Comparison of product and process oriented model accuracy for assessing countermovement vertical jump motor proficiency in pre-adolescents.

FRANCESCO SGRO', ANTONELLA QUINTO, SALVATORE PIGNATO, MARIO LIPOMA
Human and Society Sciences Faculty, University of Enna "Kore", ITALY

Published online: September 26, 2016

(Accepted for publication September 10 2016)

DOI:10.7752/jpes.2016.03145

Abstract:

The purpose of this study was to compare the level of accuracy of two different approaches, product- and process-oriented, for assessing the proficiency level of vertical jump skill in pre-adolescents. Ninety-one children were sampled from four schools and were invited to perform three countermovement vertical jumps. The jumps were initially assessed by two assessors with an observation criteria-based approach for ranking the children in three developmental levels. The performances were also acquired by means of the sensor Microsoft Kinect and its signals were used for estimating a set of temporal and kinematic parameters. The height of jump was used as proxy of the product-oriented assessment approach, while the other parameters were used for the process-oriented ones. Discriminant analyses were carried out separately for the two aforementioned approaches by using the developmental levels as dependent variables. The process-oriented approach resulted in a higher level of accuracy than the product-oriented approach and the temporal parameters were the best predictors for ranking the children in their developmental levels. These findings seem to be useful for overcoming several limitations related to the assessment of fundamental movement skills and for providing new perspectives for physical education teachers.

Keywords: physical literacy; fundamental movement skills; motor skills developmental levels; spatio-temporal parameters; Microsoft Kinect; discriminant analysis.

Introduction

Recently, several researchers have discussed the criticisms related to the fundamental movement skills (FMS) topic and about their relation with the learning process (Barnett et al., 2016). The same authors defined these skills as essential patterns of movements that do not appear naturally and needed to be trained. These skills are outlined as the foundation for several physical and sport activities and are related with academic outcomes and holistic well-being. Furthermore, the promotion of the FMS in pre-school and school children is consistent with the concept of physical literacy (Giblin, Collins, & Button, 2014). These skills are normally grouped in three categories: locomotion, object control, and stability skills (Gallahue, Ozmun, & Goodway, 2012).

The assessment of the FMS is one of the major criticisms discussed in literature and is a critical element for many disciplines (Hands, 2002). The assessment methods are normally divided in two groups: quantitative and qualitative. The first category includes the approaches mainly based on the assessment of a single parameter as a proxy of the overall performance and are typically defined as product-oriented. The results obtained with these approaches are characterized by a high level of validity, accuracy, and reliability, but they don't provide useful information about the level of motor proficiency. On the contrary, the qualitative approaches try to explain the performance by addressing several aspects of that. These approaches are accomplished by one or more assessors that have to evaluate the motor proficiency by means of the use of observation records or checklists. These approaches are acknowledged as process-oriented and seem to provide detailed information about motor proficiency. The characteristics of the observation records (i.e., number and typology of the observed criteria), the strategy used for the interpretation of these records, and the low level of inter-rater reliability are the main limits of these approaches (Hands, 2002). In this respects, new methods and instruments are warranted for overcoming the aforementioned limits.

Vertical jump is categorized among the locomotion skills. The skill proficiency level is normally met during the middle childhood and it is considered relevant for several sports (i.e., basket, volleyball, soccer) (Sgrò, Nicolosi, Schembri, Pavone, & Lipoma, 2015a; Raiola, Altavilla, Tafuri, & Lipoma, 2016). The vertical jump is also used as a test for assessing the lower limb power (Boccolini, Brazziti, Bonfanti, & Alberti, 2013). Considering a skill learning point of view, Floria and Harrison (2013) used the height of jump as a proxy for a product-oriented assessment approach for discriminating between developmental stages. However, they used a force plate as an instrument for estimating the height of the jump and it was not fully consistent with ecological constraint required by the movement assessment method in childhood (Hands, 2002). Sgrò and colleagues (2015) proposed the use of a low-cost motion capture device (i.e., Microsoft Kinect) for acquiring objective data

related to this skill in ecological form. These data were used for estimating a set of parameters that was processed to characterize the motor proficiency in childhood. This set of parameters could be considered a proxy for the process-oriented approach, but the height of jump was considered within the set of parameters, so a hybrid product-process assessment was obtained.

By considering the previous analysis of the literature, the purpose of this study was to identify the classification model that accomplished the highest level of accuracy for the developmental levels obtained by means of an observational approach. The parameters used in the processed models were acquired by means of the Microsoft Kinect (Sgrò et al., 2015a). According to previous studies (Sgro, Barresi, & Lipoma, 2015; Ivashchenko, Yermakova, Cieslicka, & Muszkieta, 2015), the discriminant analysis was used for assessing the level of accuracy of the aforementioned models. In this respect, we hypothesized that a set of parameters, as proxy of process-oriented approach, classified the children in their developmental levels with more accuracy than a single product-oriented parameter.

Method

Participants and procedure

Ninety-one children from 6 to 12 years old were randomly selected from three primary and one secondary school in three different cities. Eligibility criteria were: (1) age 6 years or older; (2) absence of any types of injury or pathologies which precluded the jump motion; (3) providing informed consent with the signature of the parents. The methodologies respected the directives of the Helsinki Declaration and the Ethical Committee of the University of Enna approved the sample, the methodologies, and the aids used in this study.

For each school, the children were randomly divided in several groups, each one composed of five or six children. Two assessors with expertise in physical education studies were involved in the experimentations provided in this research. These assessors waited the groups in the gym of each school and, after a brief period of familiarization, acquired the anthropometric characteristics of each child using wall-mounted stadiometers and a portable scale for height and weight, respectively. Next, the children performed a low-intensity warm-up program for 10 minutes. At the end of this program, one assessor showed the right execution of the assigned task by emphasizing the countermovement motion and invited all participants to jump as high as they could during the trials. Later, one-by-one, the participants performed four trials: the first trial was done for the familiarization with the assigned task while the others were considered for the assessment. Among each trial, a child was at rest for one minute. The experimental set-up used in this research was arranged in the gym of each school and it consisted of one camera (Sony Handycam-HDR-PJ740) that acquired the motion on the sagittal plane and a Microsoft Kinect sensor that acquired the jump by using an ad-hoc application developed in C#. The camera and the Kinect were positioned 2.5 meters away from the jumpers.

Qualitative assessment

The level of proficiency in vertical jump skill was assessed by means of the proficiency-criteria approach proposed in the Western Australian Teachers Resources [Department of Education Western Australian (EDWA, 2013b)]. Previous studies have already used these resources to address motor competence in childhood (Okely, Booth, & Patterson, 2001a, 2001b; Sgrò et al., 2015a). The assessors filled in a Skill Observation Record form composed of the six skill criteria (see table 1) that described the pattern of motion required in countermovement vertical jump.

Table 1 – Evaluation criteria of the vertical jump skill (Adapted from EDWA, 2013b)

Phase	Segment	Criteria
Preparation	Legs	Ankles, knees and hips bend*
	Head and trunk	Head up, trunk upright
	Arms	Arms swing behind body*
Propulsion	Legs	Legs forcefully extend
	Arms	Arms swing forward and up in time with the leg action
Landing	Legs	Ankles, knees and hips bend to absorb impact*

Note: *: Initial Focus Skill Criteria

The assessors saw the video and, for each participant and trial, they scored whether each criterion included in the aforementioned form was mastered or not. Next, the interpretation of the results was based on a rule-of-thumb approach provided in the cited resources (EDWA, 2013a). In this respect, three developmental levels were identified: the children were ranked at the *Beginning* level if they mastered only one of the initial focus skill criteria; the *Developing* level was reached by the participants who mastered at least all of the initial focus skill criteria, while the children were ranked at the *Consolidating* level if they mastered all six criteria described in Table 1. By following the aforementioned approach, the participants were grouped in the relevant developmental level.

Quantitative assessment

The quantitative assessment of the developmental levels was performed using the data acquired from the Microsoft Kinect. The Kinect is a low-cost motion capture system that is able to identify and track 20 landmarks throughout the body of each participant. These landmarks identified the joints as follows: feet, ankles, knees, hips, hip center, spine, shoulder center, elbows, wrists, hands, and head (Webb & Ashley, 2012). The 3D coordinates of those joints were sampled at 30 Hz and they were used for obtaining the coordinates of whole body center of mass (CoM) by applying the segmentation method (Winter, 2009). In detail, the X-axis identified the medio-lateral (ML) direction, the Y-axis identified the cephalo-caudal (CC) direction, and the Z-axis identified the antero-posterior (AP) direction. This process and the further motion analysis were performed by means of an ad-hoc routine developed in Matlab environment (Mathworks, Inc., Natick, Massachusetts).

The time-series of CoM in CC direction was filtered using a fourth-order zero-lag Butterworth filter for reducing noise in the motion data. The cut-off frequency was estimated using the residual analysis (Winter, 2009). Then, the velocity in CC direction was estimated as the first-derivative of the CoM displacement. According to the Linthorne model (2001), these signals were processed for identifying the relevant frames that describe the countermovement jump, as described in Fig. 1, and the set of kinematics parameters used for providing the current the motion analysis.

Fig. 1 – The dashed line represents the CC velocity signal of the center of mas (CoM), while the continuous line represents the CC position of the CoM. The black circles identify the following frames: the start of jump (A), the lowest point of the CoM (b), the pre-takeoff (C), the takeoff (D), and the landing (E).

The identification of the take-off frame (D) and the landing frame (E) was obtained by means of the approach proposed by Sgrò and colleagues (2015a). This approach used a linear regression model in the ordinary least-squares sense for the identification of those frames by considering the well-established characteristics of the velocity signal slope during a free-falling motion. The height of jump (HJ) was estimated as the difference of the coordinates in CC-direction between the start of the jump (A), that was identified as the frame when the velocity started to decrease, and the frame identified as the peak value of the same signal. This parameter was used in further analysis as proxy of the product-oriented assessment. The set of parameters used as proxy of the process-oriented assessment was composed of takeoff velocity (TV), preparation time (PreT), propulsion time (ProT), and flight time (FT). The TV was estimated as the value of the velocity signal in the frame (D). The PreT was the time between frame A and frame B, which was identified as the instant when the CoM signal reached its lowest position. The ProT was estimated between frame B and frame C. The last frame is acknowledged as the pre take-off frame and it was identified when the velocity signal reached its maximum value. Finally, the FT was estimated as the difference between the landing frame (E) and the takeoff frame (D).

Statistical analysis

The inter-observer reliability was addressed by means of inter-class correlation coefficient (ICC). The average values of the kinematic parameters were estimated for each child. These data were preliminary checked for accuracy, missing values, and univariate and multivariate outliers. Then, the assumptions required by the discriminant analysis were verified. The multicollinearity was assessed by means of the analysis of the tolerance index and the variance inflation factor (VIF). Homoscedasticity was verified with the Levene's test of homogeneity of variance (Betz, 1987; Tabachnick & Fidell, 2007). Furthermore, we verified that the group with the lowest number of participants was composed of at least 20 children and we verified that this number was higher than the independent variables used in each analysis. The discriminant analyses were performed by using the developmental levels as the dependent variable and the parameters as proxy for product- and process-oriented assessment approach as independent variables, separately. These analyses were done by verifying whether the parameters discriminated among the developmental levels and which level of accuracy was obtained in the related classification results. The discriminant role of process-oriented parameters was based on the interpretation of the values of the structure coefficients by considering only the ones with a value greater than $|0.30|$ because they provided a powerful contribution for discriminating among the developmental levels. The accuracy of the classification models was performed by comparing the cross-validation classification rate with the maximum chance criterion increased by 25%. This criterion was defined by considering the number of

participants in the largest group (Betz, 1987). The statistical procedures were performed using SPSS Version 20.0 for Apple (SPSS, Inc., Chicago, Illinois) and the significance level was set to 0.05.

Result

The inter-observer correlation coefficient was 0.91 and it confirmed a large inter-observer reliability. After data screening, six participants of the Developing group were univariate or multivariate outliers, so they were excluded from further analyses. In this respect, all the assumptions for discriminant analysis were met.

The anthropometric characteristics of the participants for each level are reported in Table 2.

Table 2 – Anthropometric characteristics of the participants in the three developmental levels.

Anthropometric variable	Beginning Level (n=20)		Developing Level (n=35)		Consolidating Level (n=30)	
	M	SD	M	SD	M	SD
Age, yr.	7.55	1.31	9.45	1.78	10.45	1.59
Height, m	1.28	0.80	1.42	0.11	1.44	0.11
Weight, kg	29.34	7.73	40.21	12.93	39.81	11.28
Body Mass Index, kg/m ²	17.63	3.36	19.46	4.45	18.77	3.88

Product-oriented assessment approach

The discriminant analysis indicated that the model based only on the height of jump parameter was significant: Wilks's $\lambda = 0.58$, $\chi^2 = 44.46$, $p < .0001$, so the proportion of total variability not explained was 58%. The results of original and cross-validated classification are shown in table 3.

Table 3 – The discriminant analysis classification results for product-oriented assessment approach.

Actual Level			Predicted Level Membership (%)		
			Beginning	Developing	Consolidating
Original	Beginning	20	60.0	40.0	0.0
	Developing	35	11.4	68.6	20.0
	Consolidating	30	0.0	40.0	60.0
Cross-Validated	Beginning	20	60.0	40.0	0
	Developing	35	11.4	62.9	25.7
	Consolidating	30	0.0	40.0	60.0

The classification results revealed that the participants were correctly classified in their developmental levels with 63.5% rate of accuracy in the original model and with 61.2% in the cross-validated model. The rate of the cross-validate classification exceeds the maximum chance criterion (51.6%). The Developing group has a higher percentage of correct classification in both results compared with the other groups.

Process-oriented assessment approach

The discriminant analysis revealed that two models were significant: (1) Wilks's $\lambda = 0.50$, $\chi^2 = 54.72$, $p < .0001$ and (2) Wilks's $\lambda = 0.86$, $\chi^2 = 12.26$, $p = .007$. The first was the best model because the proportion of total variability not explained was 50%. By considering the parameters processed in that model and their structure coefficients, the PreT and the FT were the predictors with the highest scores (0.88 and 0.76, respectively), while the TV was the predictor with the lowest score (0.31). The results of original and cross-validated classification are shown in table 4.

Table 4 – The discriminant analysis classification results for process-oriented assessment approach.

Actual Level			Predicted Level Membership (%)		
			Beginning	Developing	Consolidating
Original	Beginning	20	65.0	25.0	10.0
	Developing	35	11.4	68.6	20.0
	Consolidating	30	3.3	20.0	76.7
Cross-Validated	Beginning	20	60.0	30.0	10.0
	Developing	35	11.4	65.7	22.9
	Consolidating	30	6.7	20.0	73.3

The classification results revealed that the participants were correctly classified in their developmental levels with 70.6% rate of accuracy in the original model and with 67.1% in the cross-validated model. Anyway, the rate of the cross-validate classification exceeds the maximum chance criterion (51.59%). The consolidating group has a higher percentage of correct classification in both results compared with the other groups.

Discussion

In this study, we have used the discriminant analysis for comparing two models widely used for assessing the motor proficiency in vertical jump skill. The developmental levels of each participant were identified with an observational criteria-based approach, while the data used in the aforementioned models were estimated by means of the Microsoft Kinect. In this respect, we have verified whether the process-oriented assessment approach provided a higher level of accuracy for discriminating the participants in their developmental levels than the product-oriented assessment approach. Of note, this hypothesis has been verified.

The participants involved in this study were grouped into three developmental levels, but the distribution within the levels was not fair. In detail, the Beginning group include fewer participants than the other groups. This evidence may be explained by considering that the number of participants in the first class was limited. In line with this consideration, the data proposed in table 2 shows that the average age of each group increased accordingly with the developmental levels. This finding confirms that the level of proficiency of the fundamental movement skill was age-related, even if not age-dependent, and that level in countermovement jump skill was expected only after the age of six years old (Gallahue & Ozmun, 2002).

The data used for defining the product- and the process-oriented assessment approach was acquired by means of the Kinect. The signals of the Kinect were used for estimating several objective parameters according to a previous study (Sgrò et al., 2015a). Among these parameters, the height of jump was considered as proxy of the product-oriented assessment approach, while the others parameters were used as proxy of the process-oriented assessment approach.

The use of the height of jump was widely adopted for assessing the vertical jump skill in a school environment as a means for estimating lower limb power (Aragon-Vargas, 2000) and it could be considered to be a relevant parameter for addressing the level of proficiency (Floria & Harrison, 2013; Williams, Saunders, Maschette, & Wilson, 2013). This value can be easily acquired even without a digital aid by using a simple wall-mounted stadiometers, but this measure is characterized by several limits, such as validity and reliability. The use of the Kinect solved these limitations as it was warranted by previous study (Sgrò et al., 2015a). Anyway, the current discriminant analysis result revealed that the use of only this parameter seems not to be powerful for identifying the developmental levels in pre-adolescents with accuracy.

The process-oriented approach was based on the use of several parameters related to the vertical jump performance. The classification accuracy obtained by means of this set of parameters was higher than the ones obtained with the previous approach and exceeded the limits of accuracy identified following the indication provided by Betz (1987). Original and cross-validate models revealed that the classification of the participants in the Consolidating group was more accurate than in the others. In this respect, we hypothesized that the participants of this group showed significant and well-established proficiency levels in several movements related to the assessed skill, while the children in the other groups showed patterns of movement with few characteristics of stability. The parameters related to the timing of action were the best predictors of the differences in the developmental levels. This finding was in agreement with previous studies (Floria & Harrison, 2013). Furthermore, this set of parameters was suggested as valid for identifying the difference in proficiency levels between children categorized in Developing and Consolidating groups (Sgrò et al., 2015a). From a motor learning perspective, the parameters related to the timing characteristics of the jump could be useful for understanding the current level of motor proficiency instead of the height of jump because these ones reflect with accuracy the pattern of movements learned by each child.

Conclusion

In conclusion, the use of a proposed process-oriented approach seems to be adequate for classifying the children in the relevant developmental stages according to their levels of motor proficiency. The use of multiple parameters permits us to understand the effective motor learning of vertical jump skill and to provide a worthwhile interpretation of the difference among the developmental levels. Additionally, the use of a process-oriented assessment approach, based on a functional model and objective data, may overcome the open-issues related to the choice of relevant criteria (i.e., typology and number) aforementioned in the previous Introduction section. These findings are relevant for physical education teachers who have to promote the proficiency of fundamental movement skill during the school period. Finally, the use of Kinect for assessing the developmental levels of fundamental movement skills is in agreement with the indications provided by the National Association for Sport and Physical Education (NASPE, 2008) towards the integration of emerging technologies in the physical education curriculum. Of note, the Kinect could also be considered by teachers for supporting and increasing the motivation of children during physical activities in classrooms and for improving specific elements related to level of proficiency in a skill (Sgrò & Lipoma, 2015). Indeed, the current results and

methodologies should be considered by physical education teachers as interesting elements and perspectives for improving fundamental movement skill teaching and learning processes during the school period.

References

- Aragón, L. F. (2000). Evaluation of four vertical jump tests: Methodology, reliability, validity, and accuracy. *Measurement in physical education and exercise science*, 4(4), 215-228.
- Barnett, L.M., Stodden, D.F., Cohen, K.E., Smith, J.J., Lubans, D.R., Lenoir, M., Livonen, S., Miller, A., Laukkanen, A., Dudley, D., Lander, A. J., Brown, H., & Morgan, P. J. (2016). Fundamental Movement Skills: An important focus. *Journal of Teaching in Physical Education*, 35, 219-225.
- Boccolini, G., Brazziti, A., Bonfanti, L., & Alberti, G. (2013). Using balance training to improve the performance of youth basketball players. *Sport sciences for health*, 9(2), 37-42.
- Department of Education Western Australia. (2013a) *Fundamental movement skills: learning, teaching and assessment*. Perth, Australia: Author.
- Department of Education Western Australia (2013b) *Fundamental movement skills: the tools for learning, teaching and assessment*. Perth, Australia: Author.
- Floría, P., & Harrison, A. J. (2013). Ground reaction force differences in the countermovement jump in girls with different levels of performance. *Research quarterly for exercise and sport*, 84(3), 329-335.
- Gallahue, D.L., & Ozmun, J.C. (2002). *Understanding motor development: infants, children, adolescents, adults*. New York: McGraw-Hill.
- Giblin, S., Collins, D., & Button, C. (2014). Physical literacy: importance, assessment and future directions. *Sports Medicine*, 44(9), 1177-1184.
- Ivashchenko, O. V., Yermakova, T. S., Cieslicka, M., & Muszkieta, R. (2015). Discriminant analysis as method of pedagogic control of 9-11 forms girls' functional and motor fitness. *Journal of Physical Education and Sport*, 15(3), 576-581.
- Linthorne, N. P. (2001). Analysis of standing vertical jumps using a force platform. *American Journal of Physics*, 69(11), 1198-1204.
- Okely, A.D., Booth, M. L., & Patterson, J. W. (2001). Relationship of physical activity to fundamental movement skills among adolescents. *Medicine and science in sports and exercise*, 33(11), 1899-1904.
- Raiola, G., Altavilla, G., Tafuri, D., & Lipoma, M. (2016). Analysis of learning a basketball shot. *Journal of Physical Education and Sport*, 16(1), 3.
- Sgrò, F., Nicolosi, S., Schembri, R., Pavone, M., & Lipoma, M. (2015a). Assessing vertical jump developmental levels in childhood using a low-cost motion capture approach. *Perceptual and motor skills*, 120(2), 642-658.
- Sgrò, F., & Lipoma, M. (2015). Can An Exergames Training Program Improve The Jump For Height Skill In Childhood? *Turkish Online Journal of Educational Technology, Special Issue for INTE 2015*, 89-96.
- Sgro, F., Barresi, M., & Lipoma, M. (2015). The analysis of discriminant factors related to team match performances in the 2012 European Football Championship. *Journal of Physical Education and Sport*, 15(3), 460-465.
- Webb, J., & Ashley, J. (2012). *Beginning Kinect Programming with the Microsoft Kinect SDK*. Apress.
- Williams, M. D., Saunders, J. E., Maschette, W. E., & Wilson, C. J. (2013). Outcome and Process in Motor Performance: A Comparison of Jumping by Typically Developing Children and Those with Low Motor Proficiency. *Measurement in Physical Education and Exercise Science*, 17(2), 135-149.
- Winter, D. A. (2009). *Biomechanics and motor control of human movement*. John Wiley & Sons.