Transitional Movement Skills Dependence on Fundamental Movement Skills: Testing Seefeldt's Proficiency Barrier

Running Title: Test of the Proficiency Barrier

Matheus M. Pacheco[1] (0000-0002-9822-981X), Fernando G. Santos[1] (0000-0001-8024-909X), Maria T. S. P. Marques[1], José A. R. Maia[2] (0000-0002-3273-0046), Go Tani[1] (0000-0002-6517-5472)

[1] School of Physical Education and Sport – University of São Paulo, Brazil

[2] CIFI[2]D, Faculty of Sport – University of Porto, Portugal

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Corresponding Author

- Fernando G. Santos
- Email: fegarbeloto@gmail.com
- Phone: +55 (11) 99286-61307

Abstract

Purpose: In 1979 Vern Seefeldt postulated that individuals that did not achieve a given level of proficiency in the fundamental movement skills (FMS) would be limited in performance on new and more complex skills during development. This hypothesis, the proficiency barrier, inspired research in motor development but, to the best of our knowledge, was never empirically tested. The present article tested three potential mathematical functions (linear, sigmoidal and piecewise) describing the proficiency barrier relating FMS with a transitional movement skill (TMS, a more complex movement skill). **Methods:** 87 children aged 7 to 10 years were tested on six skills of the TGMD-2 test battery (running, hopping, leaping, kicking, catching and stationary bouncing) and dribbling (a combination of running and stationary bouncing). **Results:** The results showed evidence for the proficiency barrier based on a specific sigmoidal relation. We also identified critical movement aspects from FMS that seem to induce this relation. **Conclusion:** There is some evidence supporting Seefeldt's Proficiency Barrier.

Keywords: sport skills; motor performance; motor development.

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It is generally accepted, within the Motor Development literature, that for an individual to learn a given set of skills, he/she must learn/experience another set of more basic skills (Clark & Metcalfe, 2002; Gallahue, Ozmun, & Goodway, 2013). Hence, the posited sequential phases – from fundamental movement skills (FMS), to transitional movement skills (TMS), and then sport-specific skills (Seefeldt, 1979; Wickstrom, 1977). The FMS (e.g., throwing, kicking, running) are common motor activities without imposed specific performance goals, and are considered the building blocks of more complex and specific skills optimized for a given context (Wickstrom, 1977). TMS are advanced/refined versions or combinations of FMS (e.g., rope skipping, foursquare, dribbling) that, with further specification, can be applied into sport-specific contexts (e.g., dribbling in the handball, dribbling in the basketball) or dances in a particular way (Seefeldt, 1979).

In 1979, Vern Seefeldt postulated that if children did not reach a minimum of proficiency in FMS, they would fail to acquire transitional and sport-specific skills, i.e., they faced a "proficiency barrier". Seefeldt (1979) addressed children's motor development within the framework of movement patterns analysis, discussing how, through development, children become more efficient in biomechanical terms. Thus, for him, a certain degree of efficiency (heretofore, proficiency) was necessary on the movement patterns of FMS for one to start the process of TMS acquisition. Although this view has received attention in recent studies (e.g., De Meester et al., 2018; Stodden, True, Langendorfer, & Gao, 2013)[1], the proficiency barrier was, to the best of our knowledge, never empirically tested. This is the goal of the present paper.

Recent studies extended the idea of the proficiency barrier to link FMS proficiency to physical activity (De Meester et al., 2018) and health-related fitness (Stodden et al., 2008, 2013). In general, it was found that individuals with better outcomes on their FMS are more physically fit and tend to meet physical activity guidelines. However, although Seefeldt and others (Branta, Haubenstricker, & Seefeldt, 1984; Hamilton, Goodway, & Haubenstricker, 1999; Haubenstricker & Seefeldt, 1986; Seefeldt, 1979) addressed the need for individuals to engage in systematic physical activity practices, their focus was mainly on successful skill acquisition (Haubenstricker & Seefeldt, 1986; Seefeldt, 1979) rather than health-related physical fitness benefits. Therefore, even though the proficiency barrier could be related to also achieving physical-activity guidelines, the proficiency barrier neither explicitly addresses this issue nor aimed at it.

We contend that to meet Seefeldt's (1979) characterization of the proficiency barrier, we need to link FMS proficiency levels (status of the movement pattern) with TMS performance. There are different ways that might capture the proficiency barrier

[1] This recent consideration of the proficiency barrier is best exemplified in the NASPSPA 2017 session on Motor Development – Exploring Seefeldt's Proficiency Barrier.

but, in our view, two requirements have to be met.[2] The first is that FMS proficiency does not specify (i.e., determine) TMS proficiency levels, but rather that below a given threshold of FMS proficiency (the proficiency barrier) there is a low TMS proficiency maximum value that individuals do not exceed. The second is that above the proficiency barrier, FMS also do not specify TMS but rather allow maximizing skill performance, i.e., one needs to practice in order to demonstrate the TMS mature movement pattern.

Figure 1 shows four possibilities that capture the requirements to assess the proficiency barrier described above. These possibilities also illustrate what is not pre-established about the proficiency barrier. The first non-established parameter is how the potential maximum of TMS is achieved given FMS proficiency changes. This is of relevance as some might posit that individuals must achieve mature movement patterns on FMS to be able to achieve maximum proficiency on TMS (Figures 1.c and 1.d). However, this might be unnecessary. Seefeldt postulated that only some aspects of the movement (e.g., coordination between elbow extension and release of the ball in throwing) would be the required components ("critical antecedents") to be attained to permit learning of the TMS. Thus, individuals could have acquired the critical antecedents of the FMS to perform the TMS, even if they did not display proficiency on the FMS. In this way, above a proficiency level (proficiency barrier) the acquisition of the most efficient pattern on TMS would be possible (Figures 1.a and 1.b).

Another non-established parameter is how the potential minimum on TMS changes as a function of FMS. Although available literature agrees that FMS (e.g., stationary bouncing) must be modified when considered in conjunction to other skills (e.g., dribbling) (Tani et al., 2014), we do not yet know how to determine the degree of transfer from one situation to the other (Barnett et al., 2016). It could be that there is no transfer, just the barrier (Figures 1.a and 1.c), or there is transfer and it is either constant (Figure 1.b) or proportional (Figure 1.d). All these possibilities are considered here given the manner in which transfer is observed is a matter of the scoring scheme (Holding, 1976) and task constrains (see Newell, 1986; Pacheco & Newell, 2018) of both the learned skill (in our case, the FMS) and the new skill (in our case, the TMS).

Additionally, it may be possible that the proficiency barrier does not exist (Figure 1.e). One would still find a relation between FMS and TMS, but this would be continuous (no proficiency barrier).

[2] Seefeldt' writings are not formal or directly testable as he offers a number of concepts or phenomena (some of which we are addressing here) without fully specifying/characterizing them. In fact, Seefeldt' writings can be considered as directed to advertising, for physical education teachers, possible ways to evaluate and intervene, in broad terms. These two requirements described in the text are those that an attentive reader could extract from Seefeldt's writings.

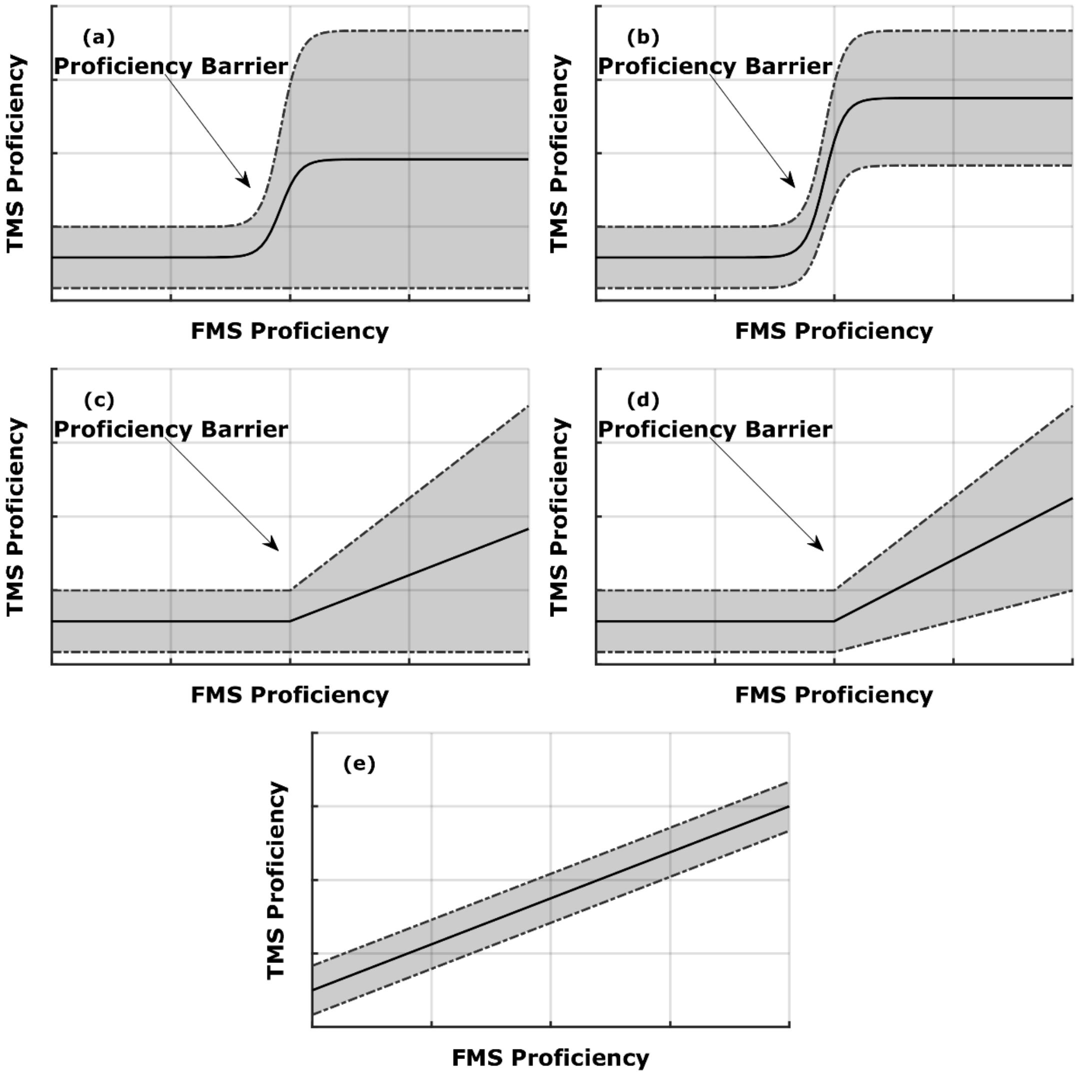

Figure 1. Five schematic models relating FMS proficiency and TMS proficiency. Models (a)-(d) show a proficiency barrier – indicated by the arrow. Model (e) shows a relation without the proficiency barrier. The dashed-dotted lines represent the minimum and maximum of the TMS proficiency distribution (shaded area) given the TMS level. See text for more details.

In this paper, we explore the relation between FMS and TMS proficiencies considering several features of Seefeldt's suggestion. First, we address its specificity by exploring the relation between six FMS (running, hop, leap, bouncing, receiving, and kicking) and one TMS (dribbling with hand) considering: (a) only the "basis" skills (running, bouncing), or (b) all six FMS. The former is predicted from Seefeldt (1979) postulation of specific critical antecedents. The latter is an instance of what has been termed as motor competence, i.e., "degree of proficiency in performing a wide array of motor skills as well as the underlying processes such as coordination, control and quality of movement" (Bardid et al., 2019, p. 311; Bardid et al., 2019b; Utesch et al., 2016). Second, we test which mathematical function best describes the relation between FMS and TMS proficiencies. Three mathematical functions are fitted to the data: linear, sigmoidal and piecewise linear. Further, we describe the maximum and minimum potential of the whole distribution in order to provide additional information on the nature of the proficiency barrier. Third, we investigate whether there are FMS specific components that, if not acquired, preclude higher levels of proficiency in TMS: the critical antecedents.

Methods

Sample

All participants enrolled in grades 2 to 5 of primary school (5-10 years old) and taking part in mandatory physical education classes (twice a week), were invited to participate. However, only those with informed consent, dated and signed by their parents/legal guardians, were considered as participants. The inclusion criteria for participating in the study were not to have any physical and/or intellectual disability that could impair their response in all assessments. In total, 87 children of both sexes (44 boys) aged 7 to 10 years participated (30% of the total number of children). The project was approved by the University of São Paulo Institutional Review Board (CAAE: 66020517.0.0000.5391).

Procedure

Fundamental movement skills. The data provided in the present study are part of a longitudinal research project that investigated the effects of different intervention programs on FMS, TMS and sport-specific skills performance over 2.5 years. The goal of this larger project was to compare specific (practice of the FMS) and general sessions (traditional PE classes) on FMS levels of proficiency. Therefore, we only used the FMS that were part of the general physical education program designed by the schoolteacher (six in total), namely running, hopping, leaping, kicking, catching and bouncing, and assessed these with the TGMD-2 test battery (Ulrich, 2000). In brief, this test battery comprises 12 fundamental movement skills (run, gallop, hop, leap, horizontal jump, slide, overhand throw, underhand roll, stationary dribble, striking a stationary ball, catch and kick) of children from 3 to 10 years of age, and results can be interpreted as norm-referenced. Further, its validity and reliability has been consistently reported (see Eddy et al., 2020 for a systematic review of motor assessments). Each skill has 3 to 5 criteria scores that qualitatively assesses the movement pattern, and the scoring is based on achieving (1) or not (0) each criterion.

The test administrator verbally instructed and demonstrated each skill to each child individually. If the child had no questions, he/she performed the first trial. If a different movement pattern was performed (e.g., instead of throwing the child performed a kick), verbal instruction and demonstration was repeated. When a clear understanding of the task was reached, each child performed two trials of the same skill (both scored). This procedure was repeated for all skills. The sum of the scores of both trials was used as performance measure, so that each child could reach a maximum of 46 points in the sum of all FMS and 16 points in the sum of running and bouncing.

Transitional movement skill. The TMS was assessed using a checklist that assesses proficient performance on a basketball dribbling skill. This test showed high validity ($\varphi = 0.85 \pm 0.05$), reliability ($\kappa = 0.77$), as well as intra- ($\kappa = 0.82$) and inter-rater ($\kappa = 0.77$) objectivity (Santos, Pacheco, Basso, Bastos, & Tani, 2020). The dribbling test required participants to cover, as fast as possible, 18 meters in a straight line by running and bouncing the basketball with their preferred hand. The checklist has a total of nine qualitative binary criteria as in the TMGD-2 (see the Supplementary File for a description of running, stationary bouncing and dribbling criteria). In addition, the time to complete the task was also recorded. We chose this TMS because it combines running and stationary bouncing, i.e., two FMS, and the assessment protocol is similar to TGMD-2 guidelines.

FMS and TMS were recorded with a camera Sony HDR-PJ540 (60 Hz). In FMS analysis the camera was positioned approximately 5 meters away from the participant, and in TMS the camera was positioned at 6 meters from the 9 meters' point of the path (18 meters). Subsequently all movies were analyzed with the aid of the Kinovea software 8.15. Only one team member (the second author) rated all 87 children videos. A week later 20 children were re-rated (intra-rater agreement) in a random order using Cohen's κ. For the FMS, assessed by TGMD-2, Cohen's κ ranged from 0.75 in leap to 0.95 in dribbling a stationary ball. In dribbling, the intra-rater agreement was calculated for each component (nine in total), and Cohen's κ ranged from 0.73 (component 9) to 0.91 (component 6).

Data Analysis

Testing the specificity of FMS and TMS relation. For the first step, we illustrated the relation between three FMS sets (the sum of criteria of running and bouncing, the sum of criteria of all six FMS collected, and the sum of criteria of the four FMS that do not include running and bouncing) with the sum of criteria of dribbling. Also, we calculated simple and partial correlations (Spearman's ρ) between two of the FMS sets and the sum of criteria in dribbling. Correlations were calculated in Matlab 2019b using corr and partialcorr functions.

Testing the function of the proficiency barrier. For the second step, we fitted three functions to the relation between the sum of criteria of running and bouncing to the sum of criteria of dribbling. The three functions fitted were linear (1), piecewise (2) and sigmoidal (3):

$$y = \alpha + \beta * x \tag{1}$$

$$y = \begin{cases} \alpha + \beta * x & \text{if } x < \varepsilon \\ \gamma + \delta * x & \text{if } x \geq \varepsilon \end{cases} \tag{2}$$

$$y = \alpha + {(\beta - \alpha)} \Big/ \left(1 + \exp\left(-\frac{(x-\gamma)}{\delta}\right)\right) \tag{3}$$

where y is the dependent variable (sum of criteria of dribbling), x is the independent variable (sum of criteria of running and bouncing), α, β, γ, δ, and ε are estimated parameters. For (1), α and β are the intercept and slope, respectively. For (2), γ and δ are also the intercept and slope but they are estimated for different domains given that the function is discontinuous at ε. In the present case, β is constrained to be zero to provide a flat curve below the proficiency barrier (as illustrated in Figures 1.c and 1.d). That is, the function would fit a flat line between FMS and TMS for values of FMS below ε (the proficiency barrier) and a different straight line for values of FMS above ε. For (3), α is the level of the TMS below the proficiency barrier and β is the level of FMS above the proficiency barrier. Also, γ is the transition point (the half-point of the proficiency barrier), and δ relates to the slope of the transition. That is, the function will show two flat lines of TMS as a function of FMS: one at α value, and one at $\alpha + \beta$. These two levels are separated by a fast increase (at a rate of δ) at the FMS value of γ (the proficiency barrier) (as illustrated in Figures 1.a and 1.b).

To fit these functions, Matlab 2019b fit function was used with the Nonlinear Least Squares method to estimate all parameter models. In addition, to estimate the ε value in equation (2), we used the Nelder Mead optimization method minimizing the Bayesian Information Criterion (BIC, Schwarz, 1974). The BIC is a measure that considers the explained variance and penalizes for the number of parameters that the function estimates to fit the data. Lower BIC reflects better fitting considering the number of parameters. To compare the functions, we also used the BIC given that these functions have different number of parameters. In other words, the three equations describing the proficiency barrier were compared in terms of their fitting (amount of data explained) but considering the number of parameters needed in each equation.

For this second step, we also illustrated how the maximum and minimum of the dependent variable changed as a function of the independent variable. For this, we adapted the algorithm of van Geert & van Dijk (2002) to analyze longitudinal data for our cross-sectional data (see also Brakke & Pacheco, 2019). The algorithm starts recording the maximum of the dependent variable when the independent variable is at its lowest value. Next, it does the same for the next value of the independent variable. If the maximum did not change, the previous maximum value is recorded for this value of the independent variable as well; if the maximum does change, the new maximum is recorded. The procedure is repeated for all values of the independent variable. In this way, a vector of maxima in the dependent variable can be plotted against the independent variable vector. The opposite procedure is done for the minimum. In this way, for hypothesized positive associations, one can illustrate how the maxima and minima change as the independent variable increases or decreases (see Figure 3.d dotted lines).

Identifying possible critical antecedents of dribbling. For the third step, we investigated which criteria of running and bouncing would predict the dribbling scores. For this, we first classified each individual's proficiency: those who scored in a criterion in both trials of TGMD-2 were classified as proficient in that criterion (e.g., "nonsupport leg bent approximately 90 degrees"). Second, we performed a dimensionality reduction analysis to find common covariance between criteria. This was done with the Horn's Parallel Analysis with tetrachoric correlations – a dichotomic version of principal component analysis – testing for "factors" (covariance patterns) that significantly explained the data when compared to shuffled data. The shuffled data were generated using random permutations of the real dataset. This was done using the pa_rule_polychoric_missing function (Garrido, Abad, & Ponsoda, 2013). We then tested whether there was a relation between the significant factors with the sum of criteria of dribbling. Simply put, we identified common factors that explained one or more criteria from the TGMD-2 in both running and bouncing to see if these common factors could explain the relation between FMS and TMS.

To identify which criterion did relate to the dribbling scores, we evaluated which vector components (criteria) significantly contributed to the significant factors. In other words, we verified which criteria from TGMD-2 were captured by the significant factors found in the previous analyses. For this, we bootstrapped the previous analysis for 1000 steps and identified which vector components showed a distribution significantly different from zero using the confidence interval built from the percentile bootstrap.

As the identified factors relate to patterns of covariation, we also identified explicitly which of the factor components of both running and stationary bouncing are present (or not) in those above or below the barrier. For this, we plotted the data of those below the identified value of the barrier (from above analyses) and those just above the value to observe whether there are specific components separating the groups. Individuals with values of FMS above 14 to 16 were not considered in this analysis given that these subjects show all or almost all criteria; thus, these subjects become uninformative for the present purpose. We then observed which criteria from running and bouncing – from the factor estimated in the previous analyses – were observed for those above or below the proficiency barrier.

FMS relation to movement product at TMS. Although Seefeldt was most concerned about the movement pattern that children could achieve in TMS given the level of FMS, one must also reveal how these movement patterns relate to movement outcomes. This extra analysis is necessary as the movement patterns have a redundant relation to the movement outcomes (Bernstein, 1967; Latash, 2000, 2012) and, thus, the proficiency barrier might be exclusive only for the movement pattern rather than its outcome. Thus, using the same fitting procedure of step 2 presented above, we tested the relation between movement pattern (considering sum of criteria for running and bouncing and the sum of criteria of dribbling) and movement outcome (the time that individuals took to accomplish the dribbling drill). This step was exploratory in nature as no *a priori* relation was expected.

Results

Specificity between FMS and TMS

Figure 2 shows the relation between three FMS sets (sum of criteria of running and bouncing; sum of criteria for all FMS; sum of criteria for all FMS but running and bouncing) and the sum of criteria of dribbling. There is a clear positive relation between FMS and TMS considering the first two sets (Figures 2.a and 2.b) that disappears in Figure 2.c.

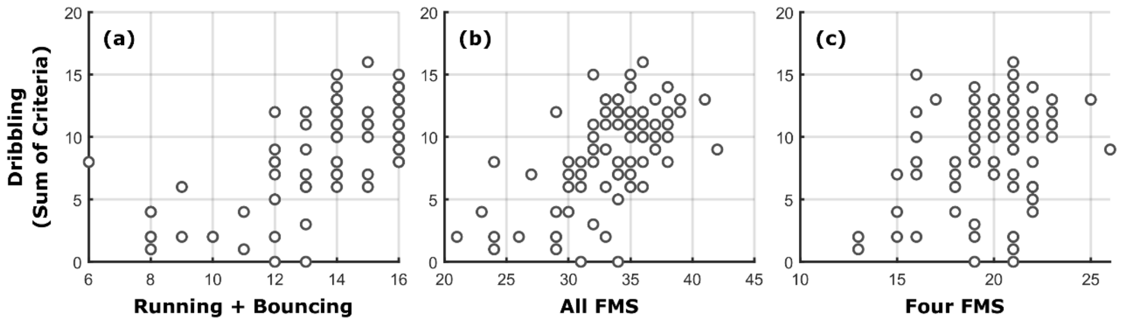

Figure 2. Relation between FMS sets (a) sum of running and bouncing criteria, (b) sum of running, hopping, leaping, kicking, catching and bouncing criteria, (c) sum of hopping, leaping, kicking and catching criteria) and the TMS (sum of dribbling criteria).

The correlation between running and bouncing with dribbling was significant (Spearman's ρ = 0.64; p < .001) and was still significant when correcting for the sum of criteria for all FMS (partial correlation, ρ_p = 0.42; p < .001). Yet, results are not the same when correlating the sum of criteria for all FMS with dribbling because although its value is significant (ρ = 0.54; p < .001) the relation disappears when controlled by the sum of criteria of running and bouncing (ρ_p = 0.09; p = .397). Thus, these results support our first expectation that the relation between FMS and TMS is specific to the FMS that integrates the to-be-acquired TMS.

Proficiency Barrier Function

Figure 3 illustrates the fitting of the linear, sigmoidal and piecewise equations, as well as the minimum and maximum change as a function of FMS.

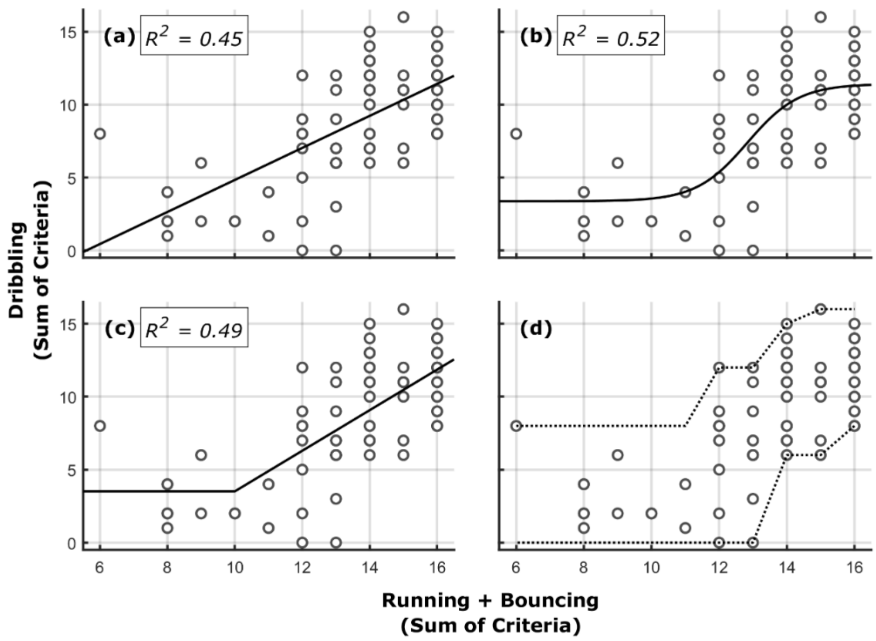

Figure 3. Relation between the sum of running and bouncing criteria and the sum of dribbling criteria displayed by the (a) linear, (b) sigmoidal and (c) piecewise fitted models; (d) shows the maximum and minimum of the TMS distribution as a function of sum of dribbling criteria.

Model fitting showed that the lowest R^2 was from the linear function (R^2 = 0.45, Figure 3.a) followed by the piecewise relation (R^2 = 0.49, Figure 3.c) and sigmoidal function (R^2 = 0.52, Figure 3.b). Similarly, BIC results revealed that the piecewise model showed the highest value (BIC=2.23), followed by the linear (BIC=2.20) and sigmoidal functions (BIC=2.17). Thus, the sigmoidal function captured the highest amount of variance even when controlling for the number of parameters. As such, it empirically supports the presence of a proficiency barrier.

Observing the fitted parameters of the function – specifically γ, we see that the middle of the change in performance of TMS (when the proficiency barrier is passed) is located at a value of 12 criteria in the FMS (γ = 12.84). The TMS sum of criteria below the proficiency barrier is around α = 3.75 and its value increase to β = 11.42.

Critical Antecedents of Dribbling

Considering the proficiency per criterion of running and bouncing, Horn's parallel analysis showed a single factor that explained the data significantly. This factor explained 51% of running and bouncing variance in terms of all their criteria. Figure 4.a shows the distribution of contribution of each vector component to this factor from the bootstrap analysis. As shown, the 4th and 5th components ("nonsupport leg bent approximately 90 degrees" in running and "contacts ball with one hand at about belt level" in bouncing) failed to reach significance in their contribution, whereas all other components contributed somewhat similarly to this factor.

Figure 4.b shows the relation of this factor to the dribbling scores. As shown, despite the fact that this factor only accounts for 51% of the variance in the criteria set variance, this factor maintains the sigmoidal relation to the dribbling scores. Thus, it seems that this factor represents the critical antecedents for dribbling acquisition.

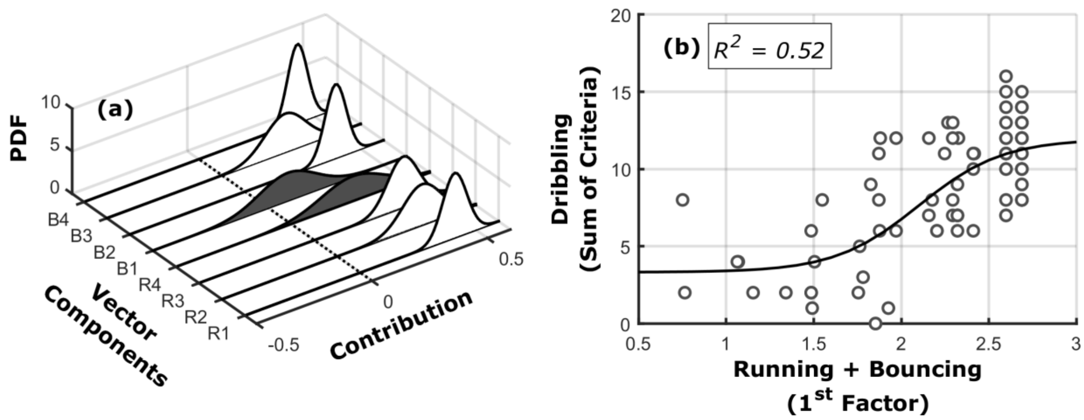

Figure 4. (a) Criteria weighing distribution (probability density function, PDF) on the principal factor extracted from the Horn's parallel analysis bootstrap procedure. White curves are significant contributions and gray curves are non-significant contributions. R1 to R4 and B1 to B4 are the running and bouncing criteria, respectively (see Table S1 in the Supplementary File). (b) Relation between the principal factor extracted from the Horn's parallel analysis and the sum of dribbling criteria with an adjusted sigmoidal curve.

Nevertheless, this factor describes patterns of covariation; we must be sure that these represent the critical antecedents of dribbling. Figure 5 shows the average frequency of these six components below (11 or less) and above (between 12 and 14) the proficiency barrier. Indeed, all six components increase in consonance. However, the components with low frequency of occurrence in the group below the proficiency barrier that increase in the group above the barrier are the first component from running (“arms move in opposition to legs, elbows bent”) and all three components of bouncing (“pushes ball with fingertips”, “ball contacts surface in front of or to the outside of foot on the preferred side”, “maintains control of ball for four consecutive bounces without having to move the feet to retrieve it”). All relate to coordination of the arms in running and control of the ball.

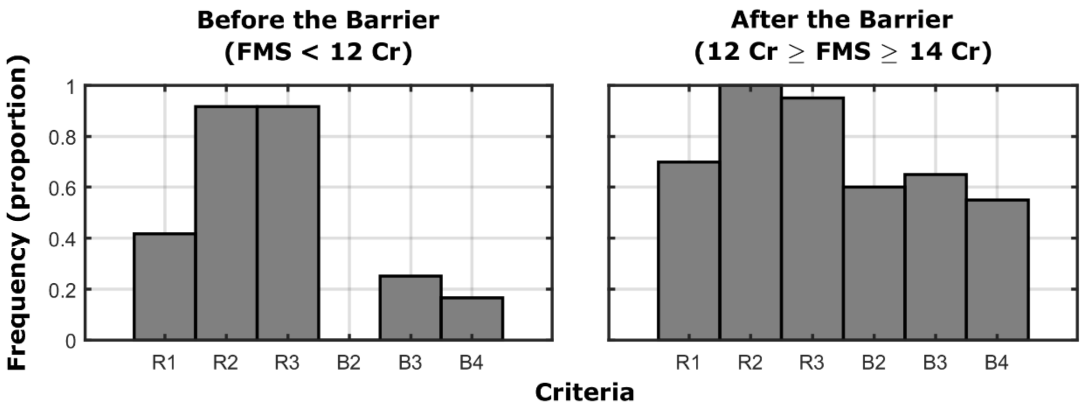

Figure 5. Frequency (proportion) of individuals showing the six criteria (see Table S1 in the Supplementary File) with significant contribution to the Horn’s parallel analysis (a) below the barrier (individuals with FMS [sum of running and dribbling criteria] below 12) and (b) above the barrier (individuals with FMS [sum of running and dribbling criteria] above 11 and below 14).

Relation Between Movement Process and Product

Figure 6.a shows the relation between the sum of running and bouncing criteria and the time to complete the dribbling drill. Although a linear relation seems to be present, there are two individuals that clearly escape the expected relation (highlighted with filled circles as outliers). Figures 6.b and 6.c shows the relation between the sum of dribbling criteria and the time to complete the dribbling drill. As expected, the relation is more consistent (less variable around a trend), although individuals show a ceiling effect in drill-completion time above 8 criteria – there is no improvement in drill-completion time even for individuals with more proficient criteria.

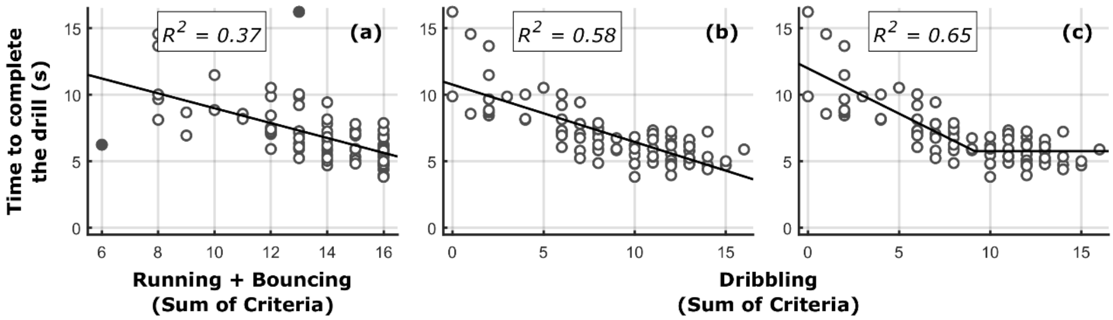

Figure 6. Relation between time to complete the drill (in seconds) and (a) the sum of running and bouncing criteria, (b)-(c) sum of the dribbling criteria. (a)-(b) also show adjusted linear curves. (c) shows an adjusted piecewise curve.

We fitted only a linear trend between sum of running and stationary bouncing criteria and time to complete the drill as we did not distinguish any other possible trend in data (Figure 6.a) (R^2 = 0.37). For the second relation (dribbling criteria and drill-completion time), given the possibility of a ceiling effect, we compared a linear equation with a piecewise one between dribbling criteria and time (Figures 6.b and 6.c, respectively). As expected, the piecewise equation demonstrated a better fit (R^2 = 0.65 compared to R^2 = 0.58). BIC concurred, showing a smaller value for the piecewise relation (0.71) compared to the linear function (1.21). Additionally, we found that the exact cutting point was around 9 criteria: those with 10 or more criteria did not decrease the time to complete the drill.

Discussion

For forty decades now, Motor Development researchers have considered that children who do not acquire the FMS to a level of proficiency would not be able to learn TMS and other more complex movement skills (Barnett et al., 2016; Clark & Metcalfe, 2002; Hulteen, Morgan, Barnett, Stodden, & Lubans, 2018; Wickstrom, 1977). The proficiency barrier is grounded on the principle of interdependence between phases of motor development, but, to the best of our knowledge, it was never formally tested. This was the main goal of the present study. We discuss our results in a stepwise manner: first, we present evidence for all aspects of Seefeldt's proficiency barrier; second, we compare our results with previous ones and also address the concept of a proficiency barrier and discuss necessary advances.

Evidence for Seefeldt's Proficiency Barrier

The best mathematical function to describe the relation between FMS and TMS was the sigmoidal which provided evidence for the proficiency barrier. Also, we found a strong support that the whole distribution of TMS performance changed as a function of the proficiency barrier. That is, the minimum and maximum performance for TMS increased after passing the proficiency barrier. This suggests that there is a degree of transfer from FMS to TMS – individuals who are above the proficiency barrier start learning the TMS at a higher performance than those who are below the proficiency barrier.

A relevant aspect of these results was that the proficiency barrier was observed between the TMS (dribbling) and its specific composing variables (running and stationary bouncing) – a specific relation proposed by Seefeldt (1979) (see also Clark & Metcalfe, 2002). As our results revealed, the development of more complex skills and inclusion of individuals in sport-specific contexts demand practice of core FMS rather than practice of a broad range of FMS. However, it is important to consider that the specific relation between FMS and TMS does not preclude the consideration of composite scores (e.g., sum of scores of all FMS) in describing children overall motor development. An individual that is proficient in many FMS will have an advantage to learn more advanced skills and will be more prone to adhere to an active lifestyle (Stodden et al., 2008; Barnett et al., 2008).

Seefeldt (1979) also postulated the existence of critical components in the FMS that would be the basis for TMS acquisition - the critical antecedents. To test this, we identified an underlying factor (a covariation pattern) in the running and stationary bouncing components and verified their relation to TMS acquisition. The single factor (Figure 4) encompassing six components from both running and stationary bouncing explains that individuals that acquire one of these components are more likely to do also for the others (see Langendorfer & Roberton, 2002), as if a coordinating pattern was emerging from practice encompassing all these components. Additionally, we found that those components related to arm coordination with the ball and running were the components differentiating those who are above or below the barrier. Intuitively, if children are able to coordinate their arms with the body (running) and with the external implement (the ball), they are ready to start learning dribbling.

The observed relation between FMS and TMS is one of transfer (as discussed earlier): “the learning of a response in one situation influences the response in another” (Adams, 1987, p. 44). The concept of FMS as the basis for transfer has been considered elsewhere (e.g., Barnett et al., 2016; Hulteen et al., 2018; O’Keeffe, Harrison, & Smyth, 2007). For instance, O´Keeffe et al. (2007) showed that after an intervention program, with 180 minutes practicing throwing (FMS), adolescents improved their performance not only in throwing (FMS), but also in badminton overhead clear and in javelin throw. Clearly, these three movement patterns are greatly improved through the proximal-to-distal (“whip movement”) pattern. In practicing the throw, one would have acquired critical antecedents integral to all these highly sport-specific skills.

Considerations and necessary advances on the proficiency barrier issue

We are not the first to address the issue of a proficiency barrier. For example, Stodden et al. (2013) following the assumption that the proficiency barrier would relate FMS skill level to health-related fitness (HRF) measures (e.g., strength, cardiorespiratory aptitude), found an association between FMS competence and HRF. De Meester et al. (2018) went further and found evidence relating skill levels of children of 7 to 11 years of age that comply with the moderate-to-vigorous physical activity requirements from the World Health Organization (WHO, 2014).

However, Seefeldt’s original notion of a proficiency barrier was simply related to motor skill level and was not towards HRF levels. As such, we contend that other issues can be further discussed that highlight the importance of the present findings. The first is that these previous studies on the proficiency barrier arbitrarily defined categories for FMS skill level to test their associations. In this way, even a linear relation observed in a continuous scale would give the impression of a barrier. The second is that the aforementioned studies did not address putative contradictory occurrences (high FMS competence leading to low HRF measures, and vice-versa) which weakens the claim for a barrier. The third is that Stodden et al. (2013) used the outcome measures (e.g., distance of throw) of the FMS instead of the movement pattern proficiency. The usage of movement outcome to characterize FMS was a concern reflected in Seefeldt's writings and, as our results showed, modify how the relation is to be observed.

Recently, Brian, Getchell, True, De Meester, and Stodden (2020) reconceptualized the proficiency barrier to deal with broader discontinuities in motor development. Their main claim was that there would be a greater need of free play and structured movement experiences to pass through a barrier between stability-based to mobility-based movements invoking phylogenetic and ontogenetic requirements on motor development. It is beyond the goal of the present manuscript to address the possibilities of such relationships. However, the proposed reconceptualization seems to suggest "a proficiency barrier" that is different from Seefeldt's original idea.

Seefeldt (1979), in justifying the proficiency barrier, stated that "our work has shown that children who are deprived of learning the fundamental skills have difficulty when they attempt to learn the transitional motor skills" (p. 316). Although the critical antecedents (and limiting conditions) are posited as a model, there is neither theoretical grounding for the barrier nor for the proposed model. This has led to criticisms and the new formulations previously mentioned (see Barnett et al., 2016; Brian et al., 2020; Hulteen et al., 2018).

We believe that there is an alternative theoretical route that can help to explain our results. The dynamical systems approach to motor behavior encompasses the possibility for earlier dynamical resources being present before the emergence of new behaviors (see Thelen & Smith, 1994) – the critical antecedents. Thelen, Kelso and Fogel (1987) have repeatedly shown that earlier "traits" of walking were present before voluntary walking emerges. Also, one can understand how FMS and TMS would relate – and allow similar dynamical resources to be shared – through the view that they share similar task constraints (Newell, 1986). Results of O'Keefe et al. (2007) discussed earlier, for instance, could be understood by the fact that all movements investigated required the proximal-to-distal "whip-like" pattern. In other terms, the throwing task constrained individuals to learn the whip pattern that would facilitate dart throwing and badminton serve. This view is in consonance to our findings but must be further investigated in future studies.

Limitations of the Study

This study is not without limitations. The first is that it is cross-sectional. The proficiency barrier would be directly observed if individuals below a given level of FMS proficiency fail to improve their proficiency on a TMS, while other individuals would improve. Nevertheless, there is the possibility of capturing it in a cross-sectional study, as we did. If the longitudinal expectation holds, then the results we found are expected to occur. Thus, our results are a necessary condition for the existence of the proficiency barrier – even if it is not sufficient.

Second, children of different ages were part of the sample group. There is no doubt that biological maturation and growth-related factors can affect motor performance (Malina, Bouchard, & Bar-Or, 2004). However, studies indicate that children of different ages, even adolescents, can present low levels of performance on FMS (Lester et al., 2017; O'Keeffe et al., 2007). Age, thus, does not determine the level of proficiency (Clark, 2007) (the correlation was maintained even when controlled by age, $r = .55$, $p < .001$). It is another question to investigate whether age interacts with the relation favoring or limiting improvements on TMS given FMS level. Clearly, the consideration on age adds to other potential influential factors (e.g., environmental factors) that can influence earlier experience on FMS or even more rudimentary skills. The inclusion of these factors requires further research.

Third, despite TGMD-2 validity as an instrument to measure the gross motor ability encompasses 12 skills, only six were assessed. This might underrepresent the FMS class. However, Valentini, Rudisill, Bandeira, and Hastie (2018), testing a shorter version of TGMD-2 showed that six skills (different than the ones considered here) correlated strongly with the whole set of locomotor and object control skills. Thus, we contend that our results still provide a good indication of the gross motor ability. Finally, only one TMS was assessed. We therefore suggest that future research is needed to generalize the relation between FMS and TMS

Conclusion

This study investigated the proficiency barrier from Seefeldt's (1979) original definition. We found evidence supporting it. Further, this study is one of the few that showed direct evidence of interdependence on the acquisition of motor skills of different motor "phases" after infancy. Accordingly, we move closer to an understanding of the fundamental aspects of the FMS – an ongoing debate (cf. Newell, 2020) – and provided empirical support for the longstanding assumption of the proficiency barrier. Additionally, our findings support the argument put forward elsewhere in favor of teaching FMS in physical education classes as an important step for learning more complex skills and, in light of available data, encourage an active life-style. Although children can and will explore their possibilities on their own, a guided tour through possibilities might optimize the process. Clearly, physical education teachers are the most prepared professionals in order to organize a curriculum where a diversity of skills can be developed.

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