, as being able to cycle as a child opens up opportunities to become more confident on a bike which may subsequently lead to confidence to cycle for transportation later in life.

Hulteen and colleagues proposed an amendment to the current FMS structure and content within motor development models (Clark & Metcalfe, 1989; Gallahue et al., 2006) to include the addition of more skills that lead to lifelong physical activity (Hulteen, Morgan, Barnett, Stodden, & Lubans, 2018). The addition of these new skills alongside traditional FMS was given the heading 'Foundational Movement Skills'. Identifying these additional foundational skills seems to be an essential primary step in developing more appropriate interventions and recommendations for policy makers (Hulteen, Morgan, et al., 2018). The addition of several skills to the motor development model was proposed, including cycling, in order to encourage the uptake of more skills during this crucial window of development (Hulteen, Morgan, et al., 2018). It is necessary to highlight cycling as an important skill within foundational movement skills as, along with its ample health benefits, it can promote continued physical activity participation across the lifespan.

In order to promote cycling in early childhood, emphasis must be placed on the development of the skill and its role alongside other accepted important FMS skills like locomotor, object control and stability. Assessment tools are important drivers of focus within motor development research. Currently, interventions that look to improve motor competence in early childhood are examined through a change in both subcomponents of FMS, and overall FMS as a composite score (Altunsöz, 2015; Bardid et al., 2013). Understanding the role of cycling within the motor development model, and subsequently determining the placement of cycling within the model, would allow researchers to include cycling in their assessments of motor competence. This, in turn, may steer researchers and policy makers to place importance on the development of cycling within early childhood.

With the addition of cycling to the motor development model, it is also important to examine the relationships that exist between cycling and actual and perceived motor competence. Stodden and colleagues (2008) developed a model to demonstrate the interactions between actual motor competence, perceived motor competence, health related physical fitness and physical activity over time. As a result, these relationships have been examined in early childhood (Lopes, Barnett, & Rodrigues, 2016; Robinson, 2011), but have never been looked at in relation to ability on a balance bike. Behavioural engagement is considered crucial for achieving positive performance outcomes as it draws on the idea of participation and includes involvement in extracurricular activities (Fredricks, Blumenfeld, & Paris, 2004). Previous research in behavioural engagement in motor skill contexts has defined motor skill engagement (MSE) as the amount of practice (Lacy & Martin, 1994). It has been previously hypothesised that increased perceived motor competence would positively influence MSE in an activity (Eccles & Harold, 1991; Eccles & Wigfield, 2002). However, to the author's knowledge, there has been no research into the relationship between either actual or perceived motor competence and MSE of a novel skill in early childhood.

Balance bikes have recently gained attention as a potentially more appropriate precursor to independent cycling than bikes with stabilisers, as a number of manufacturers claim that the skills learnt on a balance bike are directly transferable to riding a traditional bike ("Halfords," 2019; "LIKEaBIKE," 2019; “Strider," 2019.; "Littlebigbikes," 2019). However, no studies have been undertaken to evaluate the accuracy of these statements. Understanding how a child learns to cycle would perhaps first start with how a child learns on a balance bike and how they then progress onto cycling on a traditional bike with pedals. There is no research to date examining the developmental paths that children take during the development of independent cycling. In order to understand these developmental paths, there must be a measurement tool designed to assess the developmental process to independent cycling. Such a measurement tool would enhance understanding of competence in the development of cycling in the preschool years, thereby facilitating the promotion of cycling as a lifelong skill along with the FMS. Specifically, it would allow teachers and practitioners to assess competence in cycling and, moreover, track changes in skill development. In addition, having a measurement tool to assess ability to cycle independently would allow investigation into the possible transfer of skills (e.g. speed, dynamic balance) from balance bikes to independently cycling on a traditional bike.

Therefore, in summary the overall aims of the current thesis are to understand how ability on a balance bike fits within current motor development models and its relationships to commonly researched variables within the area. Furthermore, to develop a scale to assess independent cycling and to use this scale to investigate how a child progresses through the learning and developmental process to independent cycling.

Primary Objectives:

1. To explore balance bikes as a commonly used tool for learning to cycle independently and how ability on a balance bike fits within the motor development model as a foundational movement skill alongside traditional fundamental movement skills (Chapter 3 – Study 3).

2. To investigate how engagement on a balance bike, as measured through amount of practice, relates to improvement of ability on a balance bike (Chapter 4 – Study 1).

3. To investigate the relationships between actual motor competence, perceived motor competence and ability on a balance bike and whether these factors influence engagement on a balance bike (Chapter 4 – Study 1).

4. To explore the developmental paths to independent cycling and develop a tool to assess the learning process to independent cycling (Chapter 5 – Study 1, 2 ,3&4).

5. To investigate the effectiveness of a 5-week cycling intervention on ability to cycle independently on both balance bikes and bikes with stabilisers (Chapter 6 – Study 3).

6. To investigate whether dynamic balance on a balance bike progresses following a 5-week cycling intervention (Chapter 6 – Study 2).

Chapter 2 – Review of Literature

2.1 Introduction

The first bicycle was invented in the 1800's and since then cycling has become one of the most popular physical activities for adults and children alike (Hulteen et al., 2017). Learning to cycle independently is a milestone for most children and their parents. Once independent cycling is achieved, this skill can be enjoyed throughout life for various purposes including transportation, sport and leisure. Moreover, cycling offers many health benefits (Oja et al., 2011). However, while cycling is undoubtedly an important lifelong skill, there is little research exploring how the acquisition of this skill occurs.

2.1.1 Structure of the Literature Review

The presented review of literature begins with exploration into the learning process to independent cycling (section 2.2.1). Children generally learn to cycle independently in the preschool years from 3-5 years of age. Consequently, motor development during this time, namely the fundamental movement phase, is then discussed (section 2.3). Motor competence is ability at motor skills with fundamental movement skills often being used to measure actual and perceived motor competence. Therefore, assessments of actual and perceived motor competence and the current literature that has explored the relationships between the two are discussed. More recently it has been highlighted that research has focused on fundamental movement skills without consideration for other skills that may contribute to lifelong physical activity. Lifelong skills, including cycling were highlighted as important skills to be considered in research (Hulteen, Barnett, et al., 2018). Subsequently, the limited theory surrounding lifelong skills and engagement in skills is briefly reviewed (section 2.3.4). Following on, the possibility of the occurrence of transfer of skills like speed and dynamic balance, from these constrained bikes and/or fundamental movement skills are explored (section 2.4). The benefits of cycling are then discussed (section 2.5). In order to investigate the learning process to independent cycling, assessments of cycling, interventions to improve cycling skills and interventions in the preschool years must be understood. Therefore, the presented review of literature concludes with a review of these topics (section 2.6 & 2.7).

2.2 Introduction to Cycling

Cycling independently for the first time is a milestone for most children and their parents/guardians. During early childhood, cycling is one of the most commonly reported active recreational pastimes (Dunst, Hamby, & Snyder, 2009; Nielsen, Pfister, & Andersen, 2011) and throughout life is one of the most commonly reported physical activities globally (Hulteen et al., 2017). Independent cycling can be defined as cycling a traditional bike (two wheels and two pedals), without assistance of a person holding on to support the cyclist or additional wheels. Independent cycling, alike most motor skills, does not come naturally and practice and experience are required for behavioural changes to occur (Haywood & Getchell, 2005). Practicing on a traditional bike can be a daunting task, one that is likely to result in multiple falls from the bike. As a result, most children go through the learning process to independent cycling on a constrained version of a traditional bike.

2.2.1 The Learning Process to Independent Cycling

The learning process to independent cycling can be defined as the process a child goes through when learning to cycle on a constrained version of a traditional bike before mastery or independent cycling occurs. Traditionally the bike was constrained by adding two extra wheels to the back of the bike, allowing more support. This type of bike is commonly known as a bike with training wheels or in Ireland and Europe known as a bike with stabilisers. More recently, a constrained version of the traditional bike with no pedals, allowing the child to use their feet on the ground to propel themselves forward, has increased in popularity. Balance bikes, running bike and strider are common names given to this type of bike. Manufacturers claim that balance bikes teach children skills like balance which are directly transferable to cycling a traditional bike (“Strider,” 2019; “LIKEaBIKE,” 2019). However, there is no empirical evidence to support this claim. Similarly, there is no empirical evidence to suggest that bikes with stabilisers teach children transferable skills to independent cycling.

The use of constraints in the learning process of a skill is not unprecedented and is in fact common, with Newell’s model of constraints extensively recognised as a motor learning model to follow for acquisition of skills (Davids, Button, & Bennett, 2008; Haywood & Getchell, 2005; Newell, 1986). Newell’s model was first proposed by Newell in 1986 and suggests that all movements occur based on interactions between the individual, task and environment (Haywood & Getchell, 2005; Newell, 1986). While all three constraints are in constant interaction with one another, promotion of skill acquisition can occur through further manipulation of one or all three of these constraints (Davids et al., 2008). Therefore, it is possible that practicing on a balance bike or a bike with stabilisers allows mastery of parts of the skill that can then be transferred to cycling independently. However, evidence is needed to back this up and furthermore, exploration into which skills may be progressed and subsequently used in cycling independently warrants exploration.

Cycling is a motor skill and therefore is a learned goal-orientated, voluntary movement of body parts. The process of motor development acknowledges itself mainly through changes in movement behaviour over time. Acquisition of new motor skills is a vital part of life. From fundamental skills like running, jumping and kicking to skills like cycling and swimming, we continue to learn and adapt to different motor skills that enable us to function optimally in daily life. Successful acquirements of new motor skills are either learnt without prior learnt behaviours (e.g. walking) or are learnt as a transfer from a previously learnt skill (e.g. walking to running). The formation of a new skill occurs through practice, engagement and experience at a skill (see section 2.3 for discussion on motor development) that triggers multiple central nervous system processes that constitute learning (Kantak & Winstein, 2012).

One problem that arises when learning a new skill is the degrees of freedom problem that was first raised by the Russian psychologist Nikolai Bernstein (Schmidt & Lee, 2005). The problem is that there are simply too many independent states that can move freely in various directions, or in other words, too many degrees of freedom. The motor control system can't control all these degrees of freedom at once when executing a new skill and so it instead constrains as many degrees of freedom as possible while still allowing the skill or task to be accomplished. This is done in order to reduce the contribution of their independent variability. When a person practices a skill and progresses from a beginner to a skilled performer, the motor control system solves the degrees of freedom problem by realising and reorganising the degrees of freedom. As degrees of freedom are released, the movement becomes unstable which causes the motor control system to reorganise them in search for a more stable movement (Kelso, 1995). The process from destabilised patterns to the emergence of a different stable pattern is known as a self-organisation process (Kelso, 1995). This self-organisation process continues as the person practices and progresses, allowing more complex communication networks between head, body and limb movement patterns, resulting in higher levels of success (Magill, 2007). As the learner becomes an expert a new movement will emerge that is more controlled and stable while still utilising more information from the body due to the releasing of the degrees of freedom.

Independent cycling, alike other motor skills, is a skill that most cannot perform without practice. Cycling is also a skill that requires a certain amount of control and dynamic balance in the movement pattern in order to independently cycle. Having a controlled and stable movement pattern requires the degrees of freedom to first be gradually released and reorganised into control states (Kelso, 1995). As discussed previously, the learning process to independent cycling generally occurs on a constrained version of a traditional bike. Constraining the bike reduces the complexity of the skills (i.e. no pedalling and/or balancing), thus allowing the child to engage differently in the new task, providing more time for the degrees of freedom to be released and reorganised into a new controlled and stable movement pattern.

An interesting characteristic of learning motor skills is that human behaviour appears to go through distinct stages when acquiring a skill. While there are multiple models and theories that can be discussed with relation to learning [e.g. Open and Closed Loop Systems, Gentile's two stage model, Schmidt's Schema Theory (Kelso, 1995; Magill, 2007; Schmidt & Lee, 2005)], the current thesis has chosen to focus on the commonly used dynamical systems theory and Fitts and Posner's three stage model as both are relevant and continually referred to by researchers when describing what changes within the motor control system when transitioning from beginner to skilled performer (Kelso, 1995; Magill, 2007). The first stage in

Fitts and Posner's three stage model is referred to as the cognitive stage of learning. During this stage performance is typically marked by a large number of large errors (Magill, 2007). There is also a distinct lack of consistency from one attempt to the next due to the restructuring of the degrees of freedom. After an unspecified amount of practice and subsequent improvement in performance, transition into the associative stage of learning occurs. It is the cognitive activity that changes at this stage (Schmidt & Wrisberg, 2008) as the person has learned to associate specific environmental cues with the movements required to achieve the goal of the skill in an efficient manner (Magill, 2007). During this phase, that is often aptly referred to as the refining stage, performance becomes more consistent but still improvement is warranted. After much practice, the third and final stage known as the autonomous stage is reached. At this point, which in certain skills many will never reach, the skill becomes almost automatic or habitual (Magill, 2007). If this stage is reached, the person is referred to as a skilled performer. These skilled performers can detect their own errors and make the appropriate adjustments to correct them (Schmidt & Wrisberg, 2008). What is an important factor of Fitts and Posner's model is that it is a continuum of practice time, and without practice, transition between stages would not occur (see Figure 2.1).

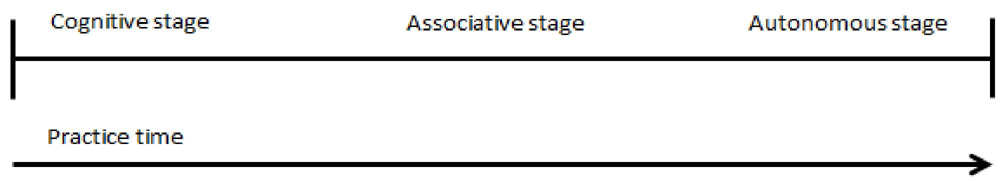


Figure 2.1. Fitts and Posner's model (Magill, 2007)

Generally during the early stages of practice of a new skill there is a large amount of improvement relatively quickly. As practice continues, the amount of improvement decreases (Magill, 2007). This is known as the power law of practice (Snoddy, 1926). The difference in rate of improvement can be partly attributed to the amount of improvement available at a given stage in the skill acquisition process. The errors made by the learner at the beginning can be large and often easy to correct after some practice. The errors made in the later stages of practice are much smaller and refined (Magill, 2007).

2.3 Motor Development in the Preschool Years

In order to explore the acquisition of cycling in early childhood, it is necessary to discuss the current motor development research during this time. Motor development is the study of motor behaviour over time and is often represented in phases of motor development (Clark & Whitall, 1898). The process of motor development can be viewed as phase-like and stage-like as all humans from infants to adults are involved in the lifelong process of learning how to move in response to constantly changing environments (Gallahue & Ozmun, 2006). Figure 2.2 describes the phases of motor development across the lifespan. The preschool years are between the ages of 2 and 5 years. As seen in Figure. 2.2 these years fall into the fundamental movement phase of motor development. More recently, Hulteen and colleagues (2018) proposed an amendment to the motor development model which included the addition of lifelong skills within the FMS phase of development (Hulteen, Morgan, et al., 2018). Lifelong skills will be discussed further in section 2.3.4.

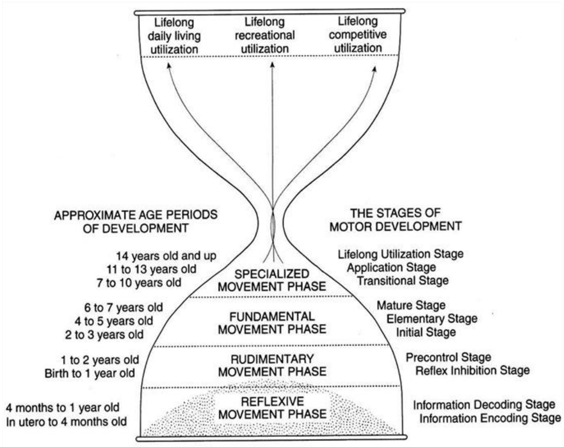


Figure 2.2. Motor Development across the lifespan (Gallahue & Ozmun, 2006)

2.3.1 Fundamental Movement Phase

The fundamental movement phase of motor development occurs as children are actively exploring and experimenting with how their bodies move and the potential for new movement (Haywood & Getchell, 2005). During this time stabilising, locomotor and manipulative movements are explored, first in isolation, and then eventually in combination with one another. Stability movements are any movements that involve gaining and maintaining equilibrium in relation to gravity. Locomotor movements involve changing location of the body relative to a fixed point on the surface, while manipulative movements are movements that use both fine and gross motor skills to manipulate objects. Stability, locomotor, and manipulative movements are known as fundamental movement skills (FMS) as they are the most basic observable patterns of movement and motor behaviour and are the building blocks for movement (Gallahue & Ozmun, 2006). FMS are generally developed in early childhood (Lubans et al., 2010); they are not naturally developed and so must be learned through practice (Gallahue & Ozmun, 2006). Having a broader experience of these FMS provides a wealth of information on which children base their perceptions of themselves and the world around them. FMS are often used to describe motor competence, however motor competence can be described using various terminology such as motor proficiency, motor ability, motor performance and motor coordination (Robinson et al., 2015). Motor competence can be defined as a person's movement coordination quality and level of performance outcome when undertaking different motor skills (Robinson et al., 2015).

There are three stages within the fundamental movement phase: initial stage, elementary stage and mature stage. The initial stage represents the child's first attempts at performing a fundamental skill. Correct performance of skills will be missing or have improperly sequenced parts. Movement is generally restricted due to freezing of degrees of freedom (Kelso, 1995) or exaggerated due to poor rhythmical flow and coordination (Gallahue & Ozmun, 2006). The elementary stage involves greater rhythmical coordination leading to greater control (Gallahue & Ozmun, 2006). Although this stage has greater coordination, movement is still restricted or exaggerated. Advancement to this stage is generally seen through maturation and is observed in the typical 3-4 year old (Gallahue & Ozmun, 2006). The mature stage is characterised by mechanically efficient, coordinated and controlled performances (Gallahue & Ozmun, 2006). Children have the developmental potential to progress to the mature stage of most FMS by the age of 6 (Gallahue & Ozmun, 2006). Progression onto a mature form of FMS proficiency depends on opportunities for practice, encouragement, feedback and instruction in an environment that contributes to learning (Lubans et al., 2010). The development of motor competence (including FMS) is affected by positive and negative influences within the task, individual and environment (Gallahue & Ozmun, 2006; Haywood & Getchell, 2005). As children progress through this phase, they can apply their combined FMS to produce specialised skills in sports and recreational activities. FMS are crucial to participation in physical activities as they represent the essential behavioural competencies for participation (Okely, Booth, & Chey, 2004). Therefore, the mastering of FMS and subsequent development of motor competence during early childhood is essential for successful participation in sports and physical activities (Stodden, Langendorfer, & Roberton, 2009) as early experiences with movement skills are crucial for the development of more advanced, sport specific skills later in life (Clark, 2005).

Developing FMS during early childhood has been shown to lead to an increase in participation in physical activity in early childhood (Figueroa & An, 2017), in adolescence (Lloyd, Saunders, Bremer, & Tremblay, 2014) and a 17-59% likelihood of participation throughout life (Lloyd et al., 2014; Logan, Kipling Webster, Getchell, Pfeiffer, & Robinson, 2015). Without competence in FMS children are less likely to access the abundance of physical activity options available to them to lay the foundations for an active lifestyle (Lubans et al., 2010;Stodden et al., 2008). On the other hand, children who develop a high level of proficiency in FMS in early childhood and continue to become skilful into middle childhood and adolescence will subsequently have more opportunities to participate and be successful in activities that require fundamental movement skills as adults (Stodden et al., 2009). Children that have a higher competency in movement skills move more efficiently (Kelso, 1995), therefore requiring less energy expenditure. This alone may contribute to more physical activity and subsequently a healthy body weight. FMS uses high levels of muscular and cardiorespiratory fitness to persist in the activities. These performance criteria are foundational aspects of health related fitness (Stodden et al., 2008). A low competence in FMS has been positively correlated with low levels of cardiorespiratory fitness (Barnett, Van Beurden, Morgan, Brooks, & Beard, 2008; Haga, 2008; Hardy et al., 2012; Lubans, Morgan, Cliff, Barnett, & Okely, 2010), a high BMI (Logan, Scrabis-Fletcher, Modlesky, & Getchell, 2010; Lubans et al., 2010; Okely, Booth, & Chey, 2004) and a high skinfold thickness (Parsons, Power, Logan, & Summerbell, 1999). As shown, there has been an interest in researching the benefits of having a high proficiency at FMS. However, other skills like cycling have been largely neglected and so at present there is limited work on the possible benefits of learning to cycle during childhood and how these benefits may correlate and predict higher levels of physical activity and subsequently a healthier life.

When children are more physically active and spend more time in moderate to vigorous physical activity they increase their motor competency (Fisher et al., 2005; Saakslahti et al., 1999; Williams et al., 2008). Having a greater motor competency in the early years means children are more likely to remain physically active throughout their lifetime (Lloyd et al., 2014). This may be explained by the hypothetical "proficiency barrier" that children meet towards the end of the FMS phase of motor development. The proficiency barrier was first proposed by Seefeldt (1979) in his motor development model (Seefeldt, Nadeau, Halliwell, Newell, & Roberts, 1980). The proficiency barrier theory originated from the idea that children generally have inaccurate and inflated levels of perceived motor competence in the early years that becomes increasingly more accurate as they transition out of the FMS phase of motor development and into middle childhood (Harter, 1999). If a child has a high level of FMS when reaching the proficiency barrier they are more likely to break through the barrier and apply these skills to sport specific skills, leading to a positive trajectory towards lifelong participation in physical activity (De Meester et al., 2018a). In contrast, if a child has not mastered FMS by this time then they are less likely to want to engage in physical activity. De Meester and colleagues found that almost 90% of children in their study (n=326) whose actual motor competence was below average did not meet the recommended physical activity guidelines of 60mins a day (De Meester et al., 2018a; World Health Organization., 2004). Therefore, the early preschool years are vital to the development of motor competence and a subsequent physically active lifestyle.

2.3.2 Assessments of Motor Competence for Preschool Children

A wide variety of assessment tools are available to assess actual motor competence levels in children; however, a limited number exist for early childhood (3-5 years). Those tools that do allow for assessment in early childhood either employ product- or process-oriented measures or in some cases a mix of both. Product-oriented measures the outcome of the skill, e.g. speed ran, or distance jumped. Process-oriented on the other hand measure the quality of the skill, e.g. right arm and right leg swinging alternate to each other or both knees bent before the jump (Burton & Miller, 1998). Motor competence is often assessed through a variety of different skills from gross motor skills, including subcomponents of FMS (locomotor, object control, stability) to fine motor skills, and can be performed using observational methods, subjective methods and motion devices (Bardid, Vannozzi, Logan, Hardy, & Barnett, 2018). Observational methods are the most common methods utilised to assess motor competence in preschool settings with the Movement Assessment Battery for Children, second edition (MABC-2) and The Test of Gross Motor Development (TGMD) being the most common assessment tools for this age range (3-5 years). Subjective methods commonly include proxy-reports and so are not appropriate in early childhood when children may not have the cognitive skills to accurately assess their own competency at motor skills (Bardid et al., 2018). The use of motion devices is not common outside of the laboratory settings, however the development of inertial measurement units to measure human movement has helped to overcome this by allowing assessment of motor competence in field settings. Inertial measurement units are discussed further in section 2.6.1.

The Test of Gross Motor Development (TGMD) is one of the most common process-oriented assessment tools used (Ulrich, 2017). The most recent edition of the TGMD series is the TGMD-3 (third edition) which provides process-oriented assessments for six locomotor skills and seven object control skills (Ulrich, 2013). Each skill is assessed on a best of two trials after one practice trial and is made up of between three and five components that are assessed on a binary scale of the component being either present (score of '1') or not present (score of '0'). The TGMD-2 was designed for children between 3 and 10 years of age, and has been widely used due to its high validity and reliability (Cliff et al., 2011; Hardy et al., 2010; O' Brien et al., 2015a). Limitations of the TGM-3 are that it doesn't assess stability or fine motor skills (Rudd et al., 2015).

The Movement Assessment Battery for Children is a commonly used product-oriented measure of motor competence in preschool children (Henderson et al., 2007). The most recent edition is the MABC-2 (second edition) and is designed for children between 3-16 years of age (S. Henderson et al., 2007). It assess three manual dexterity skills, two object control skills and three stability skills with the tasks being altered based on the participant's age (T. Brown & Lalor, 2009). Outcome scores for each skill are standardised and normative scores are provided for each age category (3-6 years; 7-10 years, 11-16 years); individuals at risk of movement difficulties are identified using a traffic light system (Henderson et al., 2007). A limitation of the MABC-2 is that it doesn't assess locomotor and is product-oriented in measurement, meaning that it doesn't assess the quality of the skill (i.e. if the components of a skill are executed using correct technique).

2.3.2.1 Assessment of Perceived Motor Competence for Preschool Children

There are a limited number of assessment tools available to measure perceived motor competence in preschool children. Harter and Pike (1984) developed the first assessment tool for preschool children “Pictorial Scale of Perceived Competence and Acceptance for Young Children”. The preschool section of this tool was designed for children from 4 to 5 years of age and within the motor competence domain measured perceived physical competence through perceptions of ability at six items (swinging, climbing, skipping, running, tying shoes and hopping). Perceived motor competence is assessed by asking the children to indicate which scenario they most identified with, through pictures of children performing each skill at four different capabilities. The Pictorial Scale of Perceived Competence and Acceptance for Young Children is a validated and reliable tool for assessing preschool children motor competence (Harter and Pike, 1984). While this scale assesses typical childhood gross and fine motor activities, it does not assess the more commonly measured skills in actual motor competence assessment (eg. jumping, catching, throwing) or lifelong skills (eg. cycling, swimming). This may be limiting when exploring the possible relationships between actual motor competence at FMS or cycling ability and perceptions of competence at these skills as the skills measured are not directly comparable.

The “Children’s Perception of Motor Competence Scale” was developed by Pérez & Sanz, (2005). This validated and reliable assessment too was designed to measure children from 4 to 6 years of age in perceived motor competence of manual dexterity skills (i.e. fine motor skills), object control skills and stability skills. The skills assessed are similar to those assessed in the MABC-2, allowing direct comparison between the two to be made (Brown & Lalor, 2009; Pérez & Sanz, 2005).

Barnett et al. (2015) used a similar approach by aligning the development of their assessment tool "Pictorial Scale of Perceived Movement Skill Competence for Young Children" with the TGMD. This scale has been validated and shown good reliability (ICC=0.83) for assessment of perceived motor competence in children between 4 and 8 years (Barnett et al. 2015, 2016). Skills assessed include object control and locomotor skills, to align with the TGMD, as well as lifelong skills such as cycling, scootering and swimming. Each skill is assessed along a 4-point scale using two picture scenarios of children performing the skill with competently or not competently. The child is asked to first indicate which child they think they are most like. From this, the child is asked to indicate whether they are very like the child in the picture or kind of like the child. An advantage of the Pictorial Scale of Perceived Movement Skill Competence for Young Children is that it allows direct comparison to commonly used assessments of actual motor competence and with lifelong skills, such as cycling.

In light of the above, the current thesis chose to use the MABC-2 due to the inclusion of fine motor skills and stability as well as being a product-oriented measurement, allowing comparisons to product-oriented measurements of cycling ability to be made. The Pictorial Scale of Perceived Movement Skill Competence for Young Children was chosen as the assessment of perceived motor competence, due to its inclusion of lifelong skills, such as cycling.

2.3.3 Relationship between Perceived Motor Competence and Actual Motor Competence

As discussed previously, children have inflated levels of perceived motor competence in early childhood that becomes more accurate as they progress into middle childhood. These high perceptions have been thought to drive acquisition of actual motor competence. Therefore, perceptions of motor competence are an important factor to consider when attempting to increase actual motor competence. Consequently, Stodden and colleagues (2008) developed a model to represent the interactions between actual motor competence, perceived motor competence and health related physical fitness and physical activity over time (Figure 2.3) (Stodden et al., 2008) It was proposed that the relationships between the variables would change as developmental age changed and therefore, early, middle and late childhood were separated within the model. Research into the relationship between perceived and actual motor competence in early childhood has shown conflicting results. LeGear et al., (2012) and Robinson, (2011) found significant weak and moderate positive associations between actual and perceived motor competence in preschool children. Similarly, Barnett, Ridgers, and Salmon (2015) found significant positive associations between actual and perceived object control skills in preschool children. However, other research conflicts with these findings by finding no relationships (Lopes et al., 2016; Spessato, Gabbard, Robinson, & Valentini, 2013). It is clear from the above that more research is needed to explore these relationships. Furthermore, as ability on a balance bike has not been previously explored, it is important to investigate how actual and perceived motor competence relate to ability on a balance bike and likelihood of engagement on a balance bike.

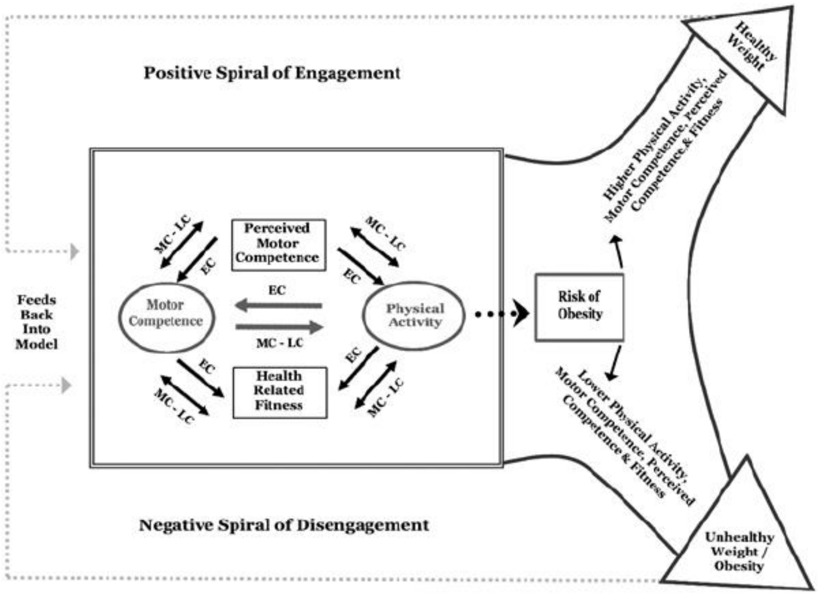


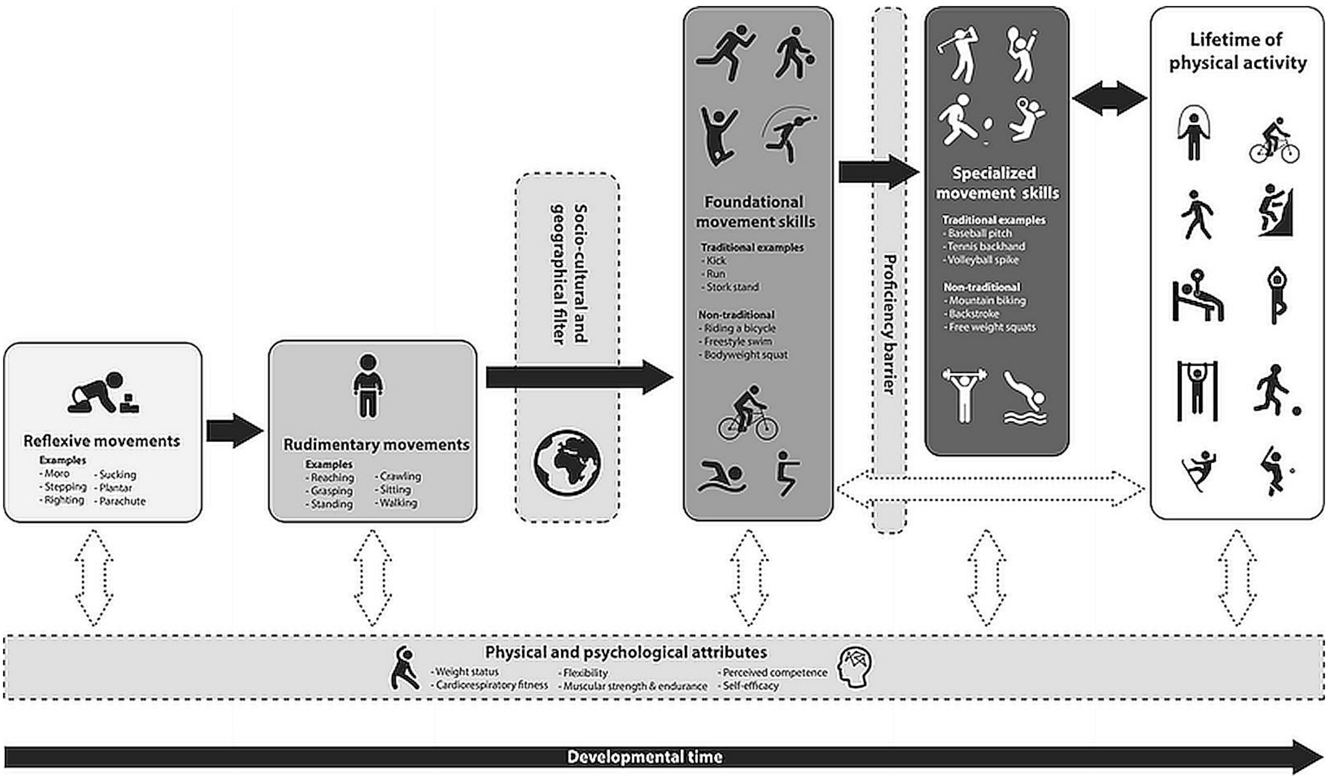
Figure 2.3. Developmental mechanisms influencing physical activity trajectories of children (Stodden et al. 2008)

2.3.3.1 Motor Skill Engagement

The theory that high perceptions of competence drive skill acquisition originated from earlier research which theorised that perceived motor competence was tied to task engagement (Harter & Pike, 1984; Nicholls, 1978; Nicholls & Miller, 1983). Therefore, behavioural engagement is also an important factor to consider when promoting skill acquisition. Behavioural engagement is crucial for positive achievement in performance as practice at skills is necessary for improvement (Fredricks et al., 2004). Previous research into behavioural engagement has defined motor skill engagement as the amount of practice (Lacy & Martin, 1994). Understanding what influences a child's level of motor skill engagement may be an important factor to consider when trying to encourage a child to learn a new skill and in designing interventions to improve motor competence. However, to the author's knowledge there has been no research into motor skill engagement in the preschool years.

2.3.4 Lifelong Skills

Childhood is a critical period as many physiological and psychological changes take place (Ortega et al., 2008). Lifestyle behaviours are established during childhood and adolescences which may subsequently influence adult behaviours (Gallahue & Ozmun, 2006). Motor competence has important implications in various aspects of the development in children (Piek, Baynam, & Barrett, 2006). An essential part of participation and a lifelong interest in a physically active lifestyle comes from mastery of basic motor skills that predominantly evolve during the preschool years (Wick et al., 2017). This may be attributed to children's high perceptions of competence in adolescence arising from mastery of skills in early childhood, while their perceived competence is inflated (True, Brian, Goodway, & Stodden, 2017). If these skills are not mastered in early childhood when levels of perceived movement competence are high, then as the child transitions into middle childhood their perceived movement competence becomes more accurate and therefore is low; this may subsequently lead to an increased likelihood of disengagement from physical activity (De Meester et al., 2018; Stodden et al., 2008). Therefore, during early childhood, it is important to research and promote all skills that are important to learn during this stage that may contribute to a physically active life. FMS have been a sole focus of motor competence research during early childhood. Hulteen and colleagues (2018) proposed amendments to the motor development model, one of which was to include more skills that lead to lifelong physical activity alongside FMS (Figure 2.4). The addition of these new lifelong skills, along with traditional FMS, was given the heading 'Foundational Movement Skills'. Foundational movement skills are defined as goal-directed movement patterns that can be developed to increase the capacity to be physically active across the lifespan. Cycling along with other skills, such as freestyle swimming stroke, bodyweight squat and scootering, were proposed (Hulteen, Morgan, et al., 2018). The addition of cycling and other skills to the motor development model encourages research into the factors that affect the motor learning processes for these skills. In order to better understand these skills, assessment tools must first be designed in order to measure ability of the skill.



2.3.4.1 Assessment of Lifelong Skills

Figure 2.4. Motor Development Model (Hulteen at al., 2018)

One valid and reliable test battery to assess lifelong skills in 14-16 year olds has been developed (Hulteen, Barnett, et al., 2018). The included lifelong skills were jog, grapevine, bodyweight squat, push-up, upward dog, warrior 1 and tennis forehand. These skills were chosen by experts through questioning "how well does the skill fit the definition of lifelong physical activity?" and "is there a need to increase skill competency of this skill" and thus capturing the skills considered as popular physical activities in adulthood. Cycling was included in this list but was not included within the test battery due to feasibility issues in assessing the skill in a school setting (Hulteen, Barnett, et al., 2018). This kind of assessment of lifelong skills is important, however this test was developed for 14-16 year olds and considering the importance of establishing lifelong behaviours in early childhood it would seem vital to develop a test battery to assess these skills during that time. Cycling warrants more investigation as a lifelong skill during the preschool years. Developing a measurement tool for cycling would enhance understanding of competence in the development of the skill of in early childhood. This would further facilitate the promotion of cycling as a lifelong skill along with FMS. Specifically, it would allow teachers and practitioners to assess competence in cycling and moreover, track changes in skill development which may highlight any individual motor development issues a child may incur, giving an overall better understanding of their motor capabilities. An assessment tool for cycling also opens up opportunities to explore factors that relate to the development of the cycling or possible transfer of skill from balance bikes or stabilisers to independently cycling on a traditional bike.

2.4 Skill Transfer

Skill transfer is the gain or loss in performance in one task as a result of practice or experience on another task. The sequencing of skills is paramount to allow learners to benefit from the transfer of a previous learnt skill (O'Keeffe, Harrison, & Smyth, 2007). The ability to adapt these learnt skills for performance through transfer of learning is essential in successful motor behaviour (Rosalie & Müller, 2014). Transferring of learning refers to the influence of previous practice or performance of skills on the learning of a new skill (Magill, 2007).

A skilled individual is capable of utilising the information that is available to them about environmental and task-related constraints in order to adapt the multitude of motor system degrees of freedom during performance of multi-articular actions (Davids, Button & Bennett, 2008). Adaptability, in this instance, refers to a blend between persistent behaviours (stability) and variable behaviours (flexibility) in achieving task goals (Davids, Bennett & Newll, 2006; Warren, 2006). Utilising previous experiences is defined by the amount of adaptability between each individual's existing coordination tendencies and the dynamics of a task in different environments with new ecological constraints to be satisfied (Warren, 2006). In these skilled individuals, stability refers to the consistent achievement of performance outcomes over time under varying environments and task constraints (Seifert et al., 2013). Stable motor behaviours are essential in acquiring new motor skills against a background of pre-existing movement repertoire. Stable behaviours don't signify the existence of typically rigid movement patterns found when learning a new skill. Rather, dexterity underpins the functional movement pattern, displaying regularities and similarities within their structural components, without being locked into a rigid, repetitive performance (Seifert et al., 2013).

2.4.1 Skill Transfer from FMS to Sport Specific Skills

As discussed preciously in section 2.3.1, FMS are the building blocks for movement and sport specific skills in later life. When a child reaches mastery of FMS they are able to refine and combine their skills and transfer them to other movements and sport specific skills (Gallahue & Ozmun, 2006). This is generally from 6-7 years of age during the mature stage of the FMS phase of development (Gallahue & Ozmun, 2006).

O'Keeffe et al., (2007) conducted an intervention to assess the transfer of the fundamental skill of an overarm throw to both badminton overhead clear and a javelin throw, and also the transfer of badminton overhead clear to a javelin throw. The intervention saw three groups of teenagers attend six PE sessions focusing on either overarm throw, badminton overhead clear or neither (normal PE class). The groups were assessed on their overarm throw, badminton overhead clear and javelin throw at pre-, post- and 2 weeks post-intervention. The overarm throw group who had been practicing the fundamental skill of throwing improved significantly pre to post in both the overarm throw (p=0.005) and the badminton overhead clear (p=0.008), showing a skill transfer of 21%. The same group also showed significant improvements pre to post at javelin (p=0.004), showing a skill transfer of 57%. The badminton overhead clear group only significantly improved in the badminton overhead clear pre to post (p=0.003) with the control group not improving in any of the three. The improvements found resulted in both specificity transfer and related skills transfer occurring. As mentioned previously, the sequence in which one learns skills is important to allow for optimum transfer of skills. The badminton overhead clear group potentially didn't have the fundamental skill of throwing and instead solely learnt the specific skill of a badminton overhead clear. What is interesting about this study is the link with FMS. Research on FMS states that mastering the fundamentals is needed for more complex skills to be learnt (Stodden et al., 2009).

Chew-Bullock et al., (2012) assessed the relationship between kicking performance (accuracy and velocity) and one leg balance in adults with different kicking abilities. Kicking off one leg would theoretically be linked with balance, particularly one-legged balance. However, only accuracy while kicking off the preferred leg was correlated with balance. Accuracy while kicking off the non-preferred leg and velocity while kicking off both the preferred and non-preferred leg did not show any relationship with balance. As only one-legged balance was assessed in this study it cannot be concluded that dynamic balance tests would have shown a relationship. The one-legged test is a common assessment of the fundamental skill of balance. Cycling is theoretically believed to be linked with skills that involve balance, like kicking. However, Chew-Bullock et al., (2012) have shown only partial relationships between the complex skill of kicking and balance. It would therefore be interesting to explore whether assessments of the fundamental skill of stability (i.e. balance) are in fact related to ability on a balance bike.

2.4.2 Skill Transfer from FMS to Cycling

To the knowledge of the author, no research to date, apart from the research within this thesis, has examined relationships or transfer of possible skills between FMS and ability on a balance bike or bike with stabilisers. Given the intuitive demands that cycling places on balance control in particular, it is surprising and intriguing that no evidence has been provided to explore the possible importance of improving balance on a balance bike or bike with stabilisers during the learning process to independent cycling. While no studies have examined how FMS might relate to the learning process to independent cycling, studies have been performed to examine how FMS relates to cycling skills in children who already knew how to cycle independently.

Linus et al. (2015) performed a cross-sectional study to examine the associations between motor competence and ability at cycling safety skills in 9-year-old children (n=40). The FMS assessment consisted of four skill components that assessed motor coordination and dynamic balance (walking backwards, moving sideways, hopping for height and jumping sideways). The cycling assessment consisted of 13 basic cycling skills that were deemed important for children to have in order to safely cycle in right hand traffic (Ducheyne, De Bourdeaudhuij, Lenoir, Spittaels, & Cardon, 2013). A full description of the cycling skills test batteries are outlined in section 2.6. A significant positive association was found between motor competence and total score for cycling safety skills ($r=.434$, $p<.01$). More specifically, a significant positive association was found between motor competence and 'looking left and right while cycling' ($r=.415$, $p<.01$), 'cycling in a circle' ($r=.339$, $p<.05$), 'cycling a slalom in and out of markers' ($r=.515$, $p<.01$) and 'signalling left and right while cycling in a straight line' ($r=.325$, $p<.05$). Results from this study indicate that there is a strong relationship between cycling skills and motor coordination and balance. This is not surprising as motor coordination and balance require a child to have good coordination between trunk and legs, leg strength, flexibility and balance (Holm, Tveter, Fredriksen, & Vøllestad, 2009; Tveter & Holm, 2010), which are skills that are also necessary to cycle.

Vinçon, Green, Blank, & Jenetzky, (2017) also performed a study that explored the possible relationships between components of motor competence (fine manual control, manual coordination, body coordination and strength and agility) with and parent's ratings of their child's ability at independent cycling in 1,177 children between 4 and 14 years of age. Significant relationships were found between ability at riding a bike and upper-limb coordination and strength subtests ($p<0.001$). It was hypothesised by the authors that reported ability at cycling would correlate with balance and/or bilateral coordination as theoretically it would have been assumed that riding a bike would be associated with motor functions of balance, body coordination and fitness (Vinçon et al., 2017). However, this hypothesis was rejected by the findings with only upper-limb coordination and strength having a significant relationship. It should be noted that the children in this study all had previously been diagnosed with Developmental Coordination Disorder (DCD) and so may not be representative of a typically developing population as explored in the current thesis. There are also some limitations to Vinçon et al., study when discussing the possibility of exploring transferable skills to cycling. The study was designed to assess the ecological validity of the BOT-2 and so ability to cycle was not a robust measure. Parents were asked to rate their child's ability to cycle by indicating whether their child was 'less good', 'equally good' or 'better' in comparison to their peers. It was not stated whether every child was capable of cycling independently and so it is not known whether a parent was comparing their child to a child who knew how to cycle or a child who was still learning. Nonetheless, these findings lead to questions of whether it is the specifics of the assessment tools used that appear to be further from the gestalt of balancing activities used in cycling or whether high levels of balance are in fact not needed when cycling independently and learning to cycle independently.

An interesting discussion emerges when exploring how cycling and FMS might relate in early childhood, a time when learning and mastering of both cycling and FMS occur. Children often go through the learning process to independent cycling and mastery of cycling (independent cycling) during early childhood (3-5 years), the same time as the learning process and mastering of the various FMS occurs. Therefore, it would seem unlikely that that these skills are first mastered and then utilised in the learning process and mastery of independent cycling. While direct transfer of mastered FMS are not likely, it would seem possible that the skill of riding a balance bike is a subcomponent of an FMS. Balance bikes, as mentioned previously, are rode by using one's feet to push off the ground; this is first performed in a motion similar to a walking gait and then progresses into a motion similar to a running gait and then further progresses into the child being able to lift both their feet off the ground and 'cruise' or 'glide'. These progression phases have similar traits to that of locomotion and stability skills. Additionally, balance bikes are an object that the child must control, like object control or manipulation skills. Another possibility is that ability on a balance bike is a skill component of its own that has the possibility to be learnt alongside FMS. As cycling has now been added as a foundational movement skill alongside FMS (Hulteen, Morgan, et al., 2018), it is important to explore these possibilities.

As no research to date has looked at learning to cycle and the effect that FMS proficiency has, it can only be speculated that either FMS, or more specifically balance, have no effect on learning to cycle. Therefore, mastery of FMS, or achieving a certain level before mastery, may not be necessary to learn to cycle independently. The alternative question is then posed, do balance bikes play a role in either progressing FMS in order to reach a level that can be transferred to a traditional bike or do they improve the specific movement parameters that transfer without consideration for FMS proficiency?

2.4.3 Skill Transfer from One Skill to Another Related Skill

There are limited studies examining skill transfer from one skill to another related skill. Seifert et al., (2013) found that experienced climbers showed the highest level of variability in upper-limb coordination, upper limb angles and lower limb coordination and subsequently could transfer their skill from rock walls to ice walls. Meanwhile, the medium ability climbers weren't as successful, with non-fluent climbers showing the worst variability and ability to transfer. The greater range of movement shown by the experienced climbers indicates how the dexterity learnt in rock climbing can be directly transferred to a related task like ice climbing. The lack of variability in movement by the non-fluent climbers provides an example of the rigid movement often observed when learning a new skill. Gautier et al., (2009) also found expert gymnasts to have greater adaptability during a handstand task than non-expert gymnasts, even though both groups were experts in handstands.

In cycling, to the author's knowledge, no studies exist that explore the relationships or transfer of possible skills between ability on a balance bike or bike with stabilisers to independent cycling, even though this is commonly assumed. While not commonly explored, Seifert et al., (2013) and Gautier et al., (2009) showed that skilled individuals have the capability to transfer and manipulate previous learnt skills to perform at a new task or in a new environment. It is widely accepted that bikes with stabilisers are precursors to traditional bikes and more recently balance bikes have gained the same credibility. However, scientific evidence is needed to back this statement up and to explore the possible skills that are being transferred.

2.5 Benefits of Cycling

Cycling is a fun and popular pastime, furthermore, it opens up opportunities for a healthy lifestyle through physical activity and transportation. Physical activity participation throughout life has an overwhelming amount of evidence supporting its positive effect on both physical and mental health (Hallal, Victoria, Azevedo, & Wells, 2006; Warburton & Bredin, 2017). Cycling can contribute to a physically active lifestyle, with many countries around the world altering their environments to include more bicycle friendly roads as a result of cycling becoming a key focus of physical activity promotion (Bull et al., 2010). Hollingworth and colleagues performed a cross-sectional study on 6,949 cyclists and found that 93% of regular cyclists met the recommended physical activity guidelines through cycling alone (Hollingworth, Harper, & Hamer, 2015).

Cycling appropriately taxes the cardiorespiratory and metabolic functions of the whole body at different intensities (Oja et al., 2011). Kelly et al., (2014) performed a systematic review on seven studies that assessed reduction in all-cause mortality and the dose-response curve of cycling. Six studies showed either statistically significant or non-significant but still beneficial associations between cycling and all-cause mortality. A systematic review by Mueller et al., (2015).showed that 27 out of 30 studies concluded that the health benefits of cycling outweigh the risks and that people under 30 were estimated to experience a road safety gain with a shift to cycling for transport.

There is indisputable evidence highlighting cycling not only as having health benefits and a means to meet recommend physical activity guidelines, but also as an economic benefit. The Netherlands are well known for their cycle-friendly infrastructure and with 27% of trips made on bicycles (statline.cbs.nl/Statweb). This cycling lifestyle has had major positive effects on both health and the economy. Cycling in the Netherlands prevents around 6,500 deaths per year and it is estimated that the Dutch live half a year longer due to cycling (Fishman, Schepers, & Kamphuis, 2015). Fishman et al., also estimated the total economic health benefit of cycling in the Netherlands at €19 billion per year compared to €0.5 billion a year spent on infrastructure for cycling.

It was once thought that many health-conditions such as atherosclerosis, which can lead to heart attack and stroke, were only applicable to adults. This is no longer the case as risk factors and developed conditions in children are evident, and with increasing frequency (Daniels, 2006). Coronary heart disease risk factors have been linked with inactivity in children as young as 3-4 (Saakslahti et al., 1999). Obesity is a major risk factor for health-related conditions. Nader et al., (2006) assessed 1,042 children over 10 years and found that children who are overweight between the ages of 2-5 are more than 5 times more likely to be overweight at the age of 12. Therefore, encouraging children to learn to cycle is important as this can promote engagement in important daily routines of physical activity in early childhood.

Over the last number of years there has been an increased awareness that children with low motor competence are at risk of psychological difficulties (Dewey, Kaplan, Crawford, & Wilson, 2002; Piek et al., 2006; Poulsen, Ziviani, & Cuskelly, 2006; Skinner & Piek, 2001). A significant indirect relationship has been found between measures of motor competence in sports skills (soccer, volleyball, and ultimate frisbee) and mental health outcomes (depressive symptoms and quality of life) through health related physical fitness in 11-13 year olds (Gu, Zhang, Chu, Keller, & Zhang, 2019). Moreover, a systematic review on thirteen studies concluded that exercise in childhood and adolescence has positive short-term effects on self-esteem and is inversely related to depressive symptoms (Hallal et al., 2006). Physical activity reduces anxiety sensitivity which acts as a precursor to panic attacks and panic disorders. If a child has a high self-esteem for physical activity then they are less likely to avoid engaging in physical activity (Haywood & Getchell, 2005). Increasing self-esteem is an important effect of physical activity participation as it not only provides a direct benefit on mental health but also influence's one's motivation to join and sustain a lifetime of physical activity. Physical and mental health is not within the scope of the current thesis; however, it is important to understand the benefits that an exercise intervention like the current cycling one may provide or moreover learning a lifelong skill like cycling which can contribute to increasing physical activity levels.

2.5.2.1 Risky Play in Childhood

Risk awareness and the value of risk are important factors to consider in preschool education. Risky play can be defined as any exciting activity that provides opportunity for challenge and exploring boundaries that could cause physical injury (Little & Wyver, 2008; Sandseter & Beate, 2007). Learning to cycle independently could therefore be considered risky play. Furthermore, learning to cycle interventions could be considered risky play interventions. Exposing children to risky play situations and overcoming challenges like learning to cycle is an essential part of living a meaningful and satisfying life (Gill, 2007). While risk taking undoubtedly important, a fall from a bike when a child was not ready to cycle without assistance may discourage a child from wanting to try again. Therefore, it is important to understand when a child is more likely to be ready to independently cycle. A measurement tool to assess the development of independent cycling would be an extremely useful tool in this instance to allow teachers and practitioners to have better insight into when it would be appropriate to remove assistance.

2.6 Assessments of Cycling Ability

Objective measurements or tools developed to assess independent cycling ability are limited. Independent cycling assessment tools that have been developed have been used to evaluate cycling skills interventions and have focused on the skills necessary to cycle safely (Ducheyne, De Bourdeaudhuij, Lenoir, Spittaels, et al., 2013).

Ducheyne and colleagues developed a test battery to assess cycling ability in children who already know how to cycle. This test was validated, and reliability tested (ICC = 0.75 - 0.98) on 9-10 year olds (Ducheyne, De Bourdeaudhuij, Lenoir, Spittaels, et al., 2013). The test consists of 13 cycling skills (‘walk with the bicycle’, ‘mount the bicycle and start to cycle’, ‘look left and right while cycling in a straight line’, ‘cycle in a straight line over a small obstacle’, ‘cycle in a circle’, ‘cycle one handed in a circle’, ‘cycle a slalom in and out of markers’, ‘look over the left shoulder while cycling in a straight line’, ‘cycle over obstacles’, ‘cycle on a slopping surface’, ‘signal left and right while cycling in a straight line’, ‘brake to come to a controlled stop’ and ‘dismount the bicycle’) that are performed in an obstacle style course (Figure 2.5). A 5-point scale was used to assess each skill. Speed and fluency of the performance and ability to keep balance and to perform the tests without interruptions were used in the scoring of general performance. Ability to complete a specific point of interest was also considered for 11 of the tests. For each specific point of interest that was fulfilled, one point was added to the general performance score. The general performance score for each skill was then converted to a score on a ten. The sum of all the scores is then converted to a score out of 100 and used as the total cycling skill score. Factor analysis was used to explore how each of the 13 tests related to each other and to the total cycling skill score. Eight of the skills loaded together and these skills were mainly the skills that were performed when cycling was ongoing (‘cycle in a straight line over a small obstacle’, ‘cycle in a circle’, ‘cycle one handed in a circle’, ‘cycle a slalom in and out of markers’, ‘look over the left shoulder while cycling in a straight line’, ‘cycle over obstacles’, ‘cycle on a slopping surface’ and ‘signal left and right while cycling in a straight line’) and these were categorised into “during-cycling skills”. Three of the skills loaded together that represented before and after cycling had begun (‘walk with the bicycle’, ‘mount the bicycle and start to cycle’ and ‘dismount the bicycle’) and were subsequently categorised into “before/after-cycling skills”. The remaining 2 tests (‘look left and right while cycling in a straight line’ and ‘brake to come to a controlled stop’) were categorised into “transitional-cycling skills”. The use of factor analysis in this instance provides a valuable tool to allow for three categories of cycling skills to be explored when assessing improvements or relationships to other variables, however, this was not utilised in proceeding experiments using this scale (Ducheyne, De Bourdeaudhuij, Lenoir, & Cardon, 2014, 2013; Ducheyne, De Bourdeaudhuij, Lenoir, Spittaels, et al., 2013; Linus et al., 2015). Nonetheless, development of a reliable measurement tool to assess independent cycling ability is extremely valuable to allow exploration into the factors that may contribute to high cycling skills and to assess the effectiveness of interventions designed to improve cycling skills.

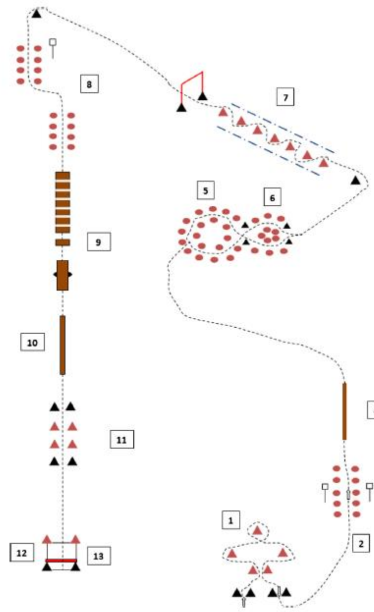


Figure 2.5. Obstacle Course Design for the assessment of Cycling Skills (Ducheyne et al., 2013)

Other cycling skill assessments have been used throughout the literature but these assessments have focused on either self-reported questionnaires that relate to cycling safety behaviours (Hatfield et al., 2015; Montenegro, 2015; Richmond, Zhang, Stover, Howard, & Macarthur, 2014) or subjective observation of safety behaviours (Richmond et al., 2014). More tools should be developed to assess cycling skills at different stages along the learning process to independent cycling - from ability at riding a balance bike/bike with stabilisers to ability to cycle independently on a traditional bike. This would allow further explorations into how children learn to cycle independently and the factors that contribute to this process.

2.6.1 Inertial Measurement Units

Inertial measurement units (IMUs) are wearable devices that consist of accelerometers and gyroscopes that allow measurement of three-dimensional acceleration and angular velocities. While IMUs have gained popularity in the field of human motion analysis (Camomilla, Bergamini, Fantozzi, & Vannozzi, 2018; J. J. Kavanagh & Menz, 2008), they are not common in the assessment of motor competence. However, the feasibility of using IMUs to examine developmental differences has been demonstrated in both locomotor and object control skills in children aged from 5-10 years (Grimpampi, Masci, Pesce, & Vannozzi, 2016; Masci et al., 2013).

IMUs are common assessment tools for human gait movement analysis (Taborri, Palermo, Rossi, & Cappa, 2016) and in analysing performance in motor skills from recreational to elite athletes (Camomilla et al., 2018). A systematic review by Camomilla and colleagues identified 286 papers that had used IMUs to explore performance in a variety of motor skills, with 10 papers exploring cycling (Camomilla et al., 2018). Cycling skills assessed included: revolution rate, velocity, bicycle roll and crank angle (both with the aim of exploring posture of the participant), lower limb vibrations, angular displacement of the hip and ankle and symmetry in arm movements. All of the included studies that assessed cycling performance using IMUs, along with others not included in this review, were performed on adults and were performed for the purpose of improving performance in cyclists or for rehabilitation (Camomilla et al., 2018; Cordillet, Bideau, Bideau, & Nicolas, 2019; Farjadian, Kong, Gade, Deutsch, & Mavroidis, 2013; Xu et al., 2015). There have been no studies to date that have looked at cycling performance in children and more specifically, performance during the learning process to independent cycling in preschool children.

While the use of IMUs in the assessment of motor competence in children is limited, the few studies that have started the exploration into the possible use of IMUs in this way have shown positive results. Cristina Bisi and colleagues investigated whether objective measurement using IMUs could be used to assess locomotor skills in 6 to 10-year-old children (n=45) (Cristina

Bisi, Pacini Panebianco, Polman, & Stagni, 2017). IMUs were placed on the lower back, ankles and wrists to capture the movement of the children during assessment of 6 locomotor skills using the validated TGMD-2 protocol (as described in section 2.3.2). Acceleration and angular velocity from the IMUs were used to automatically score the performance of the children based on performance criteria used to score the skills in the TGMD-2. Good agreement was found between observational scoring (TGMD-2) and automatic object measurement (IMUs) with the lowest agreement found for the horizontal jump (82-91% agreement) and the highest for the slide (91-100% agreement) (Bisi et al. 2017). This study provided evidence for the use of IMUs in the analysis of performance of motor skills from which qualitative performance criteria already exist.

Masci and colleagues investigated if IMUs could be used to distinguish between developmental levels of hoping and running as scored using an observational assessment that allowed categorisation of children into 4 developmental levels (Masci et al., 2013; Masci, Vannozzi, & Getchell, 2012). For the hoping experiment, 40 children between 4 and 10 years of age had IMUs placed on their trunks and were instructed to hop along a 5-metre path for 5 consecutive hops. The children were subsequently categorised into 1 or 4 categories (1 being low) using an observational check list. Both temporal and kinematic parameters were calculated from the IMUs using acceleration and angular velocity along three axes (vertical, medio-lateral and antero-posterior). Results indicated that both temporal and kinematic parameters were able to distinguish between the 4 development levels of the hop, with accuracy of prediction of placement stronger in the 1st (80%) and 4th (90%) developmental levels than the 2nd (40%) and 3rd (50%) levels (Wilks $\lambda=0.215$, $F(6,2)=55.314$, $p<.01$) (Masci et al., 2012).

Masci and colleagues further explored if IMUs could distinguish between developmental levels of running using similar methodologies (Masci et al., 2013). Forty-four children between 2 and 12 years were assessed on their running performance over a 15-metre straight track using performance criteria that subsequently allowed them to be categorised into 4 developmental levels of running, with the first developmental level being the lowest. During the run the children had an IMU placed on their lower trunk, allowing temporal and kinematic data to be captured. Step frequency, root mean square of both the acceleration components along all axes (vertical, medio-lateral and antero-posterior) and the angular velocities along the same axes were calculated. Objective measurements of running performance temporal and kinematic parameters were found to significantly distinguish between the different observational measurements of the developmental levels of running with accuracy of prediction strongest for the 4^{th} (87%) and 3^{rd} (87%) developmental levels and then for the 2^{nd} (67%) and 1^{st} (67%) levels (Wilks $\lambda=0.053$, $F(15,3)=142.6$, $p<.001$) (Masci et al., 2013). Using IMUs to distinguish between development levels of cycling could be an interesting and useful aspect to consider. As mentioned previously in section 2.5.2.1, a fall from a bike can discourage a child from wanting to continue trying to cycle independently. Therefore, it raises an interesting question as to whether IMUs could be used on balance bikes to determine when a child may be ready to independently cycle, thus providing more knowledge before the child attempts to cycle independently on a traditional bike.

Grimpampi and colleagues aimed to investigate if IMUs could be used to detect differences in developmental levels of the overarm throw (Grimpampi et al., 2016). Similar methodologies to the studies by Masci and colleagues were utilised. Fifty-eight children between 5-10 years were instructed to overarm throw a ball to a wall 6 metres away as hard as they could. During the trials the children were qualitatively assessed and categorised into one of three developmental levels, with 1 being the lowest. During the throw the children also had IMUs worn at the wrist, trunk and pelvis from which linear acceleration and angular velocity parameters were obtained and used to objectively assess the throw. Results indicated that the objective assessment of the throw was significantly different for each developmental level obtained through qualitative analysis [$F(10,102)=10.526$, $p<.0005$] with post-hoc analysis revealing significant differences between all three developmental levels (Grimpampi et al., 2016).

The research discussed above on the use of IMUs in objectively measuring motor competency at different skills has provided a convincing argument for their use in determining skill or developmental levels in locomotor and object control skills. Consequently, they may be useful tools in quick and automated assessment of motor competence without the need for a qualified observer. When assessing what factors are progressed through practicing on a balance bike, IMUs may provide useful information as they can objectively measure kinematic parameters and thus, provide further insight into the skills being learnt.

2.6.1.1 Assessment of Dynamic Balance

Dynamic balance is a facet of an underlying motor control system (Kelso, 1995; Mancini & Horak, 2010), and is important in all whole body movement skills, including cycling. Furthermore, investigation into the changes in dynamic balance with practice allows exploration into the possible transfer of skills between balance bikes and traditional bikes. While observational assessments have their advantages, they are limiting due to inter-observer variations and inter-individual differences that may not being large enough to distinguish between participants (Masci et al., 2012; Miller, Vine, & Larkin, 2007). While time/speed along a track may be viable measures of performance on a balance bike, there is a possibility that a child may present with similar times but may differ in dynamic balance. Therefore, when assessing dynamic balance on a balance bike, it may be useful to use IMUs to detect changes that may not be otherwise detected through time/speed analysis alone or visual observation.

In measurement of dynamic balance, centre of pressure is probably the most common method (Hubble, Naughton, Silburn, & Cole, 2015; Whitney et al., 2011). However, low inertia accelerometers have become widespread for assessing dynamic balance due to their low cost and ease of use (Hubble et al., 2015). Assessing balance through accelerometery has been found to be a valid and reliable measure in distinguishing between populations and conditions (Hubble et al., 2015; Moe-Nilssen & Helbostad, 2002) and correlates highly with centre of pressure (Whitney et al., 2011).

Manufacturers claim that balance bikes teach children how to balance first before progressing to independent cycling ("Halfords," 2019; "LIKEaBIKE," 2019; "Strider," 2019; "Littlebigbikes," 2019), however there is no empirical evidence to back up these claims. As mentioned previously in section 2.4.2, the FMS subset of stability warrants exploration into its relationship with ability on a balance bike. However, improvement in balance skills may be more detectable as objective measures using IMUs have the potential to provide accurate, stable, and sensitive biomarkers for testing of dynamic balance (Mancini & Horak, 2010). As highlighted, there is a need to research whether dynamic balance improves with practice on a balance bike. Following on from this, research into whether practice on a balance bike improves dynamic balance, that is then aiding in learning to cycle independently, is warranted.

2.7 Cycling Interventions

To the knowledge of the author, there have been no evidence-based cycling interventions that aimed to teach children how to cycle independently. Instead, cycling interventions, generally performed in primary schools, invariably focus on cycling safety with children who are presumed to already know how to cycle independently (Ducheyne et al. 2014; Goodman, van Sluijs, and Ogilvie 2016; Hatfield et al. 2015; Montenegro 2015; Richmond et al. 2014). These interventions have provided children with an increase in cycling skills, confidence on the bike and knowledge of cycling safety (Ducheyne et al. 2014; Hatfield et al. 2015; Montenegro 2015; Richmond et al. 2014). It should be noted that while most of these studies purported to evaluate the effectiveness of cycling interventions on 'cycling skills', the definition of cycling skills within each study varies; ranging from observational measurement of ability to perform different cycling tasks (Ducheyne et al., 2014; Ducheyne, De Bourdeaudhuij, Lenoir, & Cardon, 2013) to self-reported knowledge of safety features of cycling such as 'wearing a helmet' and 'feeling safe while cycling' (Hatfield et al., 2015; Montenegro, 2015; Richmond et al., 2014). Assessments of cycling ability, including the ones used in some of these studies, were described previously in section 2.6.

Richmond and colleagues performed a systematic review on school-based cycling skills training interventions (Richmond et al., 2014). Twenty-five studies met the inclusion criteria and lasted between a one 8-hour training block and 4 months of sessions. Five out of 11 observational studies found a significant increase in cycling safety behaviours/skills with 0 out of 2 randomised control trial (RCT) studies finding a significant increase post-intervention. Five out of 11 observational studies and 3 out of 5 RCT studies also found a significant increase in knowledge of cycling safety post-intervention. Seven studies investigated injury rates with none of the studies reporting a significant decrease post-intervention. Overall the results of this review indicated that the cycling skills interventions were not highly effective at reducing bicycle-related injuries, increasing observed safe bicycling behaviour, or self-reported knowledge or attitudes. Moreover, none of the studies in this review assessed cycling skill levels based on ability to independently cycle and rather focused on cycling safety behaviours and knowledge of safe cycling.

Since Richmond and colleagues review, more cycling intervention studies have been conducted, aimed at increasing cycling skills. Ducheyne and colleagues designed and evaluated a cycling training course for children aged 9-10 years (9.31 ± 0.5 years) (Ducheyne et al., 2014). The study consisted of 94 children that completed all stages. The children were split between an intervention group (n=25), an intervention involving a parent group (n=34) and a control group (n=35). The cycling training course involved one session a week for 45 minutes each over 4 weeks and was designed to teach children basic cycling skills that children should accomplish to safely cycle in traffic using games, practical cycling exercises and at home worksheets to be completed. The intervention involving a parent group additionally had the assistance of a parent for completing the at home worksheets. Cycling skills were measured using a 13-skill assessment as described in section 2.6. A significant interaction effect was found between the three groups over time (pre-post-5-month post) for children's total cycling skill ($F=9.5$, $p<.001$). From pre- to post- intervention a significant difference was found between the three groups ($F=16.9$, $p<.001$) with the intervention groups increasing more than the control group. Furthermore, from pre- to 5-month post-intervention a significant interaction effect was found ($F=16.8$, $p<.001$) with the intervention groups increasing more than the control group. No significant interaction was found from post- to 5 months post-intervention ($F=0.3$, $p>.05$). Similar results were also found in the pilot study of this larger study, with an increase in total cycling skill from pre- to 3 week post-intervention ($F=46.9$, $p<.001$) (Ducheyne, De Bourdeaudhuij, Lenoir, & Cardon, 2013).

Hatfield and colleagues evaluated the effects of the school-based cycling programme "Safe Cycle" (Hatfield et al., 2015). One hundred and eight children between 10 and 12 years of age (11.78 ± 0.98) took part in every aspect of the 9-week programme. Description of the contents of intervention, how often it was conducted and for how long was unfortunately not provided. Children's confidence while cycling, perceived safety while cycling, knowledge relating to cycling safety information given throughout the programme and reported crashes and near missed while cycling was obtained using a survey that was given to students at pre-, post- and 14 weeks post-intervention. Teacher interviews were also conducted. There was a significant increase in confidence while cycling from pre- to post-intervention ($t99 = 2.35$, $p<.05$) with a 6.9% increase, but not from pre- to 14 weeks post-intervention with the mean confidence scores returning close to baseline after a 5.3% decrease from post- to 14 weeks post-intervention. Significant differences were also found between pre- to post-intervention for knowledge of information relevant to cycling safety ($t99 = 5.51$, $p<.001$) with an 8.5% increase and from pre- to 14 weeks post-intervention ($t99 = 5.51$, $p<.05$) with a 5.2% increase. A significant difference was found in the number of children who reported a crash ($p<.05$) but no significant difference was reported in near-misses. No significant differences were observed in perceived safety. A limitation to this study was that the results were not compared to a control group.

Montenegro and colleagues evaluated the school-based cycling programme "CYCLE Kids" (Montenegro, 2015). The "CYCLE Kids" programme was designed for children aged 8-12 years to teach them cycling skills including cycling safety, benefits of physical activity and healthy nutritional habits through a practical cycling education course and through at home information booklets. The programme consisted of 8 lessons over 4 weeks. Montenegro and colleagues qualitatively assessed 1,451 children (mean age 10.2 years) on cycling skills and cycling frequency using a questionnaire pre- and post-intervention and a teacher questionnaire. Cycling skills were evaluated using questions on safe cycle behaviours with a binary response of either 'yes' or 'no' or 'always' or 'not always' where appropriate. These questions included; 'Do you know how to ride a bicycle?'; 'When riding a bicycle, do you wear a helmet'; 'When riding a bicycle, do you wear a helmet?'; 'Do you know how to wear a helmet correctly?'; 'Do you know how to choose the right height for your bicycle seat?'; 'Do you know how to use hand signals when riding a bicycle?'; 'Do you feel safe riding a bicycle?'; 'Do you think there are things you could learn about riding a bicycle?'; 'Do you feel confident in yourself when you ride a bicycle?'. A 12.5% increase in cycling skills and a 4% increase in cycling frequency was reported with no statistical analysis performed to assess significance of these results.

In teacher evaluations of two of the school-based cycling programmes, 'CYCLE Kids' and 'Safe Cycle', teachers reported the important outcomes of the intervention as: the programme increased the desire to cycling outside of school, increased excitement about exercising, overcoming fears of riding bicycles (Montenegro, 2015) and increasing confidence and cycling participation (Hatfield et al., 2015). Furthermore, students were reported as having higher collaborative and empathetic behaviours towards other students and improving on their relationships with teachers (Montenegro, 2015). One challenge mentioned by teachers on the 'Safe Cycle' programme was that the programme assumed that all students could ride a bike, which was not the case and caused some issues. A recommended solution to this was delivery of a learning to cycle programmes in the earlier years.

Delivering learning to cycle programmes in the preschool years has benefits that extend further than ensuring every primary school student can cycle independently before participating in these types of cycling programmes. Cycling safety is the common goal of cycling interventions in primary school children and were introduced to children between 8-12 years of age (Ducheyne et al., 2014; Ducheyne, De Bourdeaudhuij, Lenoir, & Cardon, 2013; Hatfield et al., 2015; Montenegro, 2015). It is evident that cycling interventions in primary school are effective at increasing cycling skills and increasing safety behaviours. However, children generally begin to cycle independently from 3 years and according to the European Road Safety Observatory (ERSO), cyclist fatalities in children occur most commonly between 6 and 14 years of age (European Commission, 2018). Thus, introducing learning to cycle programmes in the preschool years may allow correct ability, increase confidence and safety behaviours to be introduced at a more critical time.

2.7.1 Interventions in the Preschool Years

Positive habitual lifestyle behaviours that are learnt and established in early childhood persist through adolescence and adulthood (Ortega et al., 2008; Telama, Yang, Sciences, Leskinen, & Hirvensalo, 2013). Accordingly, many interventions have been delivered during the preschool years with the aim of improving lifestyle behaviours and subsequently health throughout life. Recent systematic reviews have found that intervening in the preschool years has been successful at increasing moderate-to-vigorous physical activity (Hnatiuk et al., 2018), cardiovascular fitness (Szeszulski et al., 2019), fundamental movement skills (Wick et al., 2017), social and emotional competence (Blewitt et al., 2018) and decreasing sedentary behaviour (Downing, Hnatiuk, Hinkley, Salmon, & Hesketh, 2018).

2.7.1.1 Interventions to Improve Motor Competence

Several interventions have been successful in improving motor competence in early childhood (3-5 years) (Altunsöz, 2015; Bardid et al., 2013, 2017; Duff, Issartel, & Brien, 2019; Riethmuller, Jones, & Okely, 2009; Van Capelle, Broderick, van Doorn, Ward, & Parmenter, 2017; Wick et al., 2017; Wood, Eddy, & Hill, 2019) and in middle childhood (6-12 years) (Burrows, Keats, & Kolen, 2014; Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2015; Han, Fu, Cobley, & Sanders, 2018; Tompsett, Sanders, Taylor, & Cobley, 2017). Morgan et al., (2013) performed a systematic review on 19 FMS interventions with children. All the reviewed studies reported significant intervention effects for at least one FMS. More specifically, Van Capelle et al., (2017) performed a systematic review on 20 FMS interventions aimed at preschool children (4.3 ± 0.4 years). They found a significant increase in FMS with intervention (SMD = 0.31, p = 0.001). Van Capelle et al., (2017) also distinguished between teacher-led (n=13), parent-led (n=1) and child centred (n=6) interventions with results showing the most significant increases in FMS in the teacher-led category (SMD = 0.13; p = 0.008). This was also supported in a systematic review by Engel et al., (2018), who found that interventions in preschool were effective at increasing FMS when teacher-led and performed at least three times a week. The interventions reviewed lasted 21 ± 17 weeks, 3 ± 1 times per week for 35 ± 17 minutes and all specifically looked to increase FMS (Van Capelle et al., 2017). The design and benefits of cycling interventions in early childhood have not been discussed in the literature and so when designing an intervention with the aim of improving cycling ability, FMS interventions may offer some foundations.

2.7.1.1 Intervention Components

While there are many studies that have investigated the effectiveness of interventions aimed at improving FMS in the preschool years, there is a gap in the literature regarding interventions aimed at improving other lifelong skills, like cycling. Therefore, developing an intervention aimed at improving cycling skills and subsequently teaching children to cycle independently and investigating its effectiveness would be the first step in encouraging positive lifelong behaviours.

Understanding the effective components or strategies to utilise when designing an intervention in the preschool years is of vital importance. Riethmuller, Jones, and Okely (2009) conducted a systematic review of the efficacy of interventions to improve motor development in preschool children. In conclusion to the review, some recommendations were made. One recommendation was to involve teachers in the implementation of the interventions (Riethmuller et al., 2009). Previous research has also suggested that children have a higher likelihood of being physically active when they have positive interactions with teachers (Dowda, Pate, Trost, Almeida, & Sirard, 2004). It was also recommended to involve parents as they are a key factor in habitual and lifelong development (Riethmuller et al., 2009). This is further highlighted in recommendations for preschool children, that emphasise the pivotal role parents have for providing encouragement, opportunities and support for physical activity (American Academy of Pediatrics. Council on Sports Medicine and Fitness, 1992; Hagan, Shaw, & Duncan, 2017; Wright & Stork, 2013). A further recommendation was to ensure that those administering the intervention are carefully chosen as they have a direct influence over children’s participation and enthusiasm through the facilitators experience, competence and confidence to deliver the programme (Riethmuller et al., 2009). Brian and Taunton (2018) provided some insightful evidence from their research on implementation strategies in preschool motor skill interventions. They compared expert and novice instructors and direct and indirect pedagogical approaches when delivering their intervention. A direct approach refers to a structured lesson plans are adhered to with all children performing each task at the same time, while an indirect approach allows the child autonomy over what task they choose to partake in, at what level of difficulty and for how long (Rink, 2014). It was found that when the intervention was expert-led, there were no significant differences between direct and indirect approaches. However, when novice-led, a direct approach showed significantly greater improvements in locomotor and object control skills ($p<.05$). In agreement with Riethmuller and colleagues’ findings, the expert-led interventions showed significantly greater improvements over the novice-led interventions, regardless of approach ($p<.05$) (Brian & Taunton, 2018; Riethmuller et al., 2009). It should be noted that both expert-led and novice-led using both approaches showed significantly greater improvements over a control group who received no intervention ($p<.05$) (Brian & Taunton, 2018).

When designing an intervention to teach children to cycle, consideration for the involvement of teachers and parents may be important. There are different ways to involve teachers and parents in interventions through direct involvement (i.e. delivery of the intervention) to indirect involvement (i.e. been given information relating to the intervention). As demonstrated by Brain and Tauntons’ work, novice-led interventions aren’t as effective as expert-led. When considering delivering an intervention to increase children’s cycling skills and teach them to cycle independently, it can’t be assumed that most teacher or parents would be experts. Concerning teachers, a solution to this is to allow for a combined partnership approach by delivering the intervention with the assistance of the preschool teacher (Riethmuller et al., 2009). A similar approach may not be suitable for parents as the logistics of a parent being involved for each child involved in the intervention at the same time may not allow the expert control of delivering the intervention and furthermore, issues with vetting for each parent to work within the whole group of children may be invasive and impractical. However, parents can still influence their child through being present without directly involving themselves in the intervention. Rebold et al. (2016) found parents to influence their child's activity levels during a play intervention through being present and watching their child participate. A child's perceptions of their parents' support has been shown to positively influence physical activity levels (Wilk, Clark, Maltby, Tucker, & Gilliland, 2018), therefore, a parent being present may provide perceived parental support for the child and increase their active involvement in the intervention.

The setting of the intervention has also been highlighted as a potential important indicator of intervention efficacy (Riethmuller et al., 2009). It was hypothesised by Riethmuller and colleagues that the setting in which a preschool motor skills intervention is delivered would have a strong influence on the outcomes of the intervention as a consequence of an increased likelihood of having a positive experience, and thus increased likelihood of learning, if they felt comfortable in their surroundings (Riethmuller et al., 2009). Furthermore, in a literature review aimed to understand how to enhance physical activity among preschool children, it was suggested to focus on activities that the children find fun (Timmons, Naylor, & Pfeiffer, 2007).

As there have been no previously published interventions to date that have sought in increase preschool children's cycling skills and ability to cycle independently, no directly-comparable evidence can used in designing such an intervention. However, in light of this review important considerations should be made including: teacher or parent participation and the setting in which the intervention is delivered. Furthermore, an exploration into these recommended strategies may provide insight into the factors that influence a child learning to cycle independently.

2.8 Conclusion

It is clear from the presented review of literature that cycling offers many benefits and is an important skill to understand. Understanding cycling begins by exploring how children progress through the learning process to independent cycling. Cycling was only recently added to the motor development model, therefore, understanding how it fits within the model and exploring how it relates to other important skills during the vital years of early childhood are important first steps. Furthermore, understanding what influences a child's level of motor skill engagement may be an important factor to consider when designing interventions to improve cycling and/or when trying to encourage a child to learn to cycle independently. In order to better understand cycling and to investigate what factors might relate to it, an assessment tool must first be designed in order to measure ability to cycle independently. After the development of an assessment tool, developmental paths to independent cycling can be investigated along with what factors on a balance bike may be learnt and subsequently used in independent cycling on a traditional bike. While it is assumed that dynamic balance is an important factor when it comes to cycling independently, there is in fact no research that has examined this. Furthermore, there is no research to suggest that either balance bikes or bikes with stabilisers do in fact aid in learning process to independent cycling. The presented thesis addresses these topics in Chapters 3-6.

Chapter 3 - Quantifying Cycling as a Foundational Movement Skill in Early Childhood

Kavanagh, J. A., Issartel, J., Moran, K., 2019. Quantifying Cycling as a Foundational Movement Skill in Early Childhood. *Journal of Science and Medicine in Sport (in press).* https://doi.org/10.1016/j.jsams.2019.08.020.

This paper has been reformatted to fit the current thesis with minor changes made as a result of examiners revisions.

3.1 Abstract

The addition of cycling to the fundamental movement phase of the motor development model has been proposed. Lifelong physical activity behaviours, like cycling, are established during childhood and it is vital that research focuses on these skills. In order to determine the position of cycling within this newly proposed model, the learning process of this skill must be examined. The current paper will quantify the skill of cycling as a learning process and investigate cycling's place as a Foundational Movement Skill. Investigation into whether a composite score could be derived from combining fundamental movement skills proficiency scores and ability on a balance bike (as a measure of the learning process of cycling) will also be conducted. Ninety-seven preschool children were assessed on ability on a balance bike (bike with no pedals) using two separate timed tracks (straight and curved) and fundamental movement skill proficiency. Data analysis included descriptive statistics, Pearson product-moment correlations and principal axis factoring. Statistically significant correlations were found between ability on a balance bike and all three subcomponents of fundamental movement skills (locomotor, object-control & stability). Principal axis factoring revealed the

presence of one component that all four variables could explain. Ability on a balance bike is a standalone Foundational Movement Skill and is not a representation of locomotor, object-control or stability. Furthermore, ability on a balance bike can be combined with locomotor, object-control and stability to produce an overall composite score for Foundational Movement Skills.

3.2 Introduction

Locomotor, object control and stability are three subcomponents that make up fundamental movement skills (FMS) (Gallahue & Ozmun, 2006) as they are the most basic observable patterns of movement and are the building blocks for more sport specific skills (Clark & Metcalfe, 1989). FMS are developed between the ages of 2 and 7 as children are actively exploring and experimenting with how their bodies move, leading to mastery of FMS and discovery of new skills (Haywood & Getchell, 2005). There are a wide variety of instruments currently used to assess FMS (TGMD®, MABC®, KTK®. BOT®). These instruments were all designed to measure the FMS components included in the motor development model (Gallahue & Ozmun, 2006). These assessment tools support policy makers and researchers to design interventions tailored to improve FMS with the long-term goal of increasing physical activity levels across the lifespan. Interventions have been successful in improving FMS in early childhood (3-5 years) (Altunsöz, 2015; Bardid et al., 2013; Wick et al., 2017) and in middle childhood (6-12 years) (Burrows et al., 2014; Cohen et al., 2015). Morgan and colleagues performed a systematic review on 19 FMS interventions with children of all ages (Morgan et al., 2013). All the reviewed studies reported significant positive intervention effects for at least one subcomponent of FMS. While it is imperative that interventions have been successful in improving FMS, the current FMS may not necessarily be the only skills that are foundational to successful adoption of lifelong physical activity (Hulteen, Morgan, et al., 2018).

Lifelong physical activity behaviours are established during childhood as many physiological and psychological changes take place during this time (Ortega et al., 2008), which may subsequently influence adolescence and adult behaviours (Robinson et al., 2015). Therefore, it is vital that theory within motor development includes all skills that need to be addressed during this critical time, not solely FMS, to ensure that children are encouraged to establish appropriate behaviours that will lead to lifelong physical activity. Hulteen and colleagues proposed an amendment to the current FMS structure and content within motor development models (Clark & Metcalfe, 1989; Gallahue & Ozmun, 2006) to include the addition of more skills that lead to lifelong physical activity (Hulteen, Morgan, et al., 2018). The addition of these new skills alongside traditional FMS was given the heading 'Foundational Movement Skills' as a replacement to the previous heading 'Fundamental Movement Skills' to allow for the inclusion of additional lifelong skills alongside traditional FMS. Foundational Movement Skills are defined as any skill that is deemed important for promoting lifelong physical activity and other positive trajectories of health and include both traditional FMS and other skills (eg. catching a ball, cycling) (Hulteen, Morgan, et al., 2018). Identifying these additional foundational skills seems to be an essential primary step in developing more appropriate interventions and recommendations for policy makers. The addition of several skills was proposed to the motor development model, such as cycling, freestyle swimming stroke, bodyweight squat and scootering, in order to encourage the promotion of more skills during this crucial development window (Hulteen, Morgan, et al., 2018), opening the door to further investigate their role and impact.

Cycling is an important lifelong skill as it can be used recreationally, for sport or for transportation and is a skill that can be utilised throughout the lifespan. Cycling currently has one of the highest activity participation rates globally (Hulteen et al., 2017). Understanding the development of the skill is a necessary step in research and to further support coaches, practitioners and parents. Furthermore, it is necessary to highlight cycling as an important skill within Foundational Movement Skills as it promotes continued physical activity participation across the lifespan. Cycling has many fitness and health benefits in childhood and into adulthood. A systematic review by Oja and colleagues showed a consistent strong positive relationship between cycling and cardiorespiratory fitness in both children and adolescents, with those who cycled to school being five times as likely to be in the top quartile of fitness compared to those who walked or passively commuted (Oja et al., 2011). One finding found that fitness significantly increased by 6-21% in children who changed from not cycling to school to cycling to school after 6 years (Janssen & LeBlanc, 2010). Middle-aged and elderly adults who commuted to work by cycling were also found to have significantly less risk of all cause cardiovascular or coronary heart disease mortality, cancer mortality and morbidity and in men were less likely to be overweight and obese (Oja et al., 2011). Promoting cycling from the early preschool years may influence positive commuting and lifestyle behaviours that would subsequently have fitness and health benefits throughout life.

In order to promote cycling in the early childhood, emphasis must be placed on the development of the skill and its role alongside other accepted important skills like locomotor, object control and stability. Assessment tools are important drivers of focus within motor development research. Currently, interventions that look to improve motor competence in early childhood are examined through a change in both subcomponents of FMS, and overall

FMS as a composite score of the FMS subcomponents (Altunsöz, 2015; Bardid et al., 2013). Understanding the role of cycling within the motor development model, and subsequently determining the placement of cycling within the model, would allow researchers to include cycling in their assessments of motor competence. This, in turn, may steer researchers and policy makers to place importance on the development of cycling within early childhood motor development research.

FMS have been examined and assessed as a learning process to mastery of the individual skills (Altunsöz, 2015; Bardid et al., 2013; Burrows et al., 2014; Cohen et al., 2015; Morgan et al., 2013). Therefore, when determining the position of cycling within this newly proposed motor development model, the learning process of cycling must be considered. Previously cycling has been placed alongside other sport specific skills, as only FMS were placed in the FMS phase of development (Hulteen, Morgan, et al., 2018). Parents and guardians frequently teach children to cycle using a constrained bike [i.e. no pedals (balance bike/strider) or with additional wheels (bike with training wheels)] before progressing to cycling with no assistance on a traditional bike. It is because of this that the authors of this paper believe that the skill of cycling, as a Foundational Movement Skill, to begin on a constrained bike as a learning process. In the past, bicycles were constrained by adding two extra training wheels to the back of the bicycle, allowing the bicycle to stand upright on its own. In more recent years, bicycles have been constrained by removing the pedals, allowing the child to use their feet to propel themselves forward. This type of constrained bike (as used in this study) has been given many different names such as balance bike, strider bike and running bike. Balance bikes are becoming increasingly popular as manufacturers are claiming that they teach the skills necessary to cycle (“LIKEaBIKE,” 2019.; “Strider,” 2019). The use of constraints in the learning process of a skill is not unique to cycling and dates back to the 1980s when it was first proposed by Newell in 1986. Newell's model of constraints proposed three constraints - environment, task and individual – that could be manipulated to provide better opportunities for skill acquisition. Since the 1980s this constraints-led approach has been extensively recognised as a motor learning model to follow for acquisition of skills (Davids et al., 2008). In motor learning, practice and experience are required for behavioural changes (Haywood & Getchell, 2005). It is not common for a child to be able to cycle independently without prior practice on a constrained version of a traditional bike. Practicing on a balance bike allows mastery of parts of the skill prior to attempting to cycle on a traditional bike without constraints. Assessing ability on a balance bike (BB) could therefore be recognised as a measure of cycling ability during early childhood, when the initial motor learning takes place and continues along a motor development pathway.

With the addition of cycling to the motor development model, its placement within the model during early childhood must be quantified to confirm that the learning process of cycling, as measured by ability on a BB, should be placed alongside FMS. In order to do so, one needs first to demonstrate that ability on a BB is not representing ability at another subcomponent of FMS. For example, if ability on a BB is strongly related to the skill of locomotor then it is possible that ability on a BB is another measure of locomotor as opposed to its own skill entity. Ability at the subcomponents of FMS are typically scored by combining assessments of different representations of the skill to produce one overall composite score (Deitz, Kartin, & Kopp, 2010; Henderson, Sugden, & Barnett, 2007). For instance, object control in the current article was assessed through combining scores of abilities at an aiming and a catching task. Furthermore, the subcomponent composite scores are combined to produce an overall composite score for FMS or motor competence. Providing standardised composite scores for overall FMS has allowed researchers to compare findings across different test batteries (Altunsöz, 2015; Bardid et al., 2013; Burrows et al., 2014; Cohen et al., 2015; Morgan et al., (2013). If moderate relationships between ability on a BB and the subcomponents of FMS are found, then it may be possible to combine ability on a BB scores with locomotor, object control and stability scores to produce one composite score. This would be a way to represent an assessment of Foundational Movement Skills (Hulteen, Morgan, et al., 2018). This overall composite score for Foundational Movement Skills would highlight the weight of cycle within motor development research and thus provide rationale for the inclusion of cycling, together with FMS, as important skills to be learnt.

It is hypothesised that ability on a constrained bike, in this case a bike with no pedals (balance bike), and ability at three components of FMS (locomotor, object control and stability) will be moderately related. Moreover, the components are hypothesised to be capable of being combined to provide a wider assessment of motor competence, as a composite score of Foundational Movement Skills.

3.3 Methods

Participants included ninety-seven preschool children (4.1 +/- .48 years, 56% female). Participants were assessed on ability to cycle a balance bike (bike with no pedals) and their FMS proficiency (object control, stability, locomotor).

Participants fundamental movement skills (FMS) were examined through assessment of object control, stability and locomotor. Object control and stability subcomponents were assessed using the Movement Assessment Battery for Children, second edition (MABC-2)

(Henderson et al., 2007). The MABC-2 assessed the participants' two object control skills (throwing a beanbag to a mat and catching a beanbag) and three stability skills (one leg balance, jumping on mats and walking a line) and the best score of the two trials was obtained for both locomotor and object control. Raw scores of object control skills and stability skills were used. The locomotor subcomponent was assessed using a 15m sprint test and a horizontal jump distance test (España-Romero et al., 2010). The 15m sprint test was measured using time through two pairs of timing gates (Brower timing system, USA), where the first timing gates were 10cm from the start line. Participants were asked to run as fast as they could and the average of two trials was used in the analysis. The horizontal jump distance test was a two footed take-off and landing task, with participants asked to jump as far as possible. The jump was on a soft horizontal jump mat (Atreq, UK) and the average of two trials was used in the analysis. The results from two locomotor tests were then standardised into z scores and combined to produce one score for locomotor skill.

Children's ability on a balance bike (BB) was measured with two types of tracks: a 15-metre straight track and a two-turn curved track (Figure 3.1). For each of them, the average of two-time trials over was calculated and the times were combined as a measure of ability on a BB. For the straight track, time to complete was measured using timing gates that were set up 15m apart with the first timing gate 10cm from the start line. For the two-turn curved track, time to complete was measured using timing gates that were set up at the start and the end of the track (Figure 3.1). Participants were instructed to go as fast as they could. Seat height was adjusted per child so that while seated, both feet lay flat on the ground and there was a slight bend in the knees. Children were required to wear a helmet and given one practice trial on each track with the instruction to go as fast as they could.

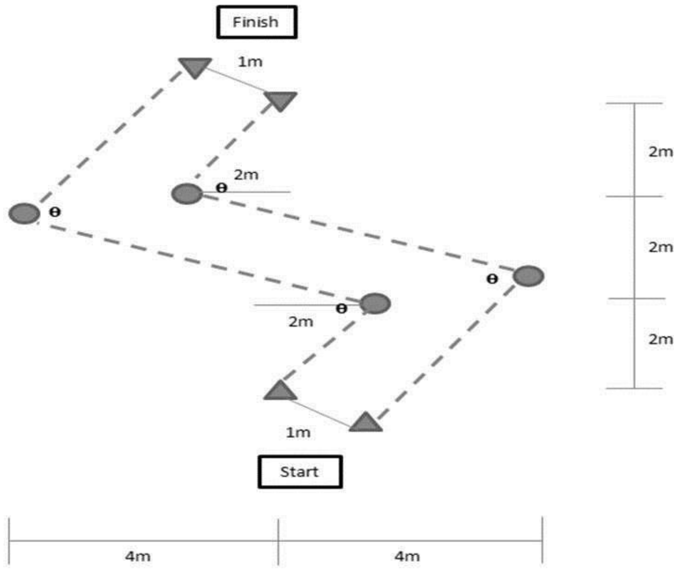


Figure 3.1. Two-turn curved track set-up
▲ = timing gates; ● = cones to indicate turn; ɵ = 90° angle

This study was approved by Dublin City University Ethical Committee and written informed consent was provided from the parents or legal guardians for all participants. Data-collection was conducted by a group of trained examiners specialised in skills acquisition in early childhood education.

Descriptive statistics were performed to assess the means and standard deviations for all the variables. Pearson product-moment correlations were run to assess the relationships between ability on a BB and the three subcomponents of FMS (locomotor, object control and stability). Interpretation of the relationships was performed using Cohen's classification where r = 0.10 – 0.29 signifies a small relationship, r = 0.30 – 0.49 signifies a moderate relationship and r = 0.50 – 1.0 signifies a large relationship (Cohen, 1988).

A principal axis factoring (PAF) was conducted to investigate if ability on a balance bike and ability at the three components of FMS (locomotor, object control and stability) can be combined to give a composite score for a latent variable named "Foundational Movement Skills competency". Prior to performing the PAF, the suitability of data for factor analysis was assessed using Kaiser-Meyer-Olkin test and Bartlett's Test of Sphericity. A Kaiser-Meyer-Olkin greater than 0.6 is deemed acceptable and greater than 0.7 is deemed good (Kaiser, 1974) and a significant ($p<.05$) Bartlett's Test of Sphericity (Bartlett, 1937). Eigenvalues greater than 1 were used to assess how many groupings or components the variables could explain (Pallant, 2011). All analyses were completed using SPSS version 22 (IBM Analytics, n.d.).

3.4 Results

The mean ± standard deviation for each of the skill categories are detailed in Table 3.1.

Table 3.1. Descriptive statistics [Mean and Standard Deviations (M ± SD)] for each skill category

Skill	M ± SD
Locomotor (Run)	**5.3 ± 1.1 (s)**
Locomotor (Jump)	**56.2 ± 20.8 (cm)**
Object Control	**10.8 ± 3.5**
Stability	**24.2 ± 16.1**
Ability on a BB[1]	**33.1 ± 14.7 (s)**

[1]Balance bike

The relationships between ability on a BB and locomotor, object control and stability were investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. There were significant moderate relationships found between ability on a BB and both locomotor ($r=.474$, $p<.001$) and object control ($r=.412$, $p<.001$), with high ability on a BB associated with high ability at locomotor and object control. There was a significant weak relationship found between ability on a BB and stability ($r=.269$, $p<.05$), with a high ability on a BB associated with a high ability at stability. The results of this analysis support the placement of cycling alongside FMS within the motor development model.

The three subcomponents of FMS (locomotor, object control and stability) and ability on a BB were subjected to principal axis factoring (PAF) to investigate they could be combined to give a composite score for a latent variable named "Foundational Movement Skills competency". Prior to performing PAF, the suitability of data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of all coefficients of .3 and above. The Kaiser-Meyer-Olkin value was .726 and Bartlett's Test of Sphericity reached statistical significance, supporting the factorability of this analysis. PAF revealed the presence of 1 component with eigenvalues exceeding 1, explaining 57.2% of the variance in the data set, meaning all four variables (ability on a BB, locomotor, object control and stability) were related enough to explain one component. Table 3.2 represents the relationships between each of the skills and the latent factor, in this case Foundational Movement Skills. The results of this analysis provide a rationale for the inclusion of ability on a BB and traditional FMS within a Foundational Movement Skill assessment.

Table 3.2. Factor loadings indicating the relationship of the individual skills to the latent variable 'Foundational Movement Skills'

Item	Factor Loadings
Locomotor	**.783**
Object Control	**.775**
Stability	**.723**
Ability on a BB[1]	**.742**

[1]Balance bike

3.5 Discussion

The results of this study support the hypothesis that ability on a BB and FMS proficiency at locomotor, object control and stability are related. This indicates that participants with higher balance bike ability are more likely to be proficient at locomotor, object control and stability and vice versa. However, ability on a BB is not strongly related to any of the subcomponents of FMS, indicating that ability on a BB, as a measure of the learning process of cycling, can be considered as a separate skill placed that place alongside FMS within the motor development model (Hulteen, Morgan, et al., 2018). While the exact commonalities between ability on a BB and the subcomponents of FMS are not the focus of this paper, the reasons as to why there is a relationship between the skills can be discussed. In order to move quickly and efficiently on a balance bike, children must use lower body strength and coordination to push their feet off the ground, propelling them forward. These requirements are not dissimilar to the requirements used during locomotor running and jumping activities where the body must be propelled through space (Haywood & Getchell, 2005). Children must also control the balance bike using the handlebars which requires coordination between the upper and lower body, similar to locomotor and object control where manipulation of objects is required to effectively throw, catch or bounce an object (Haywood & Getchell, 2005).

The results of this study also support the secondary hypothesis that ability on a BB and the subcomponents of FMS can be combined to produce one composite score for Foundational Movement Skills. Findings from the principal axis factoring identified which of the variables (ability on a BB, locomotor, object control and stability) could be used to explain the latent variable. The results of this analysis placed ability on a BB and all three subcomponents of FMS into the one component which explained 57% of the variance in the data set. This provides a rationale for ability on BB and subcomponents of FMS to be combined as a composite score and used in a measurement of Foundational Movement Skills.

Hulteen and colleagues (Hulteen, Morgan, et al., 2018) proposed that cycling be placed alongside FMS within the motor development model due to the positive lifelong implications for both physical activity and health (Figure 3.1). They proposed that cycling would be a Foundational Movement Skill as cycling has both the capability to progress into a sport specific skill and become a lifelong skill outside of sporting contexts. Within the motor development model, cycling and other skills (eg. bodyweight squat, scootering, swimming strokes) with similar path options were subsequently proposed to be included alongside traditional FMS under the heading 'Foundational Movement Skills' (Hulteen, Morgan, et al., 2018). Our results appear to compliment this approach by demonstrating the significant relationship between cycling and FMS and the lack of a strong relationship between any one component of FMS and cycling, which could suggest cycling to be a subset of that FMS. Furthermore, the results have provided rationale for the inclusion of cycling within motor development assessments, thus highlighting the importance of cycling within this newly established developmental model.

This learning process of cycling has the capability to begin and end within the FMS phase of the motor development model (Hulteen, Morgan, et al., 2018), a time when children are still exploring traditional FMS and have not yet mastered them in order to refine and combine to produce sport specific skills (Clark, 2005). As a result, in theory, ability on these constrained bikes and ability to cycle independently should not be dependent on a certain skill level of FMS, alike sport specific skills, but instead ability to cycle and traditional FMS can be developed and mastered in parallel to one another. The current paper has shown that ability on a balance bike can be categorised alongside traditional FMS and furthermore that their ability scores can be combined to produce an overall score within the newly termed Foundational Movement Skills (Hulteen, Morgan, et al., 2018). Combining scores to produce an overall score is important as it promotes measurement of all the components that make up the composite score. While there are many studies that assess FMS, stability is not included within many test batteries assessing FMS and therefore not included in their subsequent compensate scores of FMS proficiency (Engel et al., 2018; Lubans et al., 2010; Rudd et al., 2015). By not including stability within the overall assessment and scoring of FMS, it is often neglected in both measurement of FMS and design of interventions to improve FMS (Engel et al., 2018). Demonstration that ability on a BB and FMS scores can be combined means that assessment tools can look to give an overall assessment of Foundational Movement Skills and thus increasing the perceived importance of the skill and possible likelihood of increased measurement of the skill.

Models in motor development have, for many years, influenced the variables that are investigated as pathways to a healthier life (Clark & Metcalfe, 1989; Gallahue & Ozmun, 2006). For example, Gallahue and colleagues' Hourglass of Motor Development (Gallahue & Ozmun, 2006) and Clark and Metcalfe's metaphor of the Mountain of Motor Development (Clark & Metcalfe, 1989) both include fundamental movement skills as the most important measures of motor competence in early childhood as they form basic competencies from which combination and skill transfer to more specific skills occur (Clark & Metcalfe, 1989; Gallahue & Ozmun, 2006). These investigations have led to numerous studies conclusively showing how a higher proficiency in FMS relates to physical activity levels and health (Lloyd et al., 2014; S. W. Logan et al., 2015; Lubans et al., 2010). As a result, typically FMS are the focus when seeking to improve motor competence in the early and middle childhood years (Altunsöz, 2015; Bardid et al., 2013; Burrows et al., 2014; Cohen et al., 2015; Morgan et al., 2013). The growing emphasis placed on FMS in schools may be attributed to this growing body of evidence on the benefits of improving FMS (Lloyd et al., 2014; S. W. Logan et al., 2015; Lubans et al., 2010). Highlighting other important skills, such as cycling, and ensuring that they are not neglected in research by combining ability scores with ability at already emphasised skills, such as FMS, is the first step in increasing awareness of the importance of these lifelong skills. Moreover, by placing cycling alongside traditional FMS and combining ability scores to highlight importance and increase measurement, more research will be directed to explore the potential benefits of learning and improving the skill of cycling in the preschool years, like has been accomplished with traditional FMS. Cycling is a valuable lifelong skill and also one of the top activities for many societies and cultures (Hulteen et al., 2017). Hulteen and colleagues acknowledged the importance of providing relevant lifelong skills based on societal and cultural norms by adding a 'socio-cultural and geographical' filter to their motor development model (Hulteen, Morgan, et al., 2018). By including cycling alongside traditional FMS, research will be encouraged to provide investigation into a highly common and relevant skill in many societies and cultures and thus provide the best opportunity for physical activity promotion (Hulteen, Morgan, et al., 2018; Hulteen et al., 2017). Future studies should investigate the other relevant lifelong skills and how they relate to traditional FMS and assessment of Foundational Movement Skills. With the substantial amount of evidence supporting the health benefits of physical activity it is imperative that we encourage and support the factors that contribute to a physically active life.

3.6 Conclusion

The results of this study provide evidence for ability on a BB to be included alongside FMS. Also, the main findings highlight that the scores of ability on a BB and the subcomponents of FMS (locomotor, object control and stability) can be combined to produce a composite score of motor competence as a single measurement of Foundational Movement Skills proficiency. By combining the scores to produce one score, holds emphasis on all skills and the needs to integrate them all in one assessment and therefore may reduce the likelihood that ability on a balance bike would be neglected in measurement and the design of interventions. An increased proficiency level of these skills would subsequently improve both physical and mental health in childhood and into adulthood (Oja et al., 2011). By including other lifelong skills within the motor development model, a more holistic assessment of motor competence can possibly be achieved. This change may drive researchers and policy makers to include additional relevant skills in their interventions which may subsequently contribute to a greater increase in life-long physical activity levels and improved health. Cycling is an important lifelong skill to promote as it is not only a specialised sport skill but also a leisure and commuting activity that can be enjoyed throughout life with many health benefits (Oja et al., 2011). Including ability on a BB alongside traditional FMS, as a sub-set of Foundational Movement Skills, means that future research will be guided to include cycling within their frameworks, providing a more all-encompassing view of motor competence.

Future research should investigate the role of other constrained forms of cycling (i.e. additional training wheels) and the other proposed skills (swimming, body-weight, squat etc.) within Foundational Movement Skills and assessment of motor competence. Future research should also consider developing scales to assess cycling from a process-oriented approach and subsequently assess ability to cycle and fundamental movement skills through process-oriented measures. This will allow further exploration into whether process-oriented measures also correlate in similar ways to product-oriented measures. Such endeavour would provide further evidence for the inclusion of ability on a balance bike alongside traditional FMS. Furthermore, the factors that contribute to learning to cycle independently should be examined through cycling interventions and questioning of the role of the commonly used constrained bikes.

Linking section from Chapter 3 to Chapter 4

From Chapter 3, it was concluded that ability on a balance bike could be included alongside fundamental movement skills within the motor development model. Furthermore, it concluded that ability on a balance bike could be combined with ability at traditional fundamental movement skills (locomotor, object control and stability) to produce a composite score to be used as a measurement of Foundational Movement Skills. Much of the previous scientific literature on motor development in early childhood has focused on traditional fundamental movement skills, excluding other lifelong skills such as cycling.

While Chapter 3 set the precedent for the inclusion of ability on a balance bike as an additional measure of actual motor competence, Chapter 4 aims to aid the understanding of the relationships that ability on a balance bike has between traditional measures of actual motor competence, perceived motor competence and how these factors influence engagement of the skill of a balance bike.

Including ability on a balance bike to the motor development model, denotes the importance to investigate what factors influence the learning of this skill. Previous theories and models have been derived from research into factors that influence actual motor competence and perceived motor competence. Chapter 4 examines the relationship between actual and perceived motor competence as well as investigating their relationship with ability on a balance bike. Chapter 4 also examines if actual and perceived motor competence and balance bike ability influence motor skill engagement. Motor skill engagement has not been extensively researched in the area of motor development yet has implications for the development of skills as understanding what factors might contribute to a child engaging in a skill may aid the understanding of how best to encourage uptake.

Chapter 4 - How actual motor competence and perceived motor competence influence motor skill engagement of a novel cycling task

Kavanagh, J. A., Issartel, J., Moran, K., 2019. How actual motor competence and perceived motor competence influence motor skill engagement of a novel cycling task. *Scandinavian Journal of Medicine and Science in Sport (in press).* https://doi.org/10.1111/sms.13492

This paper has been reformatted to fit the current thesis, with minor changes made as a result of examiners revisions.

4.1 Abstract

In early childhood, factors that contribute to motor skill engagement (MSE) are unknown. Our aim was to explore the relationships between actual and perceived motor competence and their influences on MSE on a balance bike (bike with no pedals). A secondary aim was to investigate if MSE had an effect on ability on a balance bike. This study comprised of 45 children (29% female) aged 4.5 +/- 0.5 years. MSE was assessed using distance travelled on a balance bike over an 8-week period. Actual motor competence was assessed using the Movement Assessment Battery for Children, second edition. Perceived motor competence was assessed using the Pictorial Scale of Perceived Movement Skill Competence. Ability on a balance bike was measured using timed trials on a specifically designed track. Pearson product-moment correlations were used to assess relationships between actual and perceived motor competence and ability on a balance bike. Linear regressions were used to examine if actual or perceived motor competence or ability on a balance bike predicted MSE. Repeated measures ANOVA was used to examine if there was a difference in ability on a balance bike

between three MSE groups over 8 weeks. No relationships were found and none of the variables predicted MSE. There was a significant difference between the MSE groups on ability on a balance bike over time (p=.019). Investigating the contributors to MSE on a novel cycling task during early childhood provides knowledge to ensure children are given the best opportunities for practice and acquisition of skills.

4.2 Introduction

Motor competence can be defined as a person's movement coordination quality and level of performance outcome when undertaking different motor skills (Robinson et al., 2015). Motor competence includes fine motor skills and gross motor skills (Lubans et al., 2010). The Movement Assessment Battery for Children, second edition (MABC-2) is a well-recognised test battery for assessing both fine and gross motor skills in 3-16 year olds (Ted Brown & Lalor, 2009). Fundamental movement skills (FMS) are measures of gross motor skills and are considered the most basic observable patterns of movement and are the building blocks for future movement and physical activity (Clark & Metcalfe, 1989; Seefeldt et al., 1980). Motor development is the study of motor behaviour, including motor competence, over time and is often represented in phases of motor development (Clark & Whitall, 1898). The FMS phase of development, which occurs during early childhood, is a critical developmental period for children as many physiological and psychological changes take place (Ortega et al., 2008). Moreover, children are met with a hypothetical "proficiency barrier" at the end of the FMS phase of development (Seefeldt et al., 1980). At this point, greater mastery of FMS increases the likelihood of breaking through the barrier and applying these FMS to sport specific skills, leading to a positive trajectory towards a lifetime participation in physical activity (De Meester et al., 2018a). Being on a positive trajectory means a child will be more likely to engage in physical activities throughout adolescence and into adulthood. The proficiency barrier was first proposed by Seefedlt (1979) in his motor development model (Seefeldt et al., 1980). Hulteen and colleagues have more recently highlighted the importance of this proficiency barrier by placing it in their motor development model (Figure 4.1) (Hulteen, Morgan, et al., 2018). The proficiency barrier theory originated from the idea that children's perceptions of their motor competence or perceived motor competence, are inaccurate and generally inflated in early childhood, but become increasingly more accurate as they transition into middle childhood (Harter, 1999). In early childhood, inflated levels of perceived motor competence have been thought to drive the acquisition of actual motor competence (Stodden et al., 2008a). This is as a result of theories from earlier research suggesting that perceived motor competence was tied to task engagement (Harter & Pike, 1984; Nicholls, 1978; Nicholls & Miller, 1983).

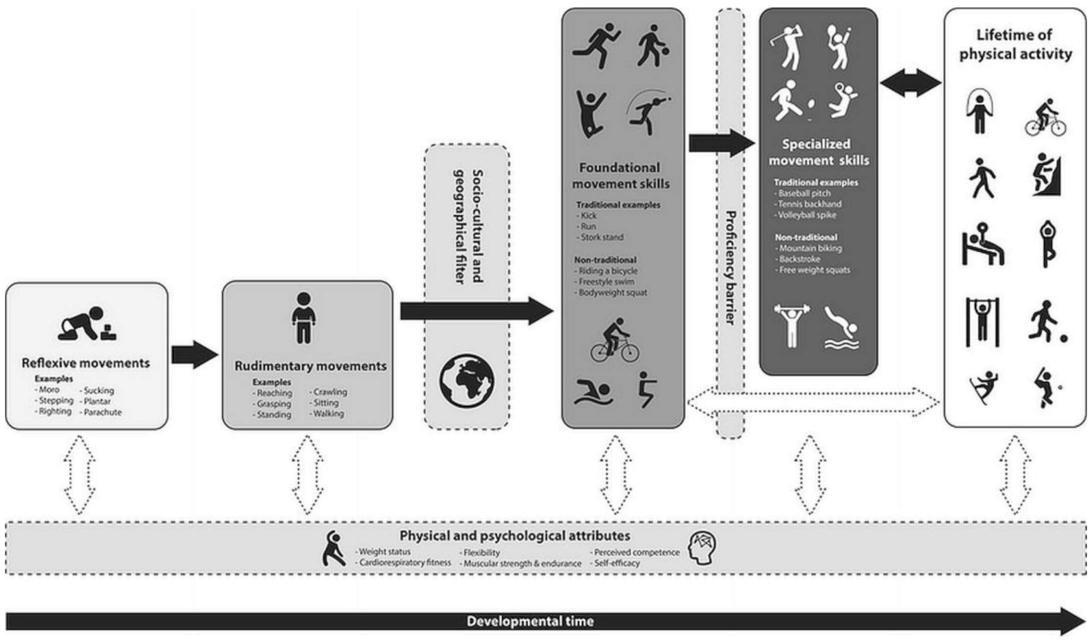


Figure 4.1. Motor Development Model as proposed by Hulteen et al., depicting the development of foundational movement skills for physical activity across the lifespan 9. Reprinted with permission.

Behavioural engagement is considered crucial for achieving positive performance outcomes as it draws on the idea of participation and includes involvement in extracurricular activities (Fredricks et al., 2004). Previous research in behavioural engagement in motor skill contexts has defined motor skill engagement (MSE) as the amount of practice (Lacy & Martin, 1994). It has been previously hypothesised that perceived motor competence would influence MSE in an activity (Eccles & Harold, 1991; Eccles & Wigfield, 2002). However, to the authors' knowledge, there has been no research into the relationship between either actual or perceived motor competence or MSE of a novel skill in early childhood. In the current study a novel skill represents a never before attempted skill.

Stodden and colleagues (2008) developed a model to demonstrate the interactions between actual motor competence, perceived motor competence, and health related physical fitness and physical activity over time (Stodden et al., 2008). Early childhood, middle childhood and late childhood were separated as they proposed that the relationships among the variables would change as developmental age changed. Research into this hypothesised model in early childhood has focused on the relationships between actual motor competence and both perceived motor competence and physical activity levels (Crane, 2017; LeGear et al., 2012; Lopes et al., 2016; Lubans et al., 2010). In most studies in early childhood, actual motor competence was measured through ability at fundamental movement skills (FMS) and physical activity was assessed through an assessment of the amount of moderate to vigorous physical activity achieved (Crane, 2017; LeGear et al., 2012; Lopes et al., 2016; Lubans et al., 2010). Research in early childhood has shown some conflicting results when assessing the relationship between actual motor competence and perceived motor competence. Barnett, Ridgers, & Salmon, (2015) found significant positive associations between actual and perceived object control skills in children aged 4-8 years (Barnett, Ridgers, & Salmon, 2015). Similarly, LeGear et al., (2012) and Robinson, (2011) found significant weak and moderate positive associations between actual and perceived motor competence in preschool children (LeGear et al., 2012; Robinson, 2011). Contrary to these results, other research has found no relationships (Lopes et al., 2016; Spessato et al., 2013).

Hulteen and colleagues proposed the addition of relevant lifelong skills, like cycling and swimming, to the FMS phase of development within the motor development model (Figure 4.1) as it was thought that skills learnt at this age were being neglected in research (Hulteen, Morgan, et al., 2018). Relevant lifelong skills along with traditional FMS are defined together as foundational movement skills (Hulteen, Morgan, et al., 2018). Cycling in particular is one of the most commonly reported active recreational pastimes during early childhood (Dunst et al., 2009). With the varying levels of participation in relevant lifelong skills in childhood, such as cycling, it is extremely important to understand the factors that may contribute to the positive engagement in these skills during the time of the initial learning process. In order for a child to learn a complex skill like cycling, engagement and persistence in the task is required. The main aim of this paper is to investigate the relationships between actual motor competence, perceived motor competence and ability on a balance bike (timed trial on a bicycle with no pedals) and the influence of actual motor competence, perceived motor competence and ability on a balance bike on MSE at a novel cycling skill during early childhood. These investigations are important as they may provide a better understanding of what drives a child's engagement at lifelong skills during this critical developmental window, with willingness to engage in a new skill being a potential important indicator of lifelong physical activity.

Learning to cycle is an acquired skill that requires practice to master (Åström et al., 2005). Being able to ride a bike is fun and a popular pastime but it also opens up more opportunities for a healthy lifestyle through physical activity and transportation. Children are frequently taught to cycle using a constrained bike [i.e. no pedals (balance bike) or with additional wheels (bike with training wheels)] before progressing to cycling with no assistance on a traditional bike. Balance bikes are a type of constrained bike that have recently gained attention as a potentially more appropriate precursor to riding a bike, with a number of manufacturers claiming that the skills learned on a balance bike are directly transferable to riding a traditional bike (“LIKEaBIKE,” 2019; “Strider,” 2019). However, no research to date appears to have examined ability on a balance bike or whether practice on a balance bike increases competency on the balance bike. The power law of practice theory would suggest that large amounts of improvement should occur during the early stages of practice on the balance bike (Magill, 2007). Therefore, a secondary aim on this paper is to investigate the practice effects of a balance bike, to examine if it is in fact a skill to be improved through practice. Furthermore, if ability on a balance bike is associated with actual motor competence or perceived motor competence.

4.3 Materials and Methods

Participants

Ninety children in total were recruited from ten preschools. Forty-five children (4.5 +/- 0.5 years; 29% female) were given balance bikes for eight weeks to free play on and were included in the current study. Participants were included if they were between 3 and 5 years of age and had never used a balance bike before.

Procedure

This study was approved by Dublin City University Ethical Committee (REC/2016/031) and written informed consent was provided from the parents or legal guardians for all participants. Data-collection was conducted by a group of trained examiners specialised in skills acquisition in early childhood education. The principal investigator provided further training to two examiners in the assessment protocols over two days, with 4 hours of training required in total. The principal investigator also trained one of the examiners in the intervention design and the games, with an additional 5 hours of training for this. A warm-up was used at the beginning of the testing session which was found to provide encouragement for the children to take part in all of the data collection. The warmup consisted of a group jog up and down a length of approx. 15m and some active stretches. Autonomy was also given to the children to showcase their own body movements that the group would then mimic. The warmup took roughly 10 minutes.

Motor Skill Engagement

Inertial Measurement Units (CATEYE Velo 5, Boulder, USA) were attached to the wheel of the balance bikes given to the children to measure each revolution of the wheel which was used to measure distance covered over the 8-week intervention period and this was subsequently used as MSE. Parents were instructed to not allow anyone other than the participant to use the bike and to hold onto the wheel with the counter attached when moving the bike to control for additional wheel spinning during non-riding time. Parents were instructed to allow the child to decide when they wanted to play on the bike. In an attempt to assess changes in greater detail, the participants were split into high (>10.5km), medium (2.5-10.5km) and low

(<2.5km) MSE groups based on distance covered on the bike over the 8 weeks. Participants were split through calculation of tertiles.

Actual motor competence

Fine motor skills, object control and stability, as assessments of actual motor competence, were assessed using the Movement Assessment Battery for Children, second addition (MABC-2). The MABC-2 is a well-validated standardised test that assesses fundamental movement skills (FMS) of children between 3 and 16 years of age (Ted Brown & Lalor, 2009). The MABC-2 assessed the participants in three fine motor skills (placing coins in a box, threading beads and drawing trail), two object control skills (throwing a beanbag to a mat and catching a beanbag) and three stability skills (one leg balance, jumping on mats and walking a line). The children were assessed on each skill twice and the best score was converted into a standardised score based on their age on a scale of 1-19.

Perceived motor competence

Perceived motor competence was assessed using the validated and reliable Pictorial Scale of Perceived Movement Skill Competence (Barnett et al., 2016). Perceived competence at each skill (run, jump, leap, hop and kick, riding a bike, riding a scooter and skating) was scored from 1-4 with a minimum score achievable of 8 and a maximum score of 32. The participant was first asked to compare themselves to one of two pictures of a child performing the skill, either 'well' or 'not well'. If they chose the child that was performing the skill 'well' they were further asked if they were 'pretty good' (awarded score of 3) or 'really good' (awarded score of 4). If they chose the child that was performing the skill 'not well' they were further asked if they were ‘sort of good’ (awarded score of 2) or ‘not too good’ (awarded score of 1). Each child was assessed individually at the beginning of the test period.

Ability on a Balance Bike

Children’s ability on a balance bike (Y-Velo, Dublin, Ireland) was measured, at pre and post intervention, using the sum of the average of two time trials over a specifically designed track that included a 4m straight-line path and a curved path (Figure 4.2). A track with both a straight and curved path was used to align the movements typically observed when playing on a balance bike. Timing gates that were set up at the start and the end of the track with the first timing gate 10cm from the start line. Participants were instructed to go as fast as they could as ability was measured using the outcome measure of time. Seat height was adjusted per child so that while seated, both feet lay flat on the ground and there was a slight bend in the knees (Cox, 2019). Children were required to wear a helmet and given one practice trial. All children were willing and able to successfully complete the course.

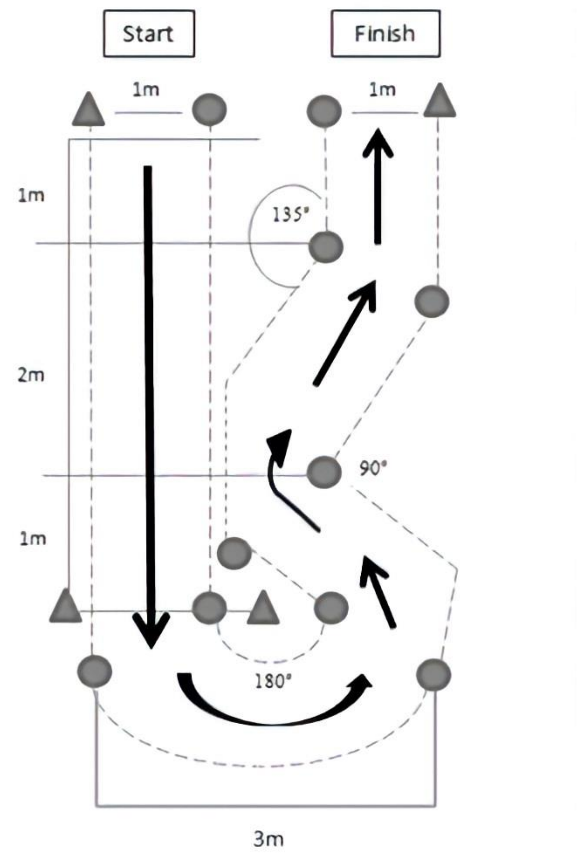


Figure 4.2 Track set-up to measure ability on a Balance Bike.
Arrows used to indicate direction of travel.

Data Analysis

Descriptive Statistics

Descriptive statistics were performed to assess the means and standard deviations of each of the variables.

Pearson Product-Moment Correlations

To examine if the children have inflated levels of perceived motor competence relative to actual motor competence, Pearson product-moment correlation analyses were run between perceived motor competence and actual motor competence. Pearson product moment correlations were also run to assess relationships between actual motor competence [and the subcomponents of actual motor competence (fine motor skills, object control and stability)] and initial ability on a balance bike, and between perceived motor competence and initial ability on a balance bike. Interpretation of the relationships was performed using Cohen's classification where r = 0.10 – 0.29 signifies a small relationship, r = 0.30 – 0.49 signifies a moderate relationship and r = 0.50 – 1.0 signifies a large relationship (Cohen, 1988).

Linear Regression

Six linear regression analyses were run to examine if actual motor competence [and the subcomponents of actual motor competence (fine motor skills, object control and stability)], perceived motor competence or ability on a balance bike predicted MSE.

3x2 Repeated Measures ANOVA

A 3x2 repeated measures ANOVA and Bonferroni post-hoc test was used to examine if there was a difference in ability on a balance bike between three MSE groups (high MSE, medium MSE, low MSE) from pre to post of the 8-week intervention period.

All analyses were completed using SPSS version 22 (IBM Analytics, USA). Significance level was set at p=.05.

4.4 Results

Descriptive statistics

All participants were assessed on their perceived motor competence, overall actual motor competence, fine motor skills, object control skills, stability, ability on a balance bike (pre and post) and motor-skill engagement. The mean ± standard deviation for each of the skill categories are detailed in Table 4.1.

Table 4.1. Descriptive statistics [Mean and Standard Deviations (M ± SD)] for each variable

	(M ± SD)	Scoring range
Overall Actual Motor Competence (a.u)	7.9 ± 3.2	1-19
Fine Motor Skills (a.u)	8.1 ± 2.9	1-19
Object Control (a.u)	9.8 ± 3.4	1-19
Stability (a.u)	8.1 ± 3.6	1-19
Perceived Motor Competence (a.u)	28.1 ± 3.9	8-32
Ability on a Balance Bike (pre) (s)	14.6 ± 5.4	N/A
Ability on a Balance Bike (post) (s)	10.1 ± 3.9	N/A
Motor-skill Engagement (km)	10.3 ± 12.4	N/A

a.u; arbitrary units, s; seconds, km; kilometres

Pearson Product-Moment Correlations

Relationships between actual motor competence perceived motor competence, and between perceived motor competence and initial ability on a balance bike and between actual motor competence and initial ability on a balance bike are presented in Table 4.2

Table 4.2. Correlations (r) between actual motor competence, perceived motor competence and ability on a Balance Bike.

	Perceived Motor Competence (a.u)		Ability on a Balance Bike pre-intervention (sec)	
	r	**p**	**r**	**p**
Overall Actual Motor Competence (a.u)	.024	.955	.123	.618
Fine Motor Skills (a.u)	.023	.705	.008	.810
Object Control (a.u)	.014	.989	.008	.771
Stability (a.u)	.089	.762	.118	.339
Ability on a Balance Bike pre-intervention (s)	.119	.196		

***Correlation is significant at the 0.05 level (p<0.05). a.u; arbitrary units, s; seconds.**

Linear Regression Analyses

The results of six linear regressions to investigate whether (i) perceived motor competence (ii) actual motor competence (combined score) (iii) fine motor skills, (iv) object control, (v) stability or (vi) ability on a balance bike at pre-intervention, could predict the dependent variable of MSE are presented in Table 4.3. None of the variables significantly predicted the MSE on a balance bike (p>.05).

Table 4.3. Linear regression results (r^2) to the dependent variable MSE.

Predictors of MSE (km)	r^2	p
Overall Actual Motor Competence (a.u)	**.003**	**.729**
Fine Motor Skills (a.u)	**.009**	**.545**
Object Control (a.u)	**.000**	**.930**
Stability (a.u)	**.000**	**.889**
Perceived Motor Competence (a.u)	**.010**	**.537**
Ability on a Balance Bike (pre) (s)	**.002**	**.782**

***Correlation is significant at the 0.05 level (p<0.05). MSE; motor skill engagement, pre; pre- 8-week intervention, a.u; arbitrary units, s; seconds, km; kilometres.**

3x2 Repeated Measures ANOVA

Differences in ability on a balance bike between three groups of MSE (high, medium and low) across two time periods (pre-intervention and post-intervention) can be seen in Figure 4.3. There was a significant interaction effect between MSE groups and time, Wilk's Lambda = .788, $F(2,33) = 4.45$, $p = .019$. The post-hoc analysis revealed a significant difference between the high and the low MSE groups ($p<0.025$) with the high MSE group producing the highest improvements in ability on a balance bike over the 8 weeks, followed by the medium group and lastly the low group. There was a substantial main effect for time, Wilk's Lambda = .590, $F(1,33) = 22.9$, $p<.001$, with both the medium and high MSE groups showing an improvement in ability on a balance bike over time (see Figure 4.3). There was no significant main effect for MSE groups, $F(2,45)=.416$, $p=.663$.

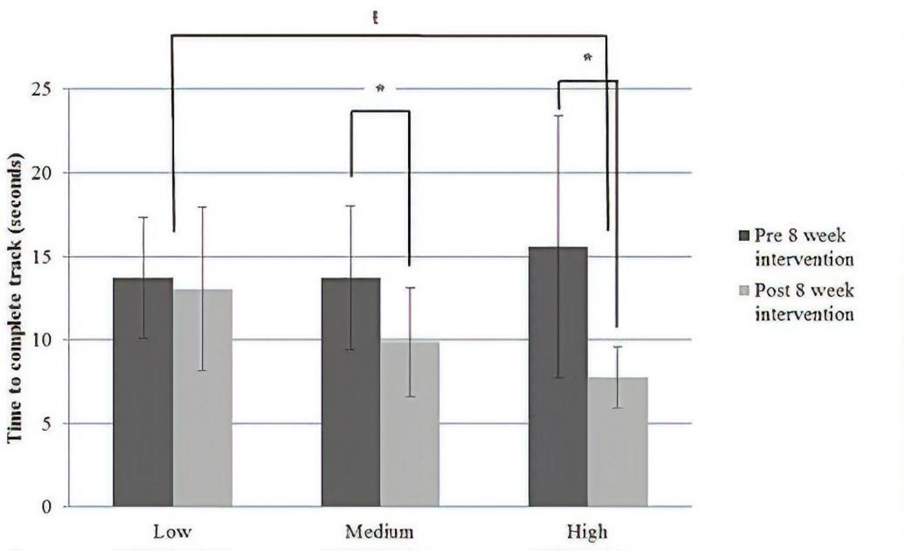


Figure 4.3. Ability on a balance bike from pre to post 8-week intervention per high, medium and low MSE groups. (Lower values indicate faster times over the course and therefore better ability).

4.5 Discussion

The main aim of this paper was to examine the relationships between actual motor competence, perceived motor competence and initial ability on the balance bike and to examine if any of these variables predict the MSE of a novel cycling task (on a balance bike). It has been suggested that during early childhood children have inflated levels of perceived motor competence (Harter, 1999). The current results support children having inflated levels of perceived motor competence as their average perceived motor competence score was 28.1 ± 3.9 (Table 4.2), which was much closer (top 25% range) to the maximum score of 32 than the minimum score of 8 (Barnett et al., 2016), indicating that children perceive themselves to be very good at most of the skills assessed. Moreover, the results also support children having inflated levels of perceived motor competence relative to their actual motor competence as there were no correlations between their perceptions of ability and actual motor ability, including when actual motor competence was split by subcomponents (fine motor skills, object-control and stability) (Table 4.3). Furthermore, these results agree with the theory that perceived motor competence has little to no relationship to actual motor competence in early childhood (Stodden et al., 2008a). The high levels of perceived motor competence found in the current study are consistent with ranges previously reported in preschool children (LeGear et al., 2012). Additionally, neither perceived motor competence nor actual motor competence were related to initial ability on a balance bike. Lopes et al. (Lopes et al., 2016) and Spessato et al. (Spessato et al., 2013) found similar results with no significant relationship between perceived motor competence and actual motor competence in preschool children. In contrast, Barnett et al. (Barnett, Ridgers, & Salmon, 2015) found positive relationships between these factors in children aged 4-8 years, with Robinson (Robinson, 2011) finding weak relationships in children aged 4 years and LeGear et al., (2012) finding moderate relationships in preschool children. The lack of associations found in our study is probably due to children in early childhood not having the cognitive ability to make accurate self-judgements of ability (Weiss & Amorose, 2005) or to be able to differentiate between actual motor competence and effort (Harter, 1999; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002).

The tendency towards inflated levels of perceived motor competence found in the current and previous studies has been hypothesised to drive acquisition of actual motor competence (Stodden et al., 2008) and MSE (Harter & Pike, 1984; Nicholls, 1978; Nicholls & Miller, 1983). However, the current study found varying levels of MSE of a novel skill that was not predicted by perceived motor competence. Investigation into other measured contributors showed similar results, with neither actual motor competence (fine motor skills, object control, stability and overall motor competence) nor initial ability on a balance bike showing predictive power toward MSE of a novel cycling task. This would indicate that it is not the perception of motor competence, actual levels of motor competence or initial ability at the chosen skill that are driving MSE. While no comparison to other studies could be made when investigating perceived motor competence as a predictor of MSE, it is not surprising perhaps that if no relationship exists between perceived motor competence and actual motor competence then no relationship would also exist between perceived motor competence and MSE. Engagement of the skills used to measure actual motor competence (i.e. fine motor skills, object control and stability) are required in order to improve ability at these skills, as they must be learned through practice as they are not developed naturally (Gallahue & Ozmun, 2006). Future research should investigate which other factors, for example parental influences (Freeberg & Payne, 2018), environment (De Barros, Câmara Fragoso, Bezerra de Oliveira, Cabral Filho, & Manhães de Castro, 2003), culture and individual differences (body composition, motivation, personality/emotional make-up) (Clark & Metcalfe, 1989; Gallahue & Ozmun, 2006), may explain why a child chooses to engage or not in a novel skill or physical activity.

A secondary aim of this paper was to examine if the volume of practice on the balance bike affects the amount of improvement in the ability of that skill. It was found that those who rode the balance bikes over greater distances (high MSE group) improved significantly more than those who did not (low MSE group) with the high MSE group improving by 101%, the medium MSE group by 13% and the low MSE group by 3% (Figure 4.3). The large improvement made by the high MSE group fits within the power law of practice theory as generally during the early stages of practice of a novel skill there is a large amount of improvement relatively quickly (Magill, 2007). This is due to the learner making large errors in the beginning that are often easy to correct after some practice. Previous studies have also shown that when you practice a certain skill you will subsequently improve at that skill (Altunsöz, 2015; Morgan et al., 2013). The improvement observed is likely due to significant improvements on the balance bike emerging from greater interactions between the individual characteristics, the task constraints and the properties of the environment (Davids et al., 2008). Consequently to these interactions, new coordination patterns emerge allowing for greater performance on the balance bike.

4.6 Limitations

The non-prescriptive nature of the intervention, while imperative to assess actual MSE, is not without limiting factors. The parents of the participants were asked to not allow anyone other than the participant to use the balance bike; however, there is no evidence that each participant was not the sole rider contributing the distance covered on the bike and subsequently the MSE group allocated. The counters used also only allowed for distance covered to be measured and not amount of practice which may have had an effect as some children may have moved slower but had longer practice times. Furthermore, environment, parental influences, physical activity levels, previous experience with similar toys, family demographics, parent's views on importance of learning new skills and opportunities to practice were not recorded during the study.

4.7 Perspectives

The current study has taken a unique approach to investigating the MSE of skills in early childhood. Until recently, lifelong skills like cycling, which are first learnt during the early childhood years, have been neglected in early childhood research. It was hypothesised that perceived motor competence would drive skill acquisition as children would have inflated levels of perceived competence that would increase likelihood to engage and persist at a novel task. The current results have shown that while children do have inflated levels of perceived competence, this does not appear to be a prominent driving factor in MSE of a novel cycling task. Similar to perceived motor competence, neither actual motor competence nor initial ability on a balance bike predicted a child's engagement levels on a balance bike. Investigating these relationships opens up opportunities for future research to investigate possible contributors to MSE during the early childhood years. Understanding the predictors of MSE of lifelong skills like cycling would mean that more effective strategies could be designed to ensure that children are given the best opportunities for practice and acquisition of skill during a critical developmental window, when perceptions of competence aren't found to be a limiting factor.

Linking Section from Chapter 4 to Chapter 5

From Chapter 4 it was found that there were no relationships between actual motor competence, ability on a balance bike and perceived motor competence. Furthermore, none of the variables predicted motor skill engagement on a balance bike. The results from this study were not surprising perhaps as previous research into these relationships has been conflicting. Both Chapter 3 and Chapter 4 introduced research into the field on ability on a balance bike. Ability on a balance bike was examined as a balance bike is a commonly used tool to learn to cycle independently and so describes a commonly used process to independent cycling.

Chapter 5 aims to examine another aspect of the process to independent cycling, which is development of the skill of independent cycling itself. As no research to date has examined any aspect of the development of independent cycling, there are no tools available to quantify performance on a traditional bike and consequently no research on stages that a child may go through during this development process. Therefore, Chapter 5 was designed to develop a scale that could assess ability on a traditional bike as a developmental process and to investigate the learning patterns that children go through when learning the lifelong skill of cycling.

Chapter 5 - Development and Reliability of the KIM Cycling Scale – A Measurement Tool for the Development Process to Cycling Independently

Kavanagh, J., Moran, K., Issartel, J., 2019. Development and Reliability of the KIM Cycling Scale – A Measurement Tool for the Development Process to Cycling Independently. *Physical Education and Sport Pedagogy (in press).*

This paper has been reformatted to fit the current thesis, with minor changes made as a result of examiners revisions.

5.1 Abstract

Cycling has gained more attention as an important lifelong physical activity. Learning to cycle independently without assistance is a milestone for most children that requires time and practice to master. Cycling was recently added to the motor development model and so a valid and reliable measure of cycling ability is required to allow accurate assessment of the skill. Cycling has many health benefits along with being a commonly reported physical activity globally and therefore is an important skill to promote in early childhood and throughout life. To date, there are no measurement tools examining the developmental process to independent cycling in the early childhood years. The current study aimed to develop and assess the inter-rater and test-retest reliability of the "KIM Cycling Scale". Development of the scale occurred in four phases: (1) development of criteria and stages, which used observation of children when learning to cycle and expert panels to develop the initial developmental stages, (2) review of instructions and criteria and pilot inter-rater and test-retest reliability, to ensure that the scale could be used as a standalone scale without requiring further instructions (3) cycling intervention, which allowed assessment of the developmental nature of children along the scale as they learn to cycle independently and to assess typical and alternate routes to independent cycling and (4) inter-rater and test-retest reliability. Ninety children took part in phase 1, thirty-six children took part in phase 2, seventy-four children took part in phase 3 and one hundred and forty-nine children took part in phase 4. All three hundred and forty-nine children were between 2 and 6 years. The developed scale included eight stages in total. The scale was found to have excellent inter-rater reliability (ICC = 0.97, 95% CI = 0.96-0.98) and good to excellent test-retest reliability [(ICC = 0.91, 95% CI = 0.87-0.94) & (ICC = 0.90, 95% CI = 0.85-0.93)]. Typical routes to independent cycling along the scale were examined and reported as being step-wise on all occasions except one where a two-stage jump was as common as the step-wise route. Alternate routes were also reported. The current study developed a reliable measurement tool for assessing children between 2 and 6 years of age on the developmental process to independent cycling. Having a cycling scale will allow teachers and practitioners to assess competence in cycling and moreover, track changes in skill development. Furthermore, parents could also use the scale to better understand and better asses their child's progression when learning to cycle.

5.2 Introduction

Independent cycling is the ability to cycle a traditional bike without the assistance of a person holding on to support the cyclist or additional 'training' wheels. Learning to cycle independently without assistance is a milestone for most children and is one of the most commonly reported active recreational pastimes during early childhood (Dunst et al., 2009; Nielsen et al., 2011) as well as being one of the most commonly reported physical activities globally (Hulteen et al., 2017). A systematic review on the health benefits of cycling in childhood and into adulthood have shown consistent, strong, positive relationships between cycling and cardiorespiratory fitness (Oja et al., 2011). Importantly, Oja and colleagues also found that those who cycled to school were five-times more likely to be in the top quartile of fitness compared to those who walked or passively commuted. A longitudinal study found fitness to have significantly increased by 6-21% in children who changed to cycling from non-cycling to school over 6 years (Cooper et al., 2008). Moreover, cycling is an important lifelong skill as it can be used recreationally, for sport or for transportation. The importance held for cycling globally is evident through the allocation of specific strategies and funds to increase cycling participation and improve infrastructure for everyone and specifically children (European Cyclists' Federation, 2017; World Health Organization., 2004). Encouraging children to learn to cycle independently from a young age can be central to many people in increasing opportunities for a physically active life.

While assessment tools have been developed to evaluate the level of cycling skill in 5-13 year olds, with a focus on cycling safety (Arnberg, Ohlson, Westerberg, & Öström, 1978; Ducheyne, De Bourdeaudhuij, Lenoir, Spittaels, et al., 2013; Macarthur, Parkin, Sidky, & Wallace, 1998), these tools are for children who can, already, cycle independently. To the authors' knowledge, no studies have assessed the developmental process to cycling independently in children (2-5 year olds).

Typically research on physical activity and motor competence has focused on fundamental movement skills such as locomotor and object control as these were thought to be the building blocks of motor development (Clark, 2005) from which more specialised skills arise (Stodden et al., 2009). Many interventions have been designed with the aim of improving fundamental movement skills in the preschool years (Altunsöz, 2015; Bardid et al., 2013). While fundamental movement skill acquisition is undoubtedly important at this age (Logan et al., 2015; Lubans et al., 2010; Robinson et al., 2015), as demonstrated in numerous interventions (Altunsöz, 2015; Bardid et al., 2013), it has been proposed that more lifelong physical activities such as cycling warrant focus, particularly during the critical development window of 2-6 years of age (Hulteen, Morgan, et al., 2018).

Cycling interventions that focus on cycling safety with children who already know how to cycle independently are common in primary school education (Ducheyne et al. 2014; Goodman, van Sluijs, & Ogilvie 2016; Hatfield et al. 2015; Montenegro 2015; Richmond et al. 2014). These interventions have shown an increase in cycling skills, confidence on the bike and knowledge of cycling safety (Ducheyne et al. 2014; Hatfield et al. 2015; Montenegro 2015; Richmond et al. 2014). In evaluations of two of the school-based cycling programmes, 'CYCLE Kids' and 'Safe Cycle', teachers reported that the programme increased the desire to cycling outside of school, increased excitement about exercising, overcoming fears of riding bicycles (Montenegro, 2015) and increasing confidence and cycling participation (Hatfield et al., 2015) to be important outcomes of the interventions. Furthermore, students were reported as having higher collaborative and empathetic behaviours towards other students and improving on their relationships with teachers (Montenegro, 2015). One challenge mentioned by teachers on the 'Safe Cycle' programme was that the programme assumed that all students could ride a bike, which was not the case and caused some issues. A recommended solution to this was delivery of a learning to ride programme in the earlier years.

Risk awareness and the value of risk are important factors to consider in preschool education. Cycling and particularly learning to cycle is a risk and so interventions based around learning to cycle could be considered as risky play interventions. An important factor in exposing children to risky play is that overcoming challenging situations like learning to cycle is an essential part of living a meaningful and satisfying life (Gill, 2007). Cycling interventions in the preschool years may provide many benefits to children; however, tools need to be developed to aid teachers and practitioners in understanding the developmental process to learning to cycle independently in order to provide them with the information needed to carry out an intervention seeking to teach children to cycle independently. While risk taking is important, a fall from a bike when a child was not ready to cycle without assistance may discourage a child from trying again. A measurement tool to assess the development of independent cycling would be an extremely useful tool in this instance to allow teachers and practitioners to have better insight into when it would be appropriate to remove assistance.

Hulteen and colleagues developed a test battery to measure some of the other proposed lifelong physical activities (grapevine, golf swing, jog, push-up, squat, tennis forehand, upward dog and warrior) in 14-16 year olds in an effort to capture the proficiency levels of skills considered as popular physical activities in adulthood (Hulteen, Barnett, et al., 2018). In a list of important skills, cycling did rate high by experts when asked: “how well does the skill fit the definition of lifelong physical activity?” and “is there a need to increase skill competency of this skill”, thus demonstrating the need for a measurement tool to assess the development of cycling ability. Unfortunately, cycling was not included within the test battery due to feasibility issues in assessing the skill in a school setting (Hulteen, Barnett, et al., 2018). Such a measurement tool would enhance understanding of competence in the development of the skill of cycling in the preschool years, thereby facilitating the promotion of cycling as a lifelong skill along with the fundamental movement skills. Specifically, it will allow teachers and practitioners to assess competence in cycling and moreover, track changes in skill development. This could also be used as a guide for parents when teaching their children to cycle. This would allow more effective intervention design to being employed and may also highlight any individual motor development issues a child may incur, giving an overall better understanding of their motor capabilities. The overall aims of the present study are to: (1) develop a scale that assesses cycling ability in 2-6 year old children, and (2) test the developmental nature, inter-rater and test-retest reliability of the scale in a sample of Irish preschool children.

5.3 Materials and Methods

The development of the KIM (Kavanagh Issartel Moran) Cycling Scale occurred in four phases (Figure 5.1). The development was performed using an iterative approach where each phase informed further amendments to the scale. Recruitment was performed by the principal investigator through school visits and information sheets. Phase 1 was the initial development of the scale through observation. Phase 2 was a two part pilot assessment of cycling ability using the scale. Firstly, discussions were had with two testers to ensure the scale was self-explanatory without needing further instructions. Instructions or explanations that were not understood were noted and changes subsequently made. Secondly, a pilot inter-rater and test-retest reliability was performed to see if any changes to the stages needed to be made. Phase 3 was performed to investigate if children progressed step-wise through the stages and thus confirming the scale as developmental. As the scale used in phase 2 relied on researchers verbally clarifying and explaining the scale to the testers, phase 4 involved a final inter-rater and test-retest reliability, using the amended scale, with two new testers who solely used the written instructions for implementing the scale. This was done so that reliability of the scale could be determined in the same setting as it would be administered by users (e.g. teachers, practitioners and parents).

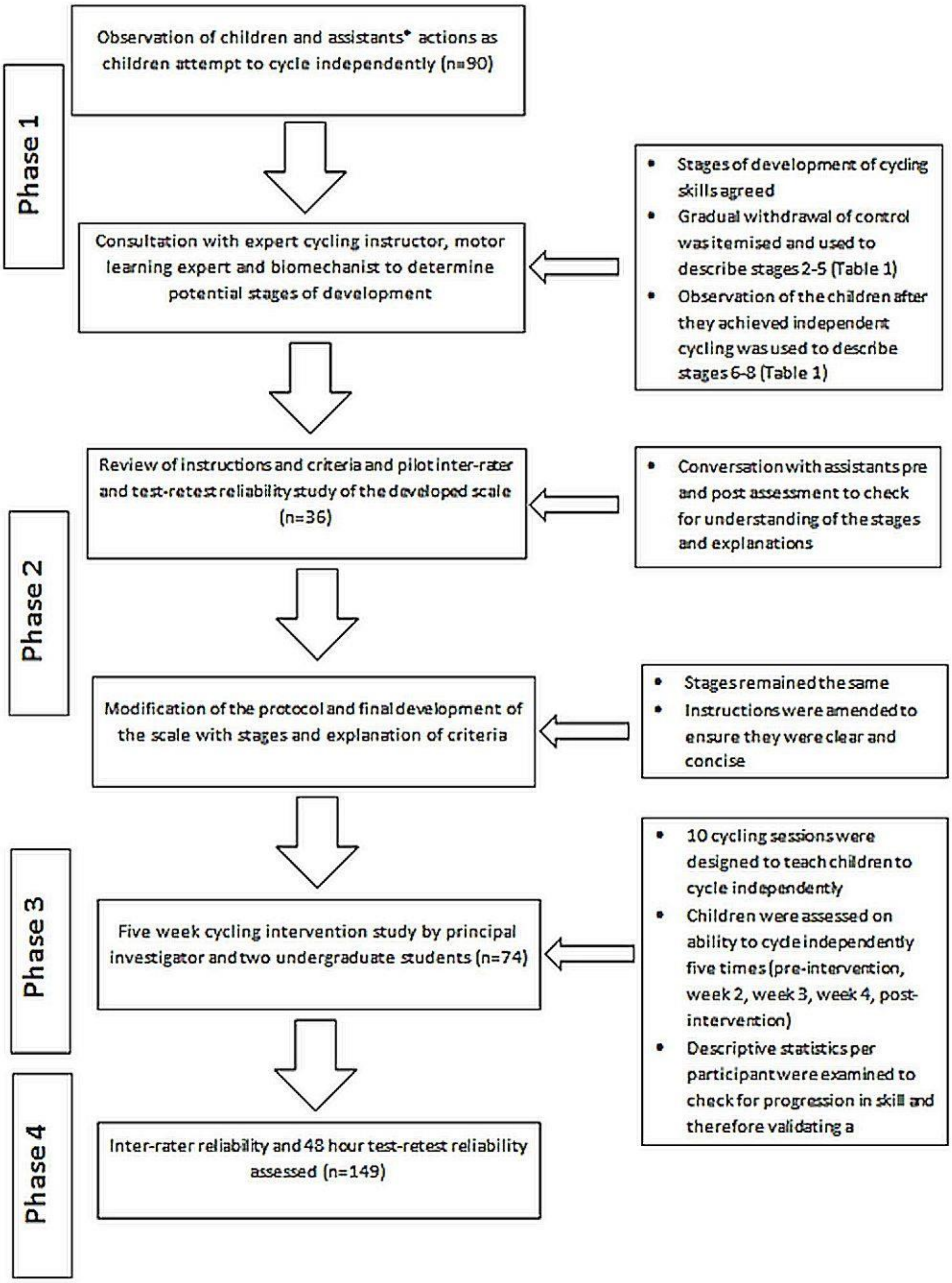


Figure 5.1. Development of the KIM Cycling Scale.
****Assistant refers to those providing assistance to the child on the bike by holding on and gaining some control of the bicycle to help the child cycle.***

Phase 1: Development of the criteria and stages

The three authors of the study (a sports biomechanist, a motor learning expert and an experienced cycling instructor) designed the "KIM Cycling Scale". During the assessment of 90 preschool children (3.57 ± .54 years old; 38% female) on their ability to cycle independently the actions of children and assistants were observed by the principal investigator, and further observed through video analysis by two other authors. This took 3 hours in total. The observations were used to create stages of development. Content validity was established by holding a number of meetings to discuss how the assistants recognised the necessary skill achieved by the child to allow a gradual withdrawal of control over time. The observed actions used by the assistants to gradually withdraw control were itemised and used to describe the criteria for stages 2-5, while observation of the children after independent cycling was achieved was used to describe stages 6-8 (see Table 5.1). Panel discussions were then used ensure that the stages captured changes in ability to cycle across the continuum of learning to cycle independently. When 100% agreement was reached by the three authors, development stages were itemised for each of the criteria and instructions for the tester were produced (Table 5.1).

Phase 2: Review of instructions and criteria and pilot inter-rater and test-retest reliability

A pilot reliability study was completed (n=36; 28% female) by the principal investigator and two assistants (CP and SB) to assess the inter-rater reliability and the test-retest reliability of the scale in preschool children (3.78 ± .64 years old). No prior training was given to the assistants. Discussions with the assistants were used to amend the instructions to ensure instructions were easy to understand prior to testing (final instructions in Table 5.1).

Table 5.1. Instructions and criteria for testers and scoring system for the KIM Cycling Scale

Instructions for tester:

- Begin by placing your preferred hand in the middle of the handlebars and allowing the child to get onto the bicycle.
- When the child is comfortable, place your second hand on the back of the seat
- Allow the child to set the speed at which they travel, do not use your own force to push the bicycle, apart from at the beginning when you may use force to initiate the movement.
- If the child is unable to pedal, give instructions on how to pedal.
- If the child is comfortable to go faster, allow them to do so, bringing your speed to a jogging pace.
- Instruct the child to 'keep their head up and look straight ahead'. Encourage them to 'keep pedalling', particularly if you are attempting to withdraw assistance
- Once past number 1 on the scale, rate the child's performance only when a jogging pace is reached.
- Minimum distance per trial is 15 metres.
- Award the child the highest stage reached for each trial.
- Take best score out of three trials.

Stage	Development Stage	Criteria
0	**Won't get on**	**The Child will not get on the bicycle**
1	**Full support needed**	**Requires firm hold of handlebars and seat, and child not able to pedal forwards**
2	**Full support needed**	**Requires firm hold of handlebars and seat, with child pedalling forwards**
3	**Semi-support needed**	**Requires intermittent hold of handlebars and firm hold of seat (Withdraw control of handlebars for at least 1 revolution of pedals)**
4	**Intermittent semi-support needed**	**Requires no hold of handlebars and intermittent hold of seat (Withdraw control of seat for at least 1 revolution of pedals while no hold of handlebars occurs)**
5	**No support but uneasy**	**Requires no holding of either handlebars or seat for more than 3 revolutions but cycling is not smooth (e.g. foot to ground contacts/wobbling)**
6	**Semi-Independent Cycling**	**Cycles smoothly with no holding once movement has begun but can't initiate cycling by themselves**
7	**Independent Cycling**	**Can initiate cycling by themselves and rides smoothly, but can't turn at least 180 degrees* smoothly while cycling (foot to ground contacts/wobbling)**
8	**Independent Cycling**	**Can initiate cycling by themselves and rides smoothly and turns at least 180 degrees* smoothly**

***180 degrees can be completed by one 180 degree turn or two 90 degree turns**

Phase 3: Cycling intervention

A cycling intervention was designed to teach a convenience sample of preschool children (n=74; 4.04 ± .48 years old; 53% female) to cycle to examine if progression occurred as proposed on the scale (Table 5.1). The cycling intervention consisted of two cycling sessions a week for five weeks on either balance bikes or bikes with stabilisers.

The principal investigator and an assistant (JMcW) together delivered all the classes. The intervention was delivered either during school time with a teacher present or outside of school time with one parent for each child present. Each class was designed to be fun and engaging for the children using games designed to teach speed, stopping, balance, control, coordination, agility and reactions (see Table 5.2). Each group consisted of 8-10 children and was 45 minutes in length. The children were instructed to arrive 10 minutes prior to each session so their bikes (balance bike or bike with stabilisers) could be adjusted to their size and helmets strapped on. Each 45-minute class was split into 35 minutes structured play and 10 minutes free play where the children either decided on the game they would like to play or designed their own game, instructing the practitioners on what they would need them to do. A teddy bear mascot named "Ryder" was also involved during the sessions to provide comfort to the children. An example of the typical layout for the intervention is shown in Figure 5.2. An additional 5 minutes was allocated after the 45 minute session so the children could be provided with stickers and 'high-fives' as compliments for a good class and incentives for continued participation (Corepal, Tully, Kee, Miller, & Hunter, 2018). The children were tested on their ability to cycle independently using The KIM Cycling Scale both pre- and post-intervention, as well as immediately after the second cycling session on week 2, 3 and 4. All testing took place on a traditional bike (without stabilisers) by the principal investigator and two assistants (JMcW and SR).

Table 5.2. Description of Games

Game	Description
Traffic Lights	Using a bat with both red and green sides, instruct the children to ride around the hall, stopping when they come to a 'red light' and continuing when they see a 'green light'. The children can take turns being the traffic lights.
Chasing*	Allow the children to chase the practitioners. The practitioners can also go on the balance bikes for added fun if they are comfortable to do so.
Puddles	Place four poly dots on the ground in a straight line to act as puddles. Instruct the children to try go as fast as they can and when possible to lift both their feet when going over the puddles to avoid getting "wet".
Mr. Wolf*	The wolf stands on one side of the hall and the children on the other. The children can move when the wolf has their back to them but when the wolf turns around, they must freeze. When the children reach the wolf, they must turn and go quickly back to the start line as the wolf chases them. The children can take turns being the wolf.
Snake	Using cones, create a snake with lots of twists and turns for the children to follow.
Animal Reactions	Allow the children to ride anywhere they want in the hall. When the practitioner says freeze the children must stop and then make whatever animal noise the practitioner calls out. To make this more challenging, obstacles and puddles can be placed around the hall.
Safari*	Place a lot of cones on one half of the hall. Underneath some of the cones place different animals (cut outs on cardboard). Instruct the children to go and look under the cones for the animals. When they find one, they must bring it back to the practitioners on the other side of the hall and place it over the picture of the animal they found. They can then go back and look again.
Ryder's Birthday*	To celebrate our mascot's birthday, the children must first organise the party. Place numbers 1 -10 around the hall to represent door numbers and a teddy bear at each house then place signs to represent the post-office, the shop and Ryder's house. All the children are given felt baskets to hang off their handlebars. The children must first bring the invitations from Ryder's house to the post-office. From there, the invitations are put in order from 1-10 with the children's help. The invitations must then be delivered to each corresponding house. The teddy bears must then be collected and brought to the shop to pick a present for Ryder. The teddy bears and presents are then brought to Ryder's house for the party.
Musical Statues	Allow the children to ride around the hall to the music. When the music stops, they must also freeze and continue when the music plays again.
Minefields	Place small beanbags on the ground. Instruct the children to move around the hall and when they go through the minefields of beanbags to try avoiding them by swerving in and out.
Easter Hunt	Like Safari but have little bunnies and chicks under the cones. This can be adapted to suit any holiday.
Football	Using a small foam football, instruct the children to work as a team to kick the ball into the goal.
Obstacles	Set up the hall with a mixture of snakes, puddles, traffic lights and minefields to allow them to show off all their learnt skills.

***Children's favourite games.**

Figure 5.2. Typical layout of the 5-week intervention.

Blue boxes represent days when ability to cycle independently was assessed. Purple text represents examples of the games chosen to be played during the 10 minutes free play.

Phase 4: Inter-rater and test-retest reliability

One hundred and forty-nine children (4.03 ± 1.02 years old) were recruited from a convenience sample of preschool and primary school children. All participants attended two sessions, 48 hours apart. Two assistants (CP and SB) scored the children on their ability to cycle independently in order to assess the reliability of the KIM Cycling Scale. Testers were given the scale (Table 1) three days prior to testing and instructed to learn the scoring system. No verbal explanation or additional information was given. Each tester separately implemented and scored the ability to cycle independently on all the children at different time periods on the same day and again on all the children 48 hours later using the same protocol. Two separate school yards of 20x10 metres each were used to ensure each tester could not observe the other tester and to avoid a contamination effect. No comparison of results or talking between testers was permitted. Each child was tested three times successively. A tester was assessing one child at the time. Children were instructed to cycle as best they could and were told that if the tester thought they were able to cycle by themselves without their assistance that they would let go but would still remain beside them. The children were allowed to withdraw from the study at any point if they did not feel comfortable (no children withdrew from the study). Children were required to wear a helmet.

For all four phases the parents of the participants were given a plain language statement and signed informed consent prior to testing. Ethical approval was granted by Dublin City University Ethics committee (REC/2016/031).

Statistical Analysis

Analyses were performed using SPSS version 23 (SPSS Inc., Chicago, IL, USA). Means and standard deviations were calculated at each time point during the cycling intervention (Phase 3) as well as for each tester during the two reliability studies (Phases 2 and 4). Descriptive statistics to asses changes in mean scores over the five-week cycling intervention were used to examine progression of ability at cycling in Phase 3. Interclass correlations (ICC) and their 95% CI were used to assess both inter-rater and test-retest reliability for both Phase 2 and Phase 4. For both inter-rater and test-retest reliability a two-way random effects, absolute agreement, single measurement and multiple raters model was performed [ICC (k,2)] (Koo & Li, 2016). The classification proposed by Portney (Portney & Watkins, 2000) was used to determine the strength of reliability using CIs of the ICCs as the reference, with poor reliability identified as a value <0.50, moderate reliability between [0.50-0.75], good reliability between [0.75-0.90] and excellent reliability >0.90 (Koo & Li, 2016; Portney & Watkins, 2000).

5.4 Results

Phase 1

As indicated in the Methods section, the result of phase 1 was the initial development of the criteria and stages of the KIM Cycling Scale.

Phase 2

Instructions were adjusted and explanation of Stages 4, 5 and 6 altered to provide better clarity to the testers. Good to excellent ICC and respective CIs were observed for inter-rater reliability and for test-retest reliability (Table 5.3). The average stage reached by the children was stage 3 over both sessions (Table 5.3).

Table 5.3. Reliability of the KIM Cycling Scale in Phase 2

Inter-rater reliability	Test-retest reliability		Session 1	Session 2
ICC (95% CIs)	**Tester**	**ICC (95% CI)**	**Mean (SD)**	**Mean (SD)**
.91 (.83-.96)	1	.95 (.91-.98)	2.91 (2.07)	2.70 (2.13)
	2	.94 (.87-.97)	2.97 (2.19)	2.82 (2.18)

Phase 3

Mean and standard deviations for scores on the KIM Cycling Scale across the five time-points [pre-intervention (T1), week 2 (T2), week 3 (T3), week 4 (T4) and post-intervention (T5)] during the cycling intervention are presented in Table 5.4.

Table 5.4. Scoring on the KIM Cycling Scale over five weeks [Mean (SD)]

Time-point				
T1	**T2**	**T3**	**T4**	**T5**
2.05 (0.92)	3.12 (1.39)	3.88 (1.62)	4.51 (1.75)	5.43 (1.99)

Changes in the percentage of children who moved from one stage to another across the time points are presented in Table 5.5. The table demonstrates the progressive nature of the stages as children develop the ability to cycle independently. Each time-point is represented by the letter "T" and each stage of the scale represented by the letter "S" (see Table 5.1 for description of stages). Seventy-four children were assessed at each of the five time-points and each child was given a score representing the Stage his/she was at. The values adjacent to the 8 different stages (S1-S8) represent the percentage of the children from that stage in the previous time-point that achieved that stage at the following time-point (Table 5.5). For example, at time-point 1 (T1) there were 24 children at stage 1; by time-point 2 (T2), 29% of those children remained at stage 1 (n=7), 38% progressed to stage 2 (n=9), 25% progressed to stage 3 (n=6) and 8% progressed to stage 4 (n=2). Similarly, at time-point 2 (T2) there were 35 children at stage 3; by time-point 3 (T3), 51% of those children remained at stage 3 (n=18), 40% progressed to stage 4 (n=14), and 9% progressed to stage 5 (n=3).

Table 5.5. Development of cycling ability (Stage S1-S8) across five time points (T1-T5)

	T1	T2			T3			T4			T5		
Stage 1	n=24	n=7	S1	29%	n=5	S1	71%	n=2	S1	40%	n=2	S1	100%
			S2	38%		S2			S2	60%		S2	
			S3	25%		S3	14%		S3			S3	
			S4	8%		S4	14%		S4			S4	
Stage 2	n=29	n=13	S2	14%	n=3	S2	23%	n=4	S2	33%	n=1	S2	25%
			S3	69%		S3	77%		S3	33%		S3	75%
			S4	17%		S4			S4	33%		S4	
Stage 3	n=17	n=35	S3	47%	n=31	S3	51%	n=14	S3	39%	n=6	S3	21%
			S4	24%		S4	40%		S4	48%		S4	43%
			S5	6%		S5	9%		S5	10%		S5	14%
			S6	6%		S6			S6			S6	21%
			S7	18%		S7			S7	3%		S7	
Stage4	n=4	n=14	S3	25%	n=18	S3	16%	n=26	S3	6%	n=17	S3	
			S4	50%		S4	25%		S4	56%		S4	42%
			S5			S5	42%		S5	22%		S5	12%
			S6	25%		S6	17%		S6	6%		S6	31%
			S7			S7			S7	11%		S7	12%
			S8			S8			S8			S8	4%
Stage 5	n=0	n=0	S5		n=9	S5	50%	n=8	S5	11%	n=7	S5	25%
			S6			S6			S6	67%		S6	50%
			S7			S7	50%		S7	22%		S7	13%
			S8			S8			S8			S8	13%
Stage 6	n=0	n=2	S6		n=3	S6	50%	n=9	S6	67%	n=20	S6	56%
			S7			S7	50%		S7	33%		S7	11%
			S8			S8			S8			S8	33%
Stage 7	n=0	n=3	S7		n=3	S7	33%	n=6	S7		n=5	S7	
			S8			S8	67%		S8	100%		S8	100%
Stage 8	n=0	n=0	S8		n=2	S8		n=5	S8	100%	n=16	S8	100%

Note: Any rows that have been removed across all timepoints indicate a non-occurrence.
n; number of children at the respective stage and time point.

Phase 4

Excellent ICC and respective CIs were observed for inter-rater reliability and good to excellent ICC values were observed for test-retest reliability, indicating overall high reliability for the KIM Cycling Scale (Table 5.6). The average stage reached by the children was between stage 3 and stage 4 over both sessions (Table 5.6).

Table 5.6. Reliability of the KIM Cycling Scale in Phase 4

Inter-rater reliability	**Test-retest reliability**		**Session 1**	**Session 2**
ICC (95% CIs)	**Tester**	**ICC (95% CI)**	**Mean (SD)**	**Mean (SD)**
.97 (.96-.98)	**1**	**.91 (.87-.94)**	**3.55 (2.32)**	**3.78 (2.49)**
	2	**.90 (.85-.93)**	**3.44 (2.37)**	**3.71 (2.50)**

5.5 Discussion

The current study developed a scale to assess a child's level towards cycling independently. To the authors' knowledge this developmental scale is the first study to develop such a scale. The KIM Cycling Scale was developed for preschool children between 2 and 6 years old. The KIM Cycling Scale was developed to include an 8-point scale ranging from full assistance is needed (stage 1), to no assistance needed and the cyclist can begin cycling themselves and turn smoothly (stage 8) (Table 5.1). After the initial stages were agreed and designed for the scale (phase 1), a reliability study was performed which found the KIM Cycling Scale to have high inter-rater and test-retest reliability (Phase 2), indicating the KIM Cycling Scale to be reliable across testers and over time. This scale was developed to be a standalone scale with written instructions for the tester so that no further reading or verbal/visual instructions would be required to perform an assessment. Similar to the pilot reliability study (Phase 2), the KIM Cycling Scale was found to have high inter-rater and test-retest reliability in Phase 4 when there were no verbal explanations prior to testing. The high level of reliability is similar to the high levels found in other test batteries assessing alternative lifelong physical activities such as grapevine, golf swing, jog, push-up, squat, tennis forehand, upward dog and warrior (Hulteen, Barnett, et al., 2018).

To ensure that the scale was developmental in nature, a five-week cycling intervention was run. This was performed to investigate if children progressed step-wise through the stages. Table 5.5 presents data on how children progressed through the stages throughout the five-week intervention (Phase 3). The most frequent forms of progression were step-wise from one stage to the immediate next stage (for example stage 1 to stage 2), apart from stage 4 which had two typical routes, one step-wise to stage 5 and another transitioning from stage 4 straight to stage 6. The observed progression conforms to the universal definition of development in that each stage was achieved before the next. While generally step-wise progression was the typical route observed for the children in this study, it does not apply to everyone and individual differences occurred resulting in alternative possible routes to independent cycling. Figure 3 demonstrates the typical and alternative routes to independent cycling as observed in the current population. The variety of learning trajectories reflect both the complexity of the skill to be learnt and inter-individual differences (Magill, 2007).

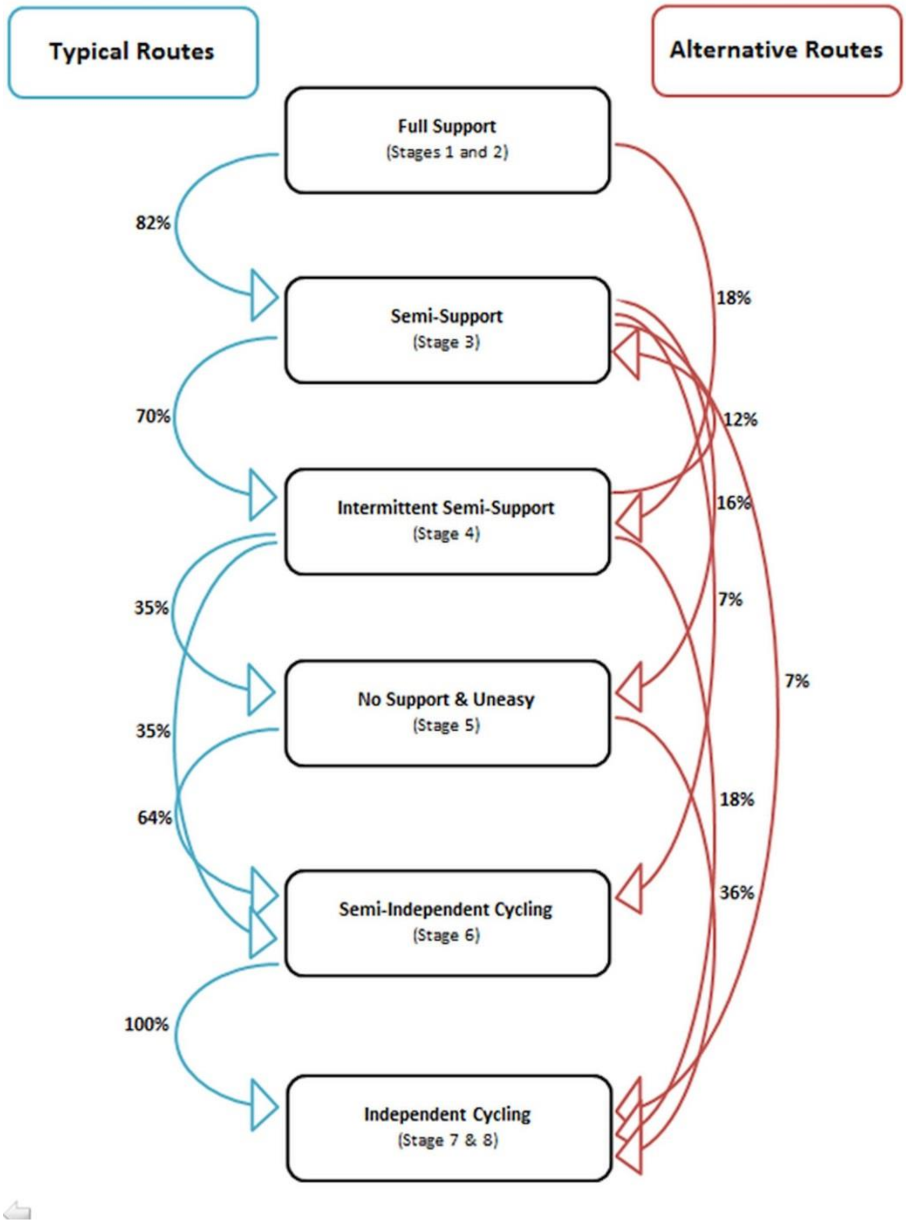


Figure 5.3. Typical and alternative routes to independent cycling

Having typical and alternative routes was first theorised by Gesell (Gesell, 1939) and then observed by Adolph (Adolph and Robinson 2013) in the examination of developmental progression to independent walking. Research into the development of locomotive skills like walking and climbing stairs has highlighted that while the average child follows a step by step progression pathway (the ‘typical route’), some children forge their own alternative paths, highlighting that the sequence of development can also be variable, similar to what is observed in the current study (Adolph, Berger, and Leo 2011; Berger, Theuring, and Adolph 2007). In the current study, 54% of the participants followed a typical route throughout T1-T5, with 32% using an alternative route once, 11% using an alternative route twice and 3% never progressing from T1-T5. Notably, it is not until Stage 3 is reached that we see the ability to progress straight to the first stage that represents independent cycling (stage 5). Regression in development occurred only between stage 4 and stage 3. It is not uncommon to observe regression between two stages as an alternative route in development of a skill (Vereijken & Adolph, 1999). Fitts and Posner’s three stage model demonstrates how there is a lack of consistency in performance from one attempt to the next due to high variability (Fitts & Posner, 1967). This may explain the regression observed in the current study, when a seemingly learnt pattern could not be reproduced at the following assessment. Overall, the KIM Cycling Scale was supported as a development scale.

Evaluations by teachers and students of school-based cycling interventions have been very positive and well received by both teachers and students with the most common responses from students being that they are engaging and fun (Hatfield et al., 2015; Montenegro, 2015). The KIM Cycling Scale will allow teachers, practitioners and parents to assess a child’s ability to cycle independently and encourage learn-to-cycle interventions in preschools, which will allow children the opportunity to learn to cycle independently before entering primary level education. Having a scale from which levels of cycling ability can be measured can inform the construction and implementation of learn-to-cycle interventions within community and school curriculums by allowing investigation into the effectiveness of these interventions and by exploring other factors that may contribute to learning to cycle independently. Furthermore, the KIM Cycling Scale will allow teachers and practitioners to have a better understanding of when a child may be ready to cycle independently and therefore when may be appropriate to remove assistance. There are also benefits of testing on a continuous scale; the feeling of progress in a skill may encourage self-belief. Such enactive-mastery (Bandura, 2002) is thought to encourage further practice and trials from a child, whereas without a scale a child (and their teachers) could only distinguished as either being able to cycle independently or not. Having a scale that exhibits progress also provides feedback to the dyad teacher-learner for all stage of learning. Results from the current cycling intervention on the KIM Cycling Scale very rarely showed a child not progressing in cycling ability. This can offer assurances to teachers and practitioners when conducting a cycling intervention that practicing will lead to steady step by step improvements. Additionally, the health benefits and positive wellbeing that comes from engaging in cycling activities (Oja et al., 2011).

Recommendations from the current cycling intervention include the use of fun games and constant encouragement to the children, appropriate training and resources for the teachers and practitioners along with specific training in relation to managing groups of children on bikes (Hatfield et al., 2015). Furthermore, some children are less likely to want to try cycling independently than others at first. Allowing the more willing children to go first, often exhibits to the others that it is ok and trust is gained in knowing the teacher will not withdraw assistance unless the child is ready and comfortable. The current cycling intervention found that after some encouragement from teachers, practitioners and other children, all children were willing to participate in the assessment of cycling ability at each of the timepoints turning the testing time into a fun and engaging activity. It has been previously recommended to involve parents in motor skill interventions as they are a key factor in habitual and lifelong development (Riethmuller et al., 2009). This is further highlighted in recommendations for preschool children, that emphasise the pivotal role parents have for providing encouragement, opportunities and support for physical activity (American Academy of Pediatrics. Council on Sports Medicine and Fitness, 1992; Hagan et al., 2017; Wright & Stork, 2013). Teachers and practitioners should be advised to allow parents access to the scale used to assess their child's cycling ability, thus promoting indirect involvement from parents during the intervention. Furthermore, encouraging parents to become familiar with the KIM Cycling Scale and the typical and alternate routes to independent cycling (Figure 5.3) provides parents with the information required to aid in their child's cycling journey as well as gaining an understanding that children develop their cycling ability in different way. Cycling has been recently added to the motor development model as an important lifelong skill in early childhood (Hulteen, Morgan, et al., 2018) and so it is important that there is a valid and reliable measure of cycling ability during the development process of learning. Alternative assessment tools have recently been developed to assess other lifelong physical activities in an attempt to promote these skills along with the traditional fundamental movement skills (Hulteen, Barnett, et al., 2018). Having a wider array of skills allows for a greater chance of a physically active life (Goodway & Robinson, 2015) which has been extensively linked to a healthier life (Warburton & Bredin, 2017). Moreover, cycling itself has been linked with significant health benefits from early childhood into adulthood (Kelly et al., 2014; Oja et al., 2011) and with strategies in place to ensure the development and upkeep of infrastructure to promote cycling as a means of active commuting (European Cyclists' Federation, 2017; World Health Organization., 2004), it is imperative that we encourage development of the skill in the early childhood years. Therefore, the development of test batteries to assess lifelong skills, and in particular cycling in the early childhood years, may have significant benefits to aid the promotion of a physically active life.

The current study has addressed this with the development of the KIM Cycling Scale which should help with the design of more effective interventions to improve cycling ability, as well as facilitating future research to investigate factors that may contribute to independent cycling. The scale will also allow teachers and practitioners to track changes in the development of independent cycling. Furthermore, parents may use the KIM Cycling Scale as a tool to better understand and better assess their child's progression when learning to cycle. The lack of a valid and reliable cycling scale may, at least in part, explain the lack of research to date into the process of learning to cycle. In summary, this study developed a reliable measurement tool for assessing children between 2 and 6 years of age on the developmental process to independent cycling.

Linking Section from Chapter 5 to Chapter 6

Chapter 5 developed a scale that could be used to assess ability to independently cycle on a traditional bike along with exploring the typical and alternate paths that children take along this learning process. Having a valid and reliable cycling scale allows investigation into the possible transfer of skills to independent cycling.

Bikes with stabilisers have traditionally been used by children to learn how to cycle independently. Balance bikes have recently gained attention as being more appropriate than bikes with stabilisers in teaching independent cycling, as manufacturers claim that practice on balance bikes teaches balance that is then transferred to independent cycling on a traditional bike. However, there is no empirical evidence to back up these claims or that bikes with stabilisers teach children to cycle independently. Therefore, Chapter 6 investigates the effectiveness of a 5-week cycling intervention on ability to cycle independently, as measured using the scale development in Chapter 5, using either balance bikes or bikes with stabilisers.

Chapter 3 showed that practice on a balance bike improves ability on a balance bike in terms of the time taken to travel a given distance. Chapter 6 aims to extend this exploration by investigating if practicing on a balance bike improves dynamic balance as measured through inertial measurement units attached to the bike. Furthermore, Chapter 6 investigates if there is a relationship between dynamic balance on a balance bike and ability to cycle independently.

Chapter 6 - The effectiveness of a 5-week cycling intervention on ability to cycle independently and dynamic balance on a balance bike

6.1 Abstract

It is claimed that Balance bikes (BB) and Bikes with Stabilisers (BS) teach children to cycle independently. BB have gained popularity, possibly in part as a result of manufacturers' claims that they also improve balance, which subsequently aids in learning to cycle independently. However, there is no empirical evidence to support these two claims. Ninety-four children (3.08 ± .48 years) took part in a 5-week cycling intervention on either BB (n=32) or BS (n=35), or as a control group (n=27). Ability to cycle independently (ACI) was measured using the 8-point KIM Cycling Scale. Dynamic balance on a BB was assessed over a 15-metre straight track using medio-lateral acceleration, captured using inertial measurement units, attached to the frame of the bike. Mixed repeated measures ANOVAs with Bonferroni post-hoc tests were used to investigate the effectiveness of the intervention on ACI and dynamic balance. Spearman's rho was used to investigate the relationship between ACI and dynamic balance. There was a significant interaction effect for ACI between groups (BB, BS and Control) from pre- to post-intervention, with post-hoc analysis showing a BB and BS groups improving significantly more than the Control group There were no significant interaction, group or time effects for dynamic balance (p>0.05). There was no significant correlation (r=0.66, p =0.07) between ACI and dynamic balance. Findings from this study indicate that a 5-week cycling intervention on either BB or BS is effective at learning to cycle independently but is not

effective at improving dynamic balance on a BB. Furthermore, dynamic balance on a balance bike is not meaningfully related to ACI.

6.2 Introduction

During early childhood, cycling is one of the most commonly reported active recreational pastimes (Dunst et al., 2009; Nielsen et al., 2011) and throughout life is one of the most commonly reported physical activities globally (Hulteen et al., 2017). Independent cycling can be defined as riding a traditional bike (two wheels and two pedals), without the assistance of a person holding on to the bike and/or the cyclist. Independent cycling, like most motor skills, does not come naturally; that is, practice and experience are required for behavioural changes to occur (Haywood & Getchell, 2005). Learning to become an independent cyclist can be a daunting task as it can result in multiple falls. As a result, most children start their learning process to independent cycling on a constrained version of a traditional bike (i.e. balance bike and bike with stabilisers).

Traditionally, the bike was constrained by adding two extra wheels to the back of the bike allowing more support (i.e. stabilisers/training wheels). More recently, the traditional bike has been constrained by removing the pedals, allowing the child to use their feet on the ground to propel themselves forward. These pedal-less bikes have become increasingly popular in recent years and tend to take different names such as balance bike, running bike or strider. It is commonly believed, along with manufacturers' claims, that balance bikes are superior to bikes with stabilisers in teaching children to cycle independently ("Halfords," 2019; "LIKEaBIKE," 2019; "Strider," 2019; "Littlebigbikes," 2019). Previous research has found that skilled individuals have the capability to transfer and manipulate previously learnt skills to perform a new task or in a new environment (Gautier et al., 2009; Seifert et al., 2013) . However, to the knowledge of the author there is no empirical evidence to suggest that using a balance bike or a bike with stabilisers aids in learning to cycle independently or that a balance bike is a more effective tool to use. Therefore, the primary aim of this paper is to investigate the effectiveness of a 5-week cycling intervention on either balance bikes or bikes with stabilisers on learning to cycle independently.

Balance bikes have regularly been marketed as effective tools to allow children to learn how to balance before progressing into cycling independently. For example, Halfords state: “As the name suggests, a balance bike is a bike for tots that teaches the art of balance” (Halfords, 2019), with Littlebigbikes stating “With a balance bike, the child learns to balance and steer first, then can progress to pedalling in their own time […]. If kids learnt to ride using a pedal bike with training wheels, they don’t develop their balance as the training wheels keep the bike upright, like a crutch” (Littlebigbikes, 2019). However, no studies appear to have directly assessed if practice on a BB increases dynamic balance on a bike. In addition, while two studies have examined the relationship between ability on a balance bike and the fundamental movement skill (FMS) of balance, one found no significant correlation (Kavanagh, Issartel, & Moran, 2019a - Chapter 4) with another showing only a significant but weak correlation ($r=.269$, $p<.05$) (Kavanagh et al., 2019b - Chapter 3).

The FMS skill of balance, while a good measure of balance ability, may not reflect the exact movement quality and balance used on a balance bike. This dynamic balance is a facet of an underlying motor control system (Kelso, 1995; Mancini & Horak, 2010), that can be used to better understand how a child progresses as a learner of a new skill and may subsequently be used when cycling independently. To measure dynamic balance on a balance bike, inertial measurement units (IMUs) attached to the bike can be used to capture movements produced by the child's motor control system, which are in turn, reflected in the lateral linear accelerations of the bike. In the biomechanical measurement of dynamic balance, centre of pressure is one the most common methods used (Hubble et al., 2015; Whitney et al., 2011). However, IMUs with linear accelerometers have become widespread in assessing dynamic balance due to their low cost and ease of use (Hubble et al., 2015). Assessing balance through accelerometery has been found to correlate highly with centre of pressure (Whitney et al., 2011) and moreover, be a valid and reliable measure of dynamic balance in distinguishing between populations and conditions (Hubble et al., 2015; Moe-Nilssen & Helbostad, 2002). Therefore, the secondary aims of the current paper are to: 1) investigate if a 5-week cycling intervention results in a change in dynamic balance on a balance bike, and 2) investigate if there is a relationship between dynamic balance and ability to cycle independently.

6.3 Methods

Participants

Ninety-four preschool children between 3-5 years were recruited for the current study (3.08 ± 0.48 years; 58% girls). Participants were split into one of two intervention groups [balance bike (BB) group (n=32), bike with stabilisers (BS) group (n=35)] and a control group (n=27). Recruitment occurred through visits to schools and information sheets to teachers and parents.

Intervention Design

The intervention consisted of 10 cycling classes over five weeks (twice per week). Each class contained between 8-10 children and was 45 minutes in length, with 35 minutes structured play and 10 minutes free play. The principal investigator and an assistant (JMcW) delivered all the classes. For a full description of the intervention please see section 5.3.

Measurements

Ability to cycling independently (ACI) was measured using the KIM Cycling Scale, which the author developed (Chapter 5), at both pre- and post-intervention. Each child was given one practice trial before performing two trials, where the highest point on the scale achieved was recorded. Encouragement to the children was provided by the practitioners giving praise after every trial. One child was assessed at a time, during which the other children continued playing games with the second practitioner. The KIM Cycling Scale is an 8-point scale that assesses development of independent cycling (see Table 5.1). From stage 5 onwards the child is deemed to be able to cycle independently. Consequently, a binary categorical variable of 'Independent Cycling' was created with '0' meaning the child was unable to cycle independently (stages 1-4) and '1' meaning the children was able to cycle independently (stages 5-8).

Dynamic balance on a balance bike was assessed on all participants, however due to sensor errors only 43 participants data were subsequently used in the analysis [BB (n=13), BS (n=14), Control (B=16)]. The average of two trials was calculated along a 15-metre straight track. Seat height was adjusted per child so that while seated, both feet lay flat on the ground and there was a slight bend in the knees. Children were required to wear a helmet and given one practice trial with the instruction to go as fast as they could. To measure dynamic balance on the balance bike, acceleration in the medio-lateral direction was captured at 512 Hz using an inertial sensor (Shimmer3, Shimmer, Ireland) secured to the frame of the balance bike (Figure 6.1). Data was written to an internal SD card. Given possible variation in how the participants began the test, in order to capture a representative sample of the BB dynamic balance, a four second period was extracted from the z-axis acceleration time-series, which represented the mid-portion of the total trial length. Dynamic balance was quantified for this subsection using root means square (RMS) (Whitney et al., 2011):

$$\boldsymbol{RMS = \frac{1}{N}\sqrt{\sum_{J=1}^{N-1}(P_j - \bar{P})}}$$

Where N is the number of time samples, $\bar{P}$ is the mean acceleration across the time series, and P_j is acceleration at time sample j.

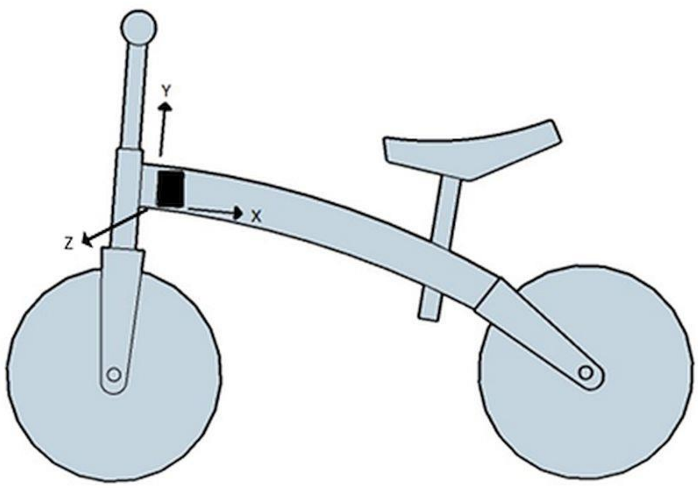


Figure 6.1. Placement of IMU on balance bike

This study was approved by Dublin City University Ethical Committee and written informed consent was provided from the parents or legal guardians for all participants. Data-collection was conducted by a group of trained examiners (JK, JMcW & SR) specialised in skill acquisition in early childhood education.

Statistical Analysis

Descriptive statistics were assessed, and the data was screened for normality. Three (group) by two (pre- to post-) mixed ANOVAs, with Bonferroni adjusted post-hoc tests, were used to assess changes in ACI and dynamic balance. A Chi-squared test was used to assess if there is a difference in the proportion of those in the BB group who could cycle independently at post-intervention compared to the BS group. Spearman's rho was used to assess the relationship between ACI at post-intervention and dynamic balance at post-intervention. All analyses were completed using SPSS version 25 (IBM Analytics).

6.4 Results

Descriptive statistics

All participants were assessed on their ability to cycle independently (ACI) and dynamic balance pre- and post-intervention. The mean ± standard deviation for ACI and dynamic balance per group are detailed in Table 6.1.

Table 6.1. Descriptive statistics [Mean and Standard Deviations (M ± SD)] for each variable

	Ability to Cycle Independently (unitless) (M±SD)		Dynamic Balance (m/s^2) (M±SD)	
	Pre	**Post**	**Pre**	**Post**
Balance Bike	1.8±0.8	5.7±1.8	0.043±0.013	0.048±0.013
Bike with Stabilisers	2.2±0.9	5.2±1.9	0.045±0.017	0.041±0.013
Control	2.4±0.8	3.3±1.7	0.032±0.007	O.039±0.017

Mixed repeated measures ANOVAs

A significant interaction effect was found for the assessment of the ability to cycle independently (ACI) between the three groups (BB, BS & Control) from pre- to post-intervention [Wilk's Lambda = 0.65, F (2,33) = 24.4, p < 0.01, partial eta squared = 0.35]. Post-hoc analyses showed that ACI was significantly greater in both the BB (p<0.027) and the BS (p=0.028) groups compared to the Control group (Figure 6.2). There was a significant main effect for time [Wilk's Lambda = 0.288, F (1,306) = 225, p < 0.01, partial eta squared = 0.71] and a significant main effect for group [F(2,13) = 4.58, p = 0.013, partial eta squared = 0.09].

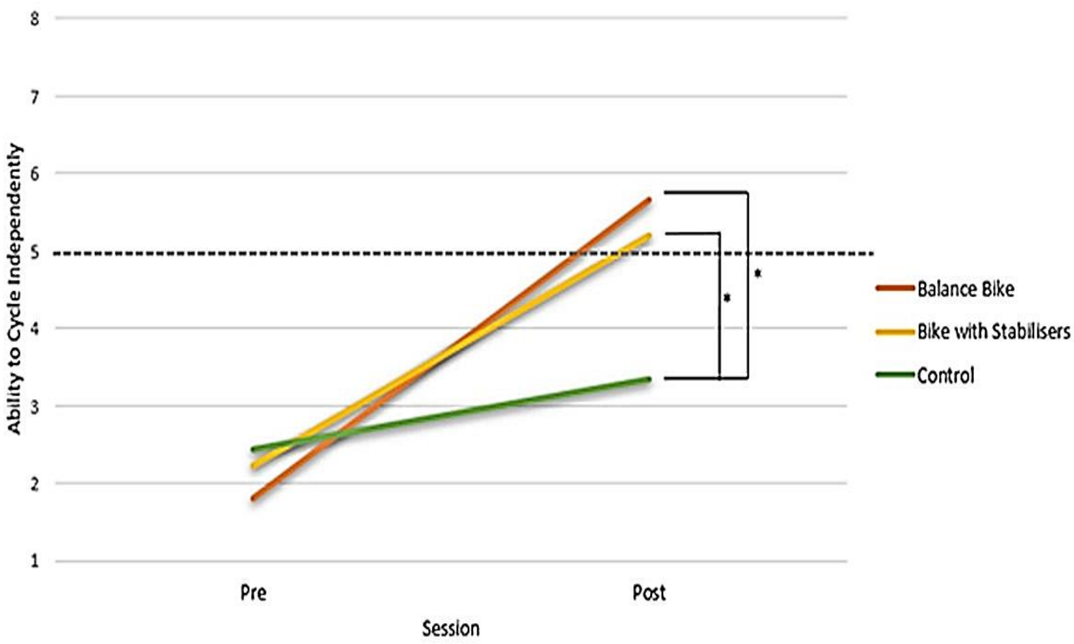


Figure 6.2. Ability to cycle independently from pre- to post-intervention by group.
****p<0.05. The dotted line represents the stage at which independent cycling is achieved.***

For dynamic balance there were no significant interaction effects [Wilks Lambda = 0.907, F(2,40) = 2.04, p = 0.14], and no significant main effects for time [Wilks Lambda = 0.973, F(1,40) = 1.1, p = 0.29] or group [F(2,40) = 3.18, p = 0.052].

Chi-Squared

A significant association (with Yates Continuity Correction) was found between group (BB and BS) and Independent Cycling [χ2(1, n=72) = 3.9, p = 0.048, phi = –0.26], with 78% of the BB group and 53% of the BS group able to independently cycle after the intervention.

Spearman's rho

There was no significant relationship found between post-intervention ACI and post-intervention dynamic balance (rho = 0.07, p = 0.66) (Figure 6.3).

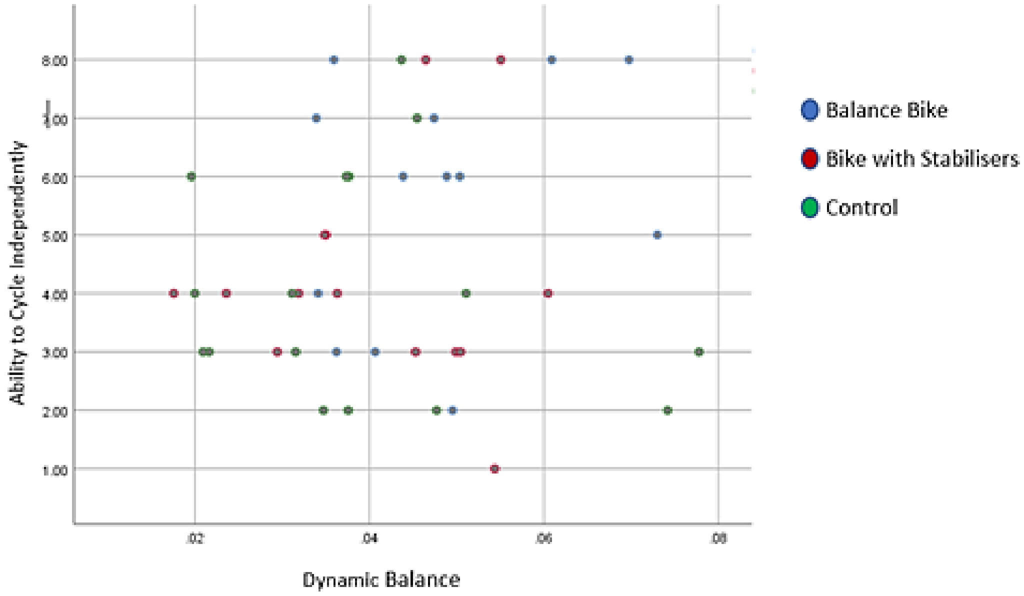


Figure 6.3. Correlation plot between ACI and dynamic balance per group

6.5 Discussion

In the current study, both balance bikes (BB) and bikes with stabilisers (BS) were found to be effective tools in aiding the learning process to independent cycling. Using constrained versions of a task [i.e. no pedals (BB) and extra wheels (BS)] to aid in learning a new skill is common, with Newell's model of constraints extensively recognised as a model to follow for skill acquisition (Davids et al., 2008; Haywood & Getchell, 2005; Newell, 1986). Therefore, it is not surprising that both bikes (BB and BS) were found to elicit improvements in ability to cycle independently following the intervention. These findings provide evidence that cycling interventions in preschools offer an opportunity for children to learn to cycle in a safe and comfortable environment.

Evidence-based cycling interventions are common in primary schools. These interventions often focus on cycling safety on a traditional bike, albeit in children older (between 8-12 years) than those in our study (Ducheyne et al., 2014; Ducheyne, De Bourdeaudhuij, Lenoir, & Cardon, 2013; Hatfield et al., 2015; Montenegro, 2015). In one of the interventions, 'Safe Cycle', a challenge mentioned by teachers was that the programme assumed that all students could ride a bike, which was not the case and caused some issues (Hatfield et al., 2015). Nevertheless, these interventions were effective at increasing cycling skills and increasing safety behaviours (Ducheyne et al., 2014; Ducheyne, De Bourdeaudhuij, Lenoir, & Cardon, 2013; Hatfield et al., 2015; Montenegro, 2015). It is interesting however, that a focus on cycling safety through the use of interventions has only been delivered in primary schools from the age of 8 when in fact children generally begin to cycle independently from 3 years of age. According to the European Road Safety Observatory (ERSO), cyclist fatalities in children occur most commonly between 6 and 14 years of age (European Commission, 2018) and so introducing learning-to-cycle programmes in the preschool years may improve cycling ability, increase confidence and improve safety behaviours at a more critical time.

While dynamic balance is a key element of effective locomotion (Kelso, 1995) and would undoubtably be required to successfully move on a balance bike, the findings seem to indicate that dynamic balance is not progressed through five weeks of practice on a BB or BS. Accordingly, it is not surprising that dynamic balance showed no significant relationship with ability to cycle independently. This would perhaps suggest that the dynamic balance capacity of this age group of children, as measured on a balance bike, was sufficiently developed to allow them to cycle independently, even before practice occurred.

The current findings contradict manufactures' claims that balance is taught on a balance bike, however align with the claims that they teach children to cycle independently ("Halfords," 2019; "LIKEaBIKE," 2019; "Strider," 2019; "Littlebigbikes," 2019). When a child reaches stage 5 of the KIM Cycling Scale, they are deemed to be able to independently cycling (i.e. without any assistance) (Chapter 5). In the current study, it was found that both the BB and BS groups were effective at progressing children's ability to cycle independently, however the BB group was found to be more effective at aiding attainment of independent cycling with 78% of the BB group and 53% of the BS group cycling independently at the end of the 5-week intervention.

These findings raise some interesting questions into what skills or factors are learnt on BB and BS that are subsequently used in independent cycling on traditional bikes. Previous research has shown that (i.e. speed) on a balance bike is influenced by amount of motor skill engagement (i.e. amount of practice) on the bike (Kavanagh et al., 2019a - Chapter 4). As dynamic balance was shown in this study to not improve following practice on a balance bike, the question becomes what other possible factors are allowing the child to improve on balance bike. It is interesting to note that as speed increases the task of independent cycling becomes easier (Åström et al., 2005). This is due to higher velocities only needing small steering angles[1] to move the ground contact points laterally, whereas at low velocities, larger steering angles are required to achieve the same results in the same amount of time (Åström

[1] Steering angle refers to the extent to which handlebars are oriented away from the front of the frame of the bike.

et al., 2005). As a result, it is usually easier to remain upright, without falling over when going faster on the bike. Therefore, it is possible that when a child attempts to cycle independently they do not exert enough power to the pedals to allow themselves to go quick enough and therefore increase the difficulty of the task and likelihood of falling and thus increase fear. By removing an aspect of independent cycling on a traditional bike (i.e. no pedals or extra wheels), the child can focus on improving steering and pedalling or propelling themselves forward by pushing off the ground, without the fear of falling over. With practice, the child then becomes more proficient at these skills and therefore can go quicker on the bike. Consequently, it may be factors such as leg strength and bimanual coordination, that would be used to pedal or propel the child forward at greater speeds, that are learnt on the constrained bikes and subsequently transferred to cycling on a traditional bike. Confidence in cycling may also be an interesting factor to consider. It may be that dynamic balance, leg strength and bimanual coordination are developed enough in children at this age to cycle independently before practice occurs; however, by practicing on BB and BS, children gain confidence to go fast which is then transferred to confidence to go fast on a traditional bike. Confidence may further explain why the children who practiced on BB were more likely to cycle independently by the end of the intervention. As a child practices on a BB and increases their speed, they go from motion similar to a running gait into the child being able to lift both their feet off the ground and ‘cruise’ or ‘glide’. It is possible that this element of using a BB, that would not occur on a BS, provides an advantage to the balance group as they gain confidence in knowing that if they start to fall to one side, they need only to put their feet down.

6.6 Conclusion

In conclusion, the current study found both BB and BS to be effective methods to aid in the learning process to independent cycling with BB offering a more effective method to reach the outcome goal (i.e. independent cycling). Cycling interventions in preschool can therefore offer a unique learning experience for children where they can learn to cycle independently in a fun, engaging and comfortable environment. Dynamic balance was not able to explain why BB offered an advantage over BS as dynamic balance on a balance bike did not progress over the 5-week intervention. As a result, investigation into other possible factors such as leg strength, bimanual coordination and confidence on the bike warrant exploration. Understanding what factors improve with practice would provide a better understanding of the role of BB and BS as precursors to independent cycling on traditional bikes. Moreover, it would allow changes in development to be tracked which may highlight a child's individual motor learning issues, giving an overall better understanding of their motor capabilities.

6.7 Limitations

The current study has perhaps four limitations to consider. Firstly, ability to cycle independently (ACI) was assessed by the same people who delivered all the BB and BS classes for the 5-week intervention. This meant that the children in the BB and BS groups may have been more comfortable during the assessment of ACI at post-intervention than the Control group. Secondly, in the assessment of dynamic balance, the distance travelled may have been too small to compare adequately across groups. Change in measures of lateral acceleration occur due to both forces associated with the bike pivoting laterally over the wheels and forces due to foot contacting the ground to propel the bike forward, with the former associated more with managing dynamic balance. Given that some children invariably push on the ground more often than others, not so much to balance (i.e. stop falling sideways) but to propel themselves along, it is possible that dynamic balance should be tested over a larger distance whereby children would have a larger and more equal number of ground contacts with their feet. Thirdly, the speed at which a child performed the task may also have affected the measure of dynamic balance; this has been observed in walking trials (Bowen et al., 2001). Future studies should explore the effect of speed on assessment of dynamic balance on a bike to determine if speed needs to be controlled. Finally, the linear nature of the task may have been too simple to optimally discern levels of dynamic balance. Indeed, it is not uncommon for assessment of the likelihood of falling in older adults to include movement about obstacles (Kwan & Straus, 2014).

Chapter 7 - Summary of Thesis, Limitations and Future Recommendations

7.1 Summary of Thesis

The learning process to independent cycling has not previously been explored in early childhood. This thesis explored children's progression when learning how to cycle, including the relationship between cycling and traditional fundamental movement skills (FMS). Four studies were conducted which were subsequently used in Chapters 3-6.

Chapter 3 investigated how cycling could be integrated within the motor development model as a foundational movement skill. Using data obtained in the pre-intervention assessment of Study 3, Chapter 3 found that ability on a balance bike was an independent skill from traditional FMS (locomotor, object control and stability). This confirmed that cycling should be placed alongside locomotor, object control and stability. Furthermore, a moderate relationship was found between ability on a balance bike and the subcomponents of FMS which proposes that having higher proficiency at FMS is related to a higher proficiency on a balance bike, and visa-versa. Consequently, practicing and improving on a balance bike may improve proficiency at FMS. Chapter 3 also found it possible to combine ability on a balance bike with FMS subcomponents to create an overall measurement of combined ability. This finding will hopefully encourage research to include cycling in the assessment of foundational movement skills and thus increase its importance as a construct of motor competence.

Chapter 4 investigated the factors that may influence engagement on a balance bike and the factors relating to ability on a balance bike, using data obtained in Study 1. This was performed using a pre- to post-intervention design where the intervention group used balance bikes over 8 weeks to free play with at home; practice [motor skill engagement (MSE)] was measured using revolution counters attached to the wheels of the bikes. It was found that a higher level of practice (i.e. MSE) on a balance bike elicited more improvements. While it has been previously hypothesised that perceived motor competence would influence MSE in an activity (Eccles & Harold, 1991; Eccles & Wigfield, 2002), the current study found most of the children to have high, inflated levels of perceived competence and so did not distinguish between the varying levels of MSE. Additionally, neither ability on a balance bike nor actual motor competence (fine motor skills, object control and stability) were found to influence MSE. These findings are interesting as they open up research to investigate which factors, for example parental influences (Freeberg & Payne, 2018), environment (De Barros et al., 2003), culture and individual differences (body composition, motivation, personality/emotional make-up) (Clark & Metcalfe, 1989; Gallahue & Ozmun, 2006) may explain why a child chooses to engage or not in a novel skill or physical activity.

Chapter 4 also sought to add to the existing body of research into the relationships between perceived motor competence and actual motor competence and to introduce research into their relationships to ability on a balance bike. Results showed no relationships between any of the variables. These results agree with the theory that perceived motor competence would have little to no relationship with actual motor competence (Stodden et al., 2008). With the addition of cycling as part of the motor development model (Hulteen, Morgan, et al., 2018) (Chapter 3), these results also added novel evidence on relationships between ability on a balance bike and actual and perceived motor competence, finding no significant relationships between them.

Some comparisons can be made between Chapter 3 and Chapter 4. In both chapters, relationships to ability on a balance bike were investigated with object control and stability both included in measures of actual motor competence (Chapter 4) and fundamental movement skills (Chapter 3). Chapter 3 found moderate and weak relationships between ability on a balance bike and object control and stability, respectively. However, Chapter 4 found no significant relationships to exist between ability on a balance bike and object control or stability. This may be explained due to the nature of assessing ability on a balance bike. In Chapter 4, assessments were performed in preschools, with limited space constraining the researchers to combined straight and curved track (see Figure 4.2). Conversely, in Chapter 3 the tracks were separated between straight and curved and were much larger due to the requirements of space needed for the intervention. Consequently, the design used in Chapter 3 is likely to be a stronger measure of ability on a balance bike than obtained in Chapter 4. As a result, it would be recommended for future research that, where possible, to use the design described in Chapter 3 to assess ability on a balance bike. The combined track described in Chapter 4 however may be a valuable design when large space is not an option, which can often be the case with preschools in Ireland. It is interesting that changing the design of the track resulted in different relationships being found between the variables. This may offer some explanation into why there are also conflicting findings found in the relationships between actual and perceived motor competence, as there are various tools used in the assessment of both.

Chapter 5 used a robust design to firstly develop a scale to assess ability to cycle independently and ensure its reliability, using data obtained in Study 1,2,3 and 4. Chapter 5 also developed typical and alternate routes to independent cycling using the KIM Cycling Scale. Outside of research into learning to walk (Adolph et al., 2011; Gesell, 1939), the evaluation of typical and alternate routes is not commonly seen in motor development research. As such, its inclusion adds an interesting viewpoint to understanding trajectories children may take when acquiring a new skill. In cycling, it highlights the complexity and inter-individual differences of learning to cycle independently. Furthermore, it provides practitioners and parents reassurance that not all children follow typical paths when learning to independently cycling. The development of the KIM Cycling Scale is also a valuable asset for future research that seeks to explore the learning process to independent cycling and the possible factors that contribute to this learning process. Moreover, the design of the KIM Cycling Scale means it can also be used by teachers, practitioners and coaches to assess how a child is progressing along the learning process to independent cycling. The intervention performed in Study 3 was also described in Chapter 5 with recommendations for future cycling interventions discussed. This should provide a foundation for teachers, practitioners, coaches and researchers to use in the design of further cycling interventions in the preschool years.

Chapter 6 used data obtained from Study 3 to investigate the effectiveness of the intervention (described in Chapter 5) on learning to cycle independently. Both balance bikes and bikes with stabilisers were found to be effective at improving the children's ability to cycle independently. These findings mean that cycling interventions in the preschool years are effective at teaching children how to cycle independently and therefore provides an evidence-based reason to design and include cycling interventions in preschools. While both balance bikes and bikes with stabilisers were effective at improving ability to cycle independently, when they were compared at post-intervention on how many children had reached stage 5 or above on the KIM Cycling (i.e. they could independently cycle), practicing on a balance bike was found to be a more effective method. This supports the claims that balance bikes are a more effective tool than bikes with stabilisers in teaching children to cycle independently. However, the question remained as to what skills are learnt through practice on a balance bike that are then used in cycling independently.

Chapter 6 therefore investigated the effectiveness of the intervention on dynamic balance on a balance bike but found no significant improvements. Additionally, no relationship was found between dynamic balance and ability to cycle independently. This opens up an interesting question for future research into what skills (e.g. leg strength, bimanual coordination, confidence) are being learnt on a balance bike that are subsequently aiding children in learning to cycle independently.

7.2 Research Limitations

As with all research, there are a number of limitations. Firstly, the non-prescriptive nature of the intervention in Chapter 4 meant that the parents of the participants were asked to not allow anyone other than the participant to use the balance bike; however, there is no evidence that each participant was the sole rider contributing to the distance covered on the bike and subsequently the motor skill engagement group allocated. In addition, the counters used only allowed for the distance covered to be measured and not the amount of practice time, which is an additional important element of engagement. To resolve this the author suggests providing the parents with an activity log to track how long the children spend engaging on the bikes.

While chapter 5 included a structured 5-week intervention, the activities of the children outside of the intervention were not monitored and so it is possible that further practice occurred in some cases. Furthermore, environment, parental influences, physical activity levels, previous experience with balance bikes or similar toys (e.g. scooters), family demographics, parents' views on the importance of learning new skills and opportunities to practice were not recorded during the study. To resolve this the author suggests providing a questionnaire to a parent of each of the participants.

In the measurement of dynamic balance on a balance bike in Chapter 6, the distance travelled may have been too small and too linear, without turns or obstacles, to adequately assess dynamic balance. Also, the speed at which the child performed the task may have affected the measure of dynamic balance. To resolve this the author suggests measuring dynamic balance on a curved track also.

Throughout the research product-oriented measures of: ability on a balance bike, fundamental movement skills and ability to cycle independently were used. While justified, a mix with process-oriented measures may have provided more information.

7.3 Future Directions

Assessment of how cycling interventions may affect cycling ability in the long term, including cycling safety, should be explored as it is possible that ability at these skills in early childhood may affect cycling skills (e.g. cycling in traffic) later in life. Furthermore, future research should investigate the role of other constrained forms of cycling (i.e. additional training wheels) within Foundational Movement Skills and assessments of motor competence. Other proposed skills (swimming, body-weight, squat etc.) should also be explored in this context.

Traditional fundamental movement skills are known to predict later physical activity levels. Future studies should explore if ability on a balance bike offers similar influences and the strength of these influences compared to traditional fundamental movement skills.

Future research should investigate possible contributors to motor skill engagement during the early childhood years. Understanding the predictors of motor skill engagement of lifelong skills like cycling would mean that more effective strategies could be designed to ensure that children are given the best opportunities for practice and acquisition of skill during a critical developmental window, when perceptions of competence aren't found to be a limiting factor.

Given that the current cycling intervention described in Chapter 5 was the first to be developed to teach preschool children to cycle independently, future studies should seek to improve upon it. In addition, it's unclear if differences are evidence when the intervention is delivered in school or in a community setting. Furthermore, investigation should be undertaken into the effects on the intervention when delivered by teachers or expert practitioners.

Dynamic balance was found to not improve and to not relate to independent cycling after a 5-week cycling intervention. Therefore, future research should investigate what factors, such as leg strength, bimanual coordination and confidence, are actually improved to be subsequently used in independent cycling.

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