



## Original research

# Quantifying cycling as a foundational movement skill in early childhood

Jennifer A. Kavanagh\*, Johann Issartel, Kieran Moran

Dublin City University, Ireland



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## ABSTRACT

**Objectives:** 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.

**Design and Methods:** 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.

**Results:** 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.

**Conclusion:** 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.

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**Practical implications**

- Combining traditional FMS and cycling into one component score allows researchers to assess Foundational Movement Skills as a greater measure of actual motor competence.
- Combining traditional FMS and cycling into one component score will lead to emphasis being placed on the skill of cycling.
- Placing emphasis on lifelong skills, like cycling, may lead to an increase in physical activity levels and health.

**1. Introduction**

Locomotor, object control and stability are three subcomponents that make up fundamental movement skills (FMS)<sup>1</sup> as they are the most basic observable patterns of movement and are the

building blocks for more sport specific skills.<sup>2</sup> 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.<sup>3</sup> 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.<sup>1</sup> 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)<sup>4–6</sup> and in middle childhood (6–12 years).<sup>7,8</sup> Morgan et al. performed a systematic review on 19 FMS interventions with children of all ages.<sup>9</sup> 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.<sup>10</sup>

\* Corresponding author.

E-mail address: [jennifer.kavanagh32@mail.dcu.ie](mailto:jennifer.kavanagh32@mail.dcu.ie) (J.A. Kavanagh).

Lifelong physical activity behaviours are established during childhood as many physiological and psychological changes take place during this time,<sup>11</sup> which may subsequently influence adolescence and adult behaviours.<sup>12</sup> 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 et al. proposed an amendment to the current FMS structure and content within motor development models<sup>1,2</sup> to include the addition of more skills that lead to lifelong physical activity.<sup>10</sup> 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 (e.g. catching a ball, cycling).<sup>10</sup> 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,<sup>10</sup> 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.<sup>13</sup> 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 et al. 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.<sup>14</sup> 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.<sup>15</sup> 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.<sup>14</sup> 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.<sup>4,5</sup> 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.<sup>4,5,9</sup> 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.<sup>10</sup> 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.<sup>16–18</sup> 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.<sup>19</sup> In motor learning, practice and experience are required for behavioural changes.<sup>3</sup> 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.<sup>20,21</sup> 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.<sup>4,5,7–9</sup> 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.<sup>10</sup> 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.

**2. Methods**

Participants included ninety-seven preschool children (4.1 ± 0.48 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).<sup>20</sup> 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 15 m sprint test and a horizontal jump distance test.<sup>22</sup> The 15 m sprint test was measured using time through two pairs of timing gates (Brower timing system, USA), where the first timing gates were 10 cm 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 m straight track and a two-turn curved track (Fig. 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 15 m apart with the first timing gate 10 cm 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 (Fig. 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

**Table 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 <sup>a</sup>	33.1 ± 14.7 (s)

<sup>a</sup> Balance bike.

and given one practice trial on each track with the instruction to go as fast as they could.

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.

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).

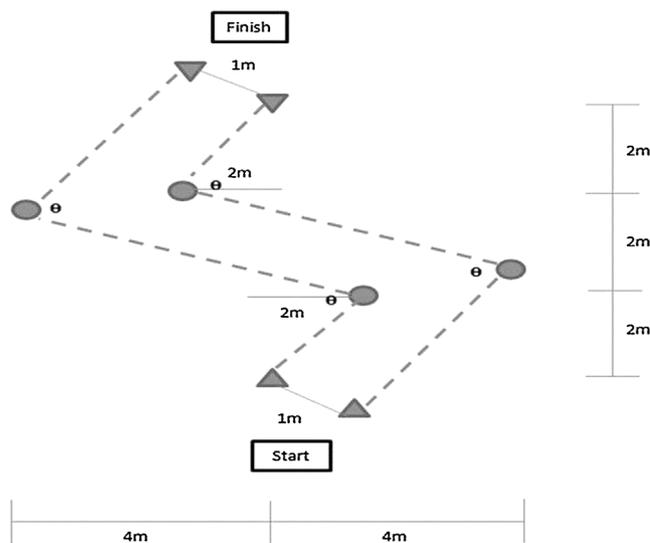
A principal axis factoring (PAF) was conducted to investigate if ability on a balance bike and ability at the three components of FMS (locomotor, object control and stability) can be combined to give a composite score for a latent variable named “Foundational Movement Skills competency”. Prior to performing 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<sup>23</sup> and a significant (p < 0.05) Bartlett’s Test of Sphericity.<sup>24</sup> Eigenvalues greater than 1 were used to assess how many groupings or components the variables could explain.<sup>25</sup> All analyses were completed using SPSS version 22.<sup>26</sup>

**3. Results**

The mean ± standard deviation for each of the skill categories are detailed in Table 1.

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 = 0.474, p < 0.001) and object control (r = 0.412, p < 0.001), 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 = 0.269, p < 0.05), 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 0.3 and above. The Kaiser-Meyer-Olkin value was 0.726 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 2 represents the relationships between each of the skills and the latent factor, in this case Foundational Movement Skills. The



**Fig. 1.** Two-turn curved track set-up. ▲ = timing gates; ● = cones to indicate turn; θ = 90° angle.

**Table 2**  
Factor loadings indicating the relationship of the individual skills to the latent variable 'Foundational Movement Skills'.

Item	Factor loadings
Locomotor	0.783
Object control	0.775
Stability	0.723
Ability on a BB <sup>a</sup>	0.742

<sup>a</sup> Balance bike.

results of this analysis provide a rationale for the inclusion of ability on a BB and traditional FMS within a Foundational Movement Skill assessment.

#### 4. 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.<sup>10</sup> 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.<sup>3</sup> 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.<sup>3</sup>

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 et al.<sup>10</sup> proposed that cycling be placed alongside FMS within the motor development model due to the positive lifelong implications for both physical activity and health (Fig. 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 (e.g. bodyweight squat, scootering, swimming strokes) with similar path options were subsequently proposed to be included alongside traditional FMS under the heading 'Foundational Movement Skills'.<sup>10</sup> 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,<sup>10</sup> 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.<sup>27</sup> 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.<sup>10</sup> 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 composite scores of FMS proficiency.<sup>28–30</sup> 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.<sup>29</sup> 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.<sup>1,2</sup> For example, Gallahue et al. Hourglass of Motor Development<sup>1</sup> and Clark and Metcalfe's metaphor of the Mountain of Motor Development<sup>2</sup> 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.<sup>1,2</sup> These investigations have led to numerous studies conclusively showing how a higher proficiency in FMS relates to physical activity levels and health.<sup>30–32</sup> As a result, typically FMS are the focus when seeking to improve motor competence in the early and middle childhood years.<sup>4,5,7–9</sup> The growing emphasis placed on FMS in schools may be attributed to this growing body of evidence on the benefits of improving FMS.<sup>30–32</sup> 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.<sup>13</sup> Hulteen et al. 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.<sup>10</sup> 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.<sup>10,13</sup> 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.

## 5. 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.<sup>14</sup> 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.<sup>14</sup> 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.

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