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INTEGRATING FUNDAMENTAL MOVEMENT SKILLS IN LATE CHILDHOOD[1, 2]

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Summary.—The study examined how children of different ages integrate fundamental movement skills, such as running and throwing, and whether their developmental status was related to the combination of these skills. Thirty children were divided into three groups (G1 = 6-year-olds, G2 = 9-year-olds, and G3 = 12-year-olds) and filmed performing three tasks: running, overarm throwing, and the combined task. Patterns were identified and described, and the efficiency of integration was calculated (distance differences of the ball thrown in two tasks, overarm throwing and combined task). Differences in integration were related to age: the 6-year-olds were less efficient in combining the two skills than the 9- and 12-year-olds. These differences may be indicative of a phase of integrating fundamental movement skills in the developmental sequence. This developmental status, particularly throwing, seems to be related to the competence to integrate skills, which suggests that fundamental movement skills may be developmental modules.

The development of skilled actions can be described from two perspectives (Connolly, 1986). One is characterized by increasing diversity of movement skills, usually the means to accomplish functions in the environment, such as orienting, locomoting, and manipulating and exploring objects. For instance, the function of locomotion is accomplished by a number of skills in the first three years of age: rolling, crawling, walking, running, hopping, and jumping, amongst others. The span of skills for locomotion will depend on a number of constraints—organismic, task, and

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environmental—and on the history of transactions between the individual and his or her physical and social environment that constitute the epigenetic landscape for action development (Connolly, 1986; Muchisky, Gershkoff-Stowe, Cole, & Thelen,1996; Newell, Liu, & Mayer-Kress, 2003). The second direction is characterized by increasing complexity of movement skills. Walking can be combined with manipulative actions, such as reaching and grasping a cup on the table as one is going to the kitchen to do the dishes. Running can be associated with jumping, as in the long-distance jump in athletics. Complexity implies that a relatively large number of elements interact, generating properties that are not present in each element in isolation.

Questions surrounding complexity in biological systems are always difficult to tackle, due to the limits of a scientific method designed to explain phenomena marked by simplicity (Goodwin, 1994). This explains, in part, the lack of studies on the integration of fundamental movement skills. Most studies in the field have focused on the description of developmental steps in a number of fundamental movement skills such as walking, running, throwing, catching, etc. (Seefeldt, 1996). However, the integration of these skills into more complex skills has not been considered. There seems to be a belief that once fundamental movement skills are acquired, they will combine naturally to form more complex skills (e.g., Gallahue & Ozmun, 1998). However, from a biological point of view, the interaction between different elements presumes each one has autonomy and identity and, at the same time, must be modified according to the goals of the more complex pattern (Csete & Doyle, 2002). Taking this notion to athletics in, for example, a specialized skill like javelin throwing, the athlete performs two main actions, running and overarm throwing. The linkage is attained by modifications in the running pattern, particularly in the action of the feet, in the trunk action, and in the way the arm holding the javelin swings back in preparation for the throw. The key to this action from a biomechanical point of view is to transfer the speed gained during running to the speed needed to release the javelin (Broer, 1973; Mero, Komi, Korjus, Navarro, & Gregor, 1994). The amount of speed transfer can be estimated by the comparison between the distance the implement reaches when the athlete performed the throwing without running and the distance he or she can reach when throwing is preceded by running. If this integration is effective, an increase of around 30% in distance is expected from the former to the latter task (Schmolinsky, 2004).

From a developmental perspective, there is a different picture. For instance, when a 5-year-old child is asked to run and throw a small ball (e.g., a tennis ball), most likely the child will interrupt running abruptly to perform the overarm throw. The child performs the two tasks but does

not integrate them. Moreover, the child might throw longer distances if running does not precede the throwing action. The athlete performing the task modifies the running pattern in order to anticipate the demands of a good throwing pattern. The child, on the other hand, performs the two tasks separately; the transition from running to throwing is lacking. Long ago, Bartlett (1958) pointed out that timing has little or nothing to do with the absolute speed at which any component in the sequence is performed. Success is due to the regulation of the flow from one component to another. The movement being performed is, in fact, oriented to the near future, which means anticipating what comes next. Therefore, among the conditions for integrating skills, one might be related to the capacity the performer has to modify the skill's spatial and temporal structure to anticipate what comes next in the action sequence.

Three features may be involved in the integration of skills. Firstly, integration depends upon the timing among the skills that comprise the sequence. Secondly, good timing will demand some kind of structural modification of the constituent elements that will be oriented to a future goal associated with the success of the whole sequence. Thirdly, the condition necessary for integration demands the existence of simple units or modules available to comprise a sequence. The first two features are concerned with issues of motor control. The latter poses a developmental question (Manoel & Connolly, 1997), and it is from this perspective that the problem of the present study will be defined. The aim of the present study was to investigate (1) how children from three different age groups—6 years old, 9 years old, and 12 years old, integrated two fundamental movement skills, running and overarm throwing, into one combined task, and (2) whether the developmental status in each skill was related to the way children performed the combined task.

Motor competence was thought to depend upon a limited number of motor skills that are then combined and recombined due to the needs arising from the child's interaction with the physical and social environments (Connolly & Bruner, 1974). In a similar vein, Fitts and Posner (1967) proposed that motor skill acquisition involves novel skills only up to the ages of 7 or 8 years; from then on, acquisition would rely on the integration of what was acquired during infancy and childhood. Bruner (1970, 1973) and Connolly (1970) proposed that once a child acquires an action program, it becomes stable (i.e., it is adaptable to various circumstances), and for this reason, it can be used in different contexts to form new and more complex action programs. These authors named this process modularization. This means skill acquisition would involve a stage in which an action program is turned into a module that will be used to form new and more complex programs (Fitts & Posner, 1967; Elliott & Connolly, 1974). Fundamental

movement skills might be considered such basic modules, which can be used to form more specialized and complex skills.

In fact, it has been assumed that the acquisition of specialized movement skills would depend upon the mastery of fundamental movement skills that correspond to reaching a mature stage in developmental terms (Seefeldt, 1980; Seaman & DePauw, 1982; Gallahue & Ozmun, 1998). The criterion to define mature stages has been the capacity a child has to perform skills in a manner similar to that shown by a skilled performer. For instance, a child is thought to be in a mature stage for overarm throwing when he or she throws like a skilled baseball pitcher. However, this does not imply movement pattern stability. To check for stability would require asking the child to perform the overarm throwing action under different circumstances. If he or she meets each situation with adequate movement patterns, it would be a sound indication that a mature stage had indeed been reached (Manoel & Oliveira, 2000). However, not all descriptions of mature stages in fundamental movement skills do account for stability; therefore it might be possible that there is a developmental phase for integrating fundamental movement skills. This would entail the stabilization of such skills, leading them to become modules ready to be integrated to form new and specialized skills. From this reasoning, a number of hypotheses can be stated: (1) individuals who do not show mature stages in fundamental movement skills will not be able to integrate these skills; (2) individuals who show mature stages in fundamental movement skills will be able to integrate these skills; (3) if individuals who have reached the mature stages in fundamental movement skills still show difficulties in integrating them, this might be taken as evidence of the existence of a developmental phase for integrating fundamental movement skills; and (4) it can be expected that skill integration will be more effective from 8 years of age onward, because at the age of 7 years children tend to achieve mature stages in most of the fundamental movement skills.

Method

Participants

Thirty children of both sexes without previous sports experience in athletics, basketball, or handball participated voluntarily in this study after an informed consent was signed by their parents. The children were invited to take part and were informed that they could leave the study at any time. They were assigned to one of three groups, with 10 individuals (5 boys, 5 girls) in each, according to their age: Group 1 (G1) was 6 years old (M age = 72.4 mo., $SD = 6$); Group 2 (G2) was 9 years old (M age = 108.2 mo., $SD = 7$) and Group 3 (G3) was 12 years old (M age = 144.2 mo., $SD = 6$).

Instrumentation

Each child's performance was recorded by two video cameras (SUPER-VHS, Panasonic AG 456–VP), with a speed of recording of 33–35 frames per second, mounted on tripods. A tennis ball weighing 60 g was used for the overarm throwing and the combined task. The distance reached by each throw was measured by a fiberglass measuring tape (Sokkia Eslon Fiberglass) of 30 m.

Tasks and Procedure

Participants in the study had to perform three tasks: running, overarm throwing, and the combined task (running followed by overarm throwing). Each individual was taken to a sports court where the following tasks were performed:

Running a distance of 19 m.—Each individual was instructed to run in a straight lane (marked on the floor of the sports court) at a speed they felt comfortable running. They were required to run 10 times; the interval between one run and the next was 3 min. The instruction given to each individual was as follows: "You have to run from this point to the end of the lane. No need to hurry; just go as comfortable as possible. You will have to repeat this 10 times. Tell me when you are ready, and I will give you the go signal."

Overarm throwing.—Each individual had to throw a tennis ball as far as possible. This was repeated 10 times with a rest of 2 min. between each throw. The instruction given to each participant was as follows: "Take this ball and go to the throwing zone. On my signal, throw the ball as far as possible, using your preferred arm overhead. Every time we will measure the distance you throw the ball from this point to the point where the ball first touched the court. I will tell you the distance you reached. Try to improve it on your next throw. You will repeat this 10 times."

Combined task.—Each individual had to run and then throw a tennis ball as far as possible. The runway lane was 10 m in length (the same lane used for the running task), plus 2 m that corresponded to the throwing zone (Fig. 1). The beginning of the runway and the beginning and the end of the throwing zone were marked by rubber cones. The task was repeated 10 times, with a rest of 3 min. between each trial. The instruction emphasized the importance of taking advantage of the running to throw the ball farther. The instruction given was as follows: "Take this ball and go to the starting point of the runway lane. You will have to throw it as far as possible. To help you out, you can run from this point until that rubber cone, where you can throw. Try to use the speed you gain running to help you in throwing. Every time we will measure the distance you throw the ball, from this point to the point where the ball first touched the court. I will tell

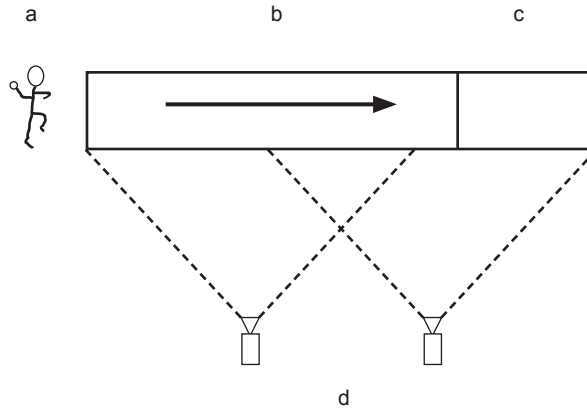

FIG. 1. Schematic representation of the experimental setting for the combined task with (a) the starting position of the participant, (b) the direction of his or her move through the running path, (c) the throwing zone, and (d) the location of the two video cameras with their respective view fields.

you the distance you reached. Try to improve it on your next throw. You will repeat this 10 times."

Each participant was informed of the results regarding the distance reached in every trial of the two tasks, the overarm throwing and the combined task. This information was used as feedback, but also as reinforcement to the child to try his or her best in the next attempt. Words of encouragement were used in a friendly environment without ever putting any pressure on children that might have any effect other than that they try their best.

Data Recording and Analysis

The present study relied on systematic observation of the children's actions. It must be pointed out that the use of observation to describe behaviors has a long tradition in the study of motor development, with theoretical and practical implications. The theoretical implication was that observation is the first step to gather information on the behavior of organisms, usually in unconstrained environments, which will be essential to formulate questions about how and why an individual behaves (Lorenz, 1981). The practical implication was that observation is a powerful tool for the practitioner to evaluate and remediate behaviors (Knudson & Morrison, 1997). To allow a more detailed analysis, all of the children's performances were video recorded. Two video cameras were positioned in order to have a wide field view of the runway lane and the throwing zone, as schematically represented in Fig. 1. The cameras were 7 m apart and both were 20 m away from the center of the runway lane and the

throwing zone. The field views of both video cameras were interpolated in order to facilitate the recordings of the transition from running to throwing. The distance the ball was thrown was measured from the end of the throwing zone to the place where the ball first touched the floor. The same procedure was adopted for the combined task.

The video recordings of all tasks were later analyzed in the laboratory in a specially equipped video editing unit that allowed frame-by-frame analysis. The identification of the developmental status of the running and throwing skills was done on the basis of the component analysis developed by Roberton and Halverson (1984). Component analysis was developed on the basis of a set of rich data on fundamental movement skills gathered between the 1940s and 1960s by researchers in motor development. Using cross-sectional and longitudinal designs, these studies had filmed children doing a number of fundamental movement skills (walking, running, throwing, catching, jumping, striking, kicking, rolling, etc.) in a controlled environment. The films were later analyzed, resulting in descriptions of the action of each body part, for instance, arm, trunk, feet.

The differences in the action in children of different ages or for the same individual over time were considered to reflect a sequence of developmental changes. This notion was reinforced by the fact that the performance of older children in a given fundamental movement skill resembled the performance of a skilled adult performing a similar skill. One of the best examples is overarm throwing. At the age of 3 or 4 years, a child will throw a ball using only the arm; all the other body parts, trunk, feet, will be "frozen." In contrast, a 10-year-old boy, when asked to throw a ball, will show backswing actions with the arm and trunk, followed by hip and trunk rotation, stepping with arm-leg opposition, and finalizing with the arm projecting forward with the final ball release. The movement sequence is very similar to that shown by a javelin thrower. These descriptions (by young and older children) and those of the intermediate ways to perform the task (by children of different ages between) are organized in a sequence of steps from the more rudimentary way to move to a more sophisticated, complex, and specific ways to perform a task. As this process is thought to be regulated by development, each step is assigned a developmental step.

Roberton and Halverson (1984) have organized and translated the data available from a number of fundamental movement skills into sequences of developmental steps for each body action. In the case of running, Roberton and Halverson (1984) identified two components: an arm action component with four developmental steps, and a leg action component with three developmental steps. For throwing, five components were identified: preparatory arm backswing component with four devel-

opmental steps, humerus action component with three developmental steps, forearm action component with three developmental steps, trunk action component with four developmental steps, and foot action component with four developmental steps.

The analysis of the combined task posed a great challenge, because no descriptions were available. In order to elaborate a component analysis of the combined task, a pilot study was designed with 21 individuals, seven young adults (*M* age = 22.5 yr.), seven children (*M* age = 7.1 yr.) and seven individuals with Down syndrome[3] (*M* chronological age = 19 yr.). The overall results of this pilot study were published elsewhere (Gimenez, Manoel, Oliveira, & Basso, 2004). The purpose of the pilot study was to decide upon (a) the appropriate distances for the running task and the runway in the combined task, (b) the adequate positions for the cameras, and (c) the component analysis of the combined task. Each individual was asked to perform each task five times; all tasks were video recorded. After deciding upon the distance for running, the length of the runway for throwing, and the position of the cameras, the video recordings were used to develop a component analysis for the combined task.

A component analysis for the running and throwing actions was elaborated on the basis of the existing checklist developed by Roberton and Halverson (1984) and the notation of the behaviors observed in these two actions. The main preoccupation was to compile movements expressing some kind of adjustment for the combination of running and throwing. The combined task was divided in three phases: (a) the *running phase* from the start of the run to the transition phase; (b) the *transition phase* corresponding to the moment when the running is stopped and/or modified in preparation for taking the stance for throwing; and (c) the *throwing phase* from the preparation for throwing to ball release. Component analysis was elaborated for each phase. There were two inclusions in the running pattern (see the Appendix, p. 583): (1) the trunk action component with three developmental steps, and (2) new developmental steps for the leg action components: crossed step, lateral step, and alternate step followed by crossed step. The progression in the developmental steps was defined by the extent to which the running components created optimal conditions for the throwing phase. The checklist for the analysis of the overarm throwing was also adapted with three action components, instead of the five action components employed for the analysis of the overarm throwing task. The key point in the pilot study was to develop an analysis to capture the main aspects in the transition phase. The child could simply stop running to adopt the stance for throwing, or she could make a num-

[3]These individuals took part because there was an interest in carrying out a similar investigation in a sample of children with Down syndrome.

ber of movements without losing momentum before throwing. Among these actions, it was found that some participants in the pilot study made a stop and a leap to then take the stance for throwing, while others did a leap and a stop to then take the stance for throwing, and still others would just leap to get into the stance for throwing. The most effective way to integrate running and throwing is to gradually change the leg action in the running by adopting wide crossed steps. This is accompanied by a change in the trunk that gradually rotates backwards, with the whole body adopting a posture that will correspond to the posture more efficient for throwing because more momentum can be added to the throwing action (Mero, *et al*., 1994). The transition phase consisted of five developmental steps:

(1) *Stop*. The child stopped abruptly and then he or she would get into position for throwing

(2) *Stop and Leap*. The child stopped running and then leaped to find a better position for throwing

(3) *Leap and Stop*. This was interpreted as the first attempt to make a transition from running to throwing. The child would mark the end of running with a leap to find a better position for throwing, but still stop before performing the actual throwing

(4) *Leap*. The child finished running with a leap, immediately followed by throwing without stop

(5) *Wide Crossed Step*. The transition from running to throwing was done smoothly by changing the strides from alternate to crossed step. Usually the child took two to three wide crossed steps before throwing

The integration of behavior was described according to the developmental steps of the components in each phase. For instance, a hypothetical behavior is depicted in Fig. 2. At the top of the schematic figure there are two main actions that comprise the combined task: running and throwing. Each of these actions is comprised of three components. The numbers corresponding to each component refer to the developmental steps, with more advanced steps corresponding to higher numbers. Between the two actions there is the transition phase—the number indicating the degree of integration of running and throwing. The hypothetical example in Fig. 2 shows the arm was delayed at head height during all running (Developmental Step 4). The trunk showed a gradual rotation near the throwing zone (Developmental Step 3). The alternate steps were followed by crossed steps (Developmental Step 3). In the transition phase, there were wide crossed steps (Developmental Step 5). In the throwing phase, the arm was delayed and the trunk rotated away from the throwing zone (Developmental Steps 2 and 3, respectively) and, finally, the feet were positioned showing arm-leg opposition (Developmental Step 3), i.e., the forward leg was opposed to the throwing arm.

The developmental steps were elaborated to describe changes in skills

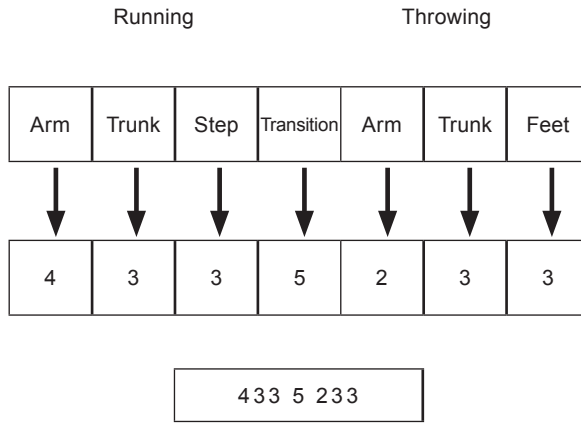

FIG. 2. Hypothetical representation of the developmental steps for each component of the combined task. The number in each square corresponds to a developmental step; in the example given, running is reasonably integrated with overarm throwing.

integration, from a state in which there is no integration to a state when the skills are fully integrated. This meant that, in the running phase, the components should involve a great deal of anticipation of the throwing phase. The transition phase should be marked by fluency, which means that the passage from running to throwing involves wide crossed steps.

All video recordings were analyzed by at least two judges (the first and the third authors), who are physical education teachers with good experience in teaching fundamental movement skills to children. The application of the checklist for the three tasks by the judges was reliable. Using the inter-observer correlation (Thomas & Nelson, 1996) for the two observers, a value of .87 was obtained from the analysis of 100 attempts selected randomly.

Another variable considered in the study was the efficiency in the combined task. To define the parameters to measure efficiency, it was considered that task goal is the first aspect to be taken into consideration (Knudson & Morrison, 1996). The goal of the combined task was to throw the ball as far as possible. Therefore, efficiency was calculated by the difference between the distance the ball was thrown in the overarm throwing task and the combined task. This calculation yielded an index of efficiency in the combined task (IEC) which is expressed as follows:

$$\text{IEC} = [(\text{mean distance in the combined task} \div \text{mean distance in the throwing task}) - 1] \times 100$$

For instance, an individual who had an average of 21 m in the combined task and 17 m in the throwing task had an IEC of 23.5%. Positive indexes, as in the example, would be indicative that the individual was ca-

pable of taking advantage of the running speed to propel the ball. Indexes close to zero or even a negative indicate that the individual could not benefit from the running speed, transferring it to the velocity of ball release, therefore showing poor integration efficiency.

Statistical Analysis

The descriptive statistics were calculated by the mode of observed behaviors (most common pattern presented in 10 trials) for each action component. This was calculated for each task. To verify the existence of possible associations between the patterns presented by the age groups in the combined task and the developmental steps in the fundamental movement skills of running and overarm throwing, a test of correlation of contingency was computed. The test for possible age differences in the IEC was done by a non-parametric Kruskal-Wallis analysis of variance (ANOVA) after the data distribution failed to comply with the assumption for a normal distribution. Nevertheless, the sample data was found fit to be treated by the Kruskal-Wallis test after submitting it to a test in the statistical package SPSS for Windows, Version 12. A *post hoc* test to explore the differences found was conducted by calculation with the Mann-Whitney *U* test.

Results

The analysis of how children integrate fundamental movement skills was carried out by identifying the action component's developmental steps in the combined task and the IEC. The frequency of developmental steps shown in the combined task for each group are depicted in Fig. 3. As described before, each number corresponds to a developmental step for each component. The greater the number, the more advanced the individual will be in a given component. Eleven patterns of combinations were identified; they are listed on the left-hand side of Fig. 3. Each bar in the graph has a distribution of individuals who used one of the combination f patterns. Overall, individuals were capable of combining running and throwing, since they showed modifications in the running action to anticipate the throwing action. The most common behavior was the use of wide, crossed steps (Developmental Step 5) followed by a leap (Developmental Step 4), and a leap and stop (Developmental Step 3). The only exception was for two 9-year-old children (from G2), who performed the task with a stop between running and throwing. The frequency of more advanced behaviors (with the following combination of Developmental Steps: 534 5 233) was greater in G3 than in G2 and G1. Patterns with less advanced combinations were more frequent for G1.

The most common behavior among the 6-year-old children (G1) was the alternate movement of the arms, trunk forward, and feet during the

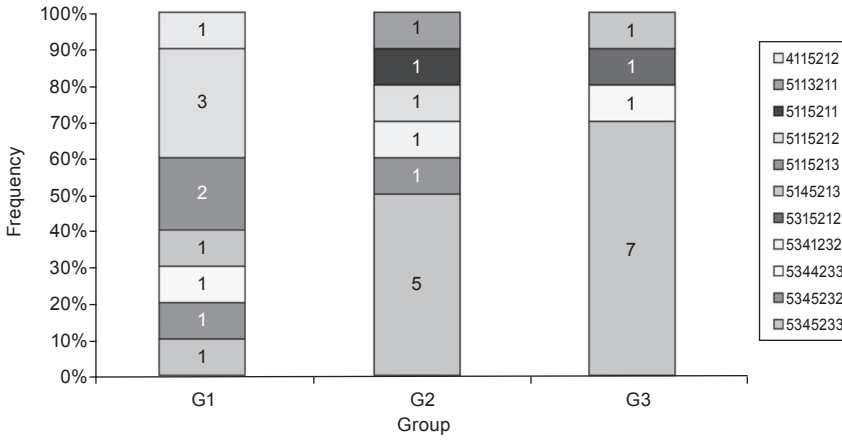

FIG. 3. The frequency of patterns of the combined task for each group. Numbers in the legend correspond to the developmental steps of each component for running, transition, and overarm throwing; numbers in the bars refers to the number of children who showed a given pattern.

running task (Table 1). Close to the throwing zone, these individuals made a backward arm movement in relation to the body and, at the same time, they made a trunk inflection without altering the foot action. The transition happened without stop or leap. At the throwing phase, the individuals accentuated the trunk inflection and the delay of the arm; in addition, they positioned the feet without arm-leg opposition. This pattern was well characterized by three of the 10 participants from G1 (S1, S8, and S10). Two other participants, S3 and S7, presented other patterns, with the difference being the feet at the moment of throwing, as they showed arm-leg opposition. The other participants differed in other components of the pattern. Among them, S4 presented an advanced pattern, similar to that presented by a skilled adult in this task. He performed the running task with alternating arms, alternating feet, and the trunk forward. When S4 approached the throwing zone, he made a backward arm swing, keeping the hand at head height, and then made a gradual rotation of the trunk away from the throwing zone and performed a crossed step. The transition from running to throwing was smooth, without stop or leap. Finally, at the moment of throwing, the delay of the arm and the rotation of the trunk were accentuated, in addition to the feet with arm-leg opposition. S9 presented a similar pattern, the difference being in the foot action at the throwing phase, when he did not present arm-leg opposition.

The most frequent pattern for the 9-year-old children (G2) was running with alternate arm movements, with the trunk forward and alternate steps. This was followed by a backswing arm movement at head height,

TABLE 1
MODE OF THE COMPONENT'S DEVELOPMENTAL STEPS IN EACH PHASE OF THE COMBINED TASK FOR EACH GROUP

Participant	Group 1 (6 years old)	Group 2 (9 years old)	Group 3 (12 years old)
S1	511 5 212	534 1 232	534 5 233
S2	514 5 213	534 5 232	531 5 212
S3	511 5 213	511 5 211	534 5 233
S4	534 5 233	511 5 212	514 5 213
S5	411 5 212	511 3 211	534 5 233
S6	534 4 233	534 5 233	534 5 233
S7	511 5 213	534 5 233	534 5 233
S8	511 5 212	534 5 233	534 4 233
S9	534 5 232	534 5 233	534 5 233
S10	511 5 212	534 5 233	534 5 233

Note.—The first three numbers correspond to the developmental steps of the running phase; the number in the middle corresponds to the developmental step of the transition phase; and the last numbers corresponds to the developmental steps of the throwing phase.

and a change from alternate steps to crossed steps, together with a gradual rotation of the trunk in preparation for throwing. The transition from running to throwing was smooth and followed by accentuated arm movement and trunk rotation (away from the throwing zone), with the feet showing arm-leg opposition (Table 1). This pattern was common for five individuals (S6, S7, S8, S9, and S10).

The other patterns shown by G2 differed mainly in relation to the trunk component during the preparation for throwing, and also in relation to the foot and trunk components at the throwing phase. Two children (S3 and S4) did not show a gradual rotation of the trunk in preparation for throwing. At the moment of throwing, three individuals (S2, S3, and S4) did not accentuate trunk rotation. The feet showed arm-leg opposition, though two individuals (S2 and S3) did not present this opposition, and one individual (S4) threw with the feet in parallel.

Two 9-year-old children (S1 and S5) did not integrate running and throwing. S1 ran with alternate arm movement, trunk forward, and alternate steps. Then, close to the throwing zone, he began to modify running in preparation for throwing, but came to a full stop in order to do so. S5 showed similar behavior with a difference: close to the throwing zone, he made a jump followed by a stop.

The 12-year-old children (G3) presented the most advanced patterns for the combined task (Table 1). The most frequent pattern was front running with alternate arm movements, trunk forward, and alternate steps. Then there was a gradual trunk rotation associated with the arm back swing, keeping the hand at head height. The alternate steps were turned

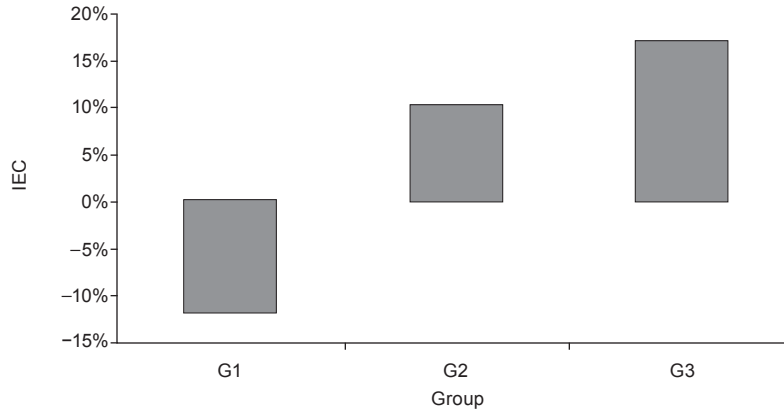

FIG. 4. The index of efficiency in the combined task (IEC) for each group, 6-year-old children (G1), 9-year-old children (G2), and 12-year-old children (G3).

into crossed steps. At the throwing phase, trunk rotation and the delay of the hand holding the ball were accentuated, and the feet showed arm-leg opposition. This pattern was typical of seven individuals (S1, S3, S5, S6, S7, S9, and S10).

The other patterns presented differed mainly in the trunk component (for individuals S2 and S4) and the foot component in the throwing preparation and at the actual throwing (for one individual, S2). There was also one individual (S8) who jumped while throwing.

In sum, there were differences in the way each age group integrated running and throwing. These differences may have contributed to the variability found in the IEC (Fig. 4). For instance, 6-year-old children had low efficiency (−11.7%) in comparison with the index shown by 9-year-olds (10.2%) and 12-year-olds (17.1%). These differences turned out to be significant, given the results of the Kruskal-Wallis test [χ^2 (2,28) = 8.90, $p = .012$). The Mann-Whitney *post hoc* test confirmed the differences between G1 and G2, and G1 and G3 ($p = .013$). To check for effect size, the data were analyzed by a univariate ANOVA and the resulting effect size was $\eta^2 = 0.35$, reinforcing the view that the variance observed is very likely to be due to age differences.

Although the analysis of the Developmental Steps indicated that all children combined both tasks with some differences in the patterns employed, the IEC indicates that skill integration may begin only after nine years of age. One of the factors contributing to this might be the developmental status of each skill, running and throwing.

Older children, 9 and 12 years of age, G2 and G3 respectively, did not differ in their behavioral modes in the running and throwing (Table 2).

TABLE 2
MODE OF THE COMPONENT'S DEVELOPMENTAL STEPS IN RUNNING AND OVERARM THROWING, AND FOR EACH PHASE OF THE COMBINED TASK FOR EACH GROUP

Group	Mode Pattern of Components, Combined Task	Mode Pattern of Components, Running	Mode Pattern of Components, Throwing
Group 1 (6 years old)	511 5 212	33	43334
Group 2 (9 years old)	534 5 233	43	43344
Group 3 (12 years old)	534 5 233	43	43344

Note.—Each number corresponds to the component's developmental step for each fundamental movement skill and the combined task.

They presented mature patterns for running and throwing, as can be seen from the component analysis. The 6-year-old children showed less developed patterns, taking into consideration the arm component for running and the trunk component for throwing. Further studies should be conducted to assess whether the developmental steps of these components are critical for the timing of integrating fundamental skills. Some indicators can be derived from the results of a correlation test done between patterns of running, throwing, and the combined task. The test of correlation of contingency showed that the developmental steps of running did not correlate with those of the combined task. Throwing, on the other hand, does correlate with the pattern of the combined task [Contingency χ^2 (2, 28) = 0.91, $p = .03$, ES = 0.17].

DISCUSSION

Integrating motor actions may be central to the development of motor skills during childhood. The present study began to tackle this issue by looking at how children combine fundamental movement skills. Most of the children (even the 6-year-olds) were already capable of combining running and throwing. However, this was done with different levels of efficiency. The index of efficiency in the combined task was negative for young children, evidencing that they could not benefit from the speed that they could theoretically gain in ball release by having a run before throwing. The differences found in the integration patterns presented by each age group may be one of the reasons why the children differed in efficiency.

The reason why these patterns vary may be associated with the developmental status of running and throwing. Young children showed less developed running and throwing skills in comparison with older children in the sample. It might be possible that the developmental rate of some components may influence how skills are integrated. The results of the correlation test suggested that the arm component for running and the trunk component for throwing may act as rate limiting factors for integrating

skills. Throwing pattern, in particular, was positively correlated with the pattern of the combined task.

The present results are in line with other studies that looked at integration in manipulative skills (Todor, 1975; Moss & Hogg, 1983). Another study, done by Getchell and Whitall (2003) has also shown a developmental trend in the way children from 4 to 10 years of age combine clapping with the fundamental skills of walking or galloping. The authors showed that the stability of each skill is important for synchronizing clapping with locomotion, though the coupling patterns begin to resemble those of adults only by the age of 10 years.

Apart from the developmental status of the fundamental movement pattern, skill integration may depend on the way each skill can be modified. In the present study, modifications led to more rudimentary developmental steps in throwing for 30% of the children in G1 and 20% of the children in G2. It is interesting to note the reverse trend for running, where 60% of the 6-year-old children showed advanced developmental steps for the arm component in the running phase of the combined task. Further studies must look in detail at when and how each component changes from a simple to a complex task. From the perspective of modularity in biological (Csete & Doyle, 2002) and motor systems (Manoel, Basso, Correa & Tani, 2002), each component (module) of a more complex pattern has to show some variability that will facilitate when two or more components need to be combined. In development, modules cannot be fixed, otherwise, it might be difficult to combine them into more complex patterns.

Models of motor development have not considered that the transition from fundamental movement skills to specialized skills might involve yet another phase, a phase for integrating fundamental movement skills. Seefeldt (1996) once mentioned that specialized sports skills are not readily acquired by children even when they have mature fundamental skills. The results presented here gave some hint that a new phase needs to be added between fundamental and specialized skills. At least three points can be taken to support this hypothesis. Firstly, there were differences in the way children of different ages integrated patterns. Secondly, there seems to be a relationship between age and the quality of integration. Thirdly, the efficiency shown in the combined task indicates that 9-year-old and 12-year-old children are still mastering skill integration. If, indeed, there is such a developmental phase, this might explain why low and weak correlations have been found between the level of fundamental skills and overall everyday skills (Sääkslahti, Numminen, Niinikoski, Rask-Nissilä, Viikari, Tuominen, & Välimäki, 1999; Raudsepp & Peep, 2006). In general, everyday skills will entail a combination of two or more fundamental skills. The fact that these fundamental skills might be ad-

vanced in developmental terms does not imply that children will integrate them successfully.

One point that needs consideration in future studies is the development of checklists and component analyses to observe and classify action components in combined tasks with different fundamental movement skills. This is one limitation of the present study, since there were no previous models with which the present model of component analyses could be compared. It is worth pointing out that such instruments used to categorize skill integration need to be tested in terms of content validity. This can be done in studies using cross-sectional and longitudinal designs (Roberton, 1982). In cross-sectional studies, a distribution of individuals according to age is expected in each developmental step; younger individuals will predominate in rudimentary developmental steps, while older individuals will predominate in advanced developmental steps. In longitudinal studies, each individual is expected to progress steadily through the developmental steps (from 1 to 2, from 2 to 3, and so on) without showing non-adjacent jumps (e.g., transiting from developmental step 1 to 3). The present study used a cross-sectional design and, together with the pilot study (Gimenez, *et al.*, 2004), it complied with the first requirement of content validity, as younger individuals presented behavior that corresponded to the rudimentary developmental steps for the combined task, while older children tended to show behaviors classified as advanced developmental steps. The results for the IEC can also be taken to reinforce that the checklist has a good content validity. Nevertheless, further studies focusing on the construction of the component analysis of skill integration are needed.

The issue of integrating skills has practical as well as theoretical aspects. On the practical side, if we know how children integrate skills, we might be able to structure better learning environments. Little is known about this in the process of sports specialization (Bompa, 1995). There is a common sense that one should start as early as possible to be a great sports athlete, but the fact that a 4-year-old child can handle a tennis racket does not mean he or she is playing tennis. There is a long process of acquiring, stabilizing, and adapting skills in which the integration of fundamental movement skills might be one essential part. Apart from the implication for sports pedagogy, one must take into account the importance that fundamental movement skills have for acquiring active, healthy lifestyles (Stodden, Goodway, Langendorfer, Roberton, Rudsill, Garcia, & Garcia, 2008). Intervention programs designed to help children acquire fundamental movement skills (e.g., Logan, Robinson, Wilson, & Lucas, 2011) may benefit from the knowledge that such acquisition is dependent upon a developmental phase involving the integration of fundamental movement skills.

The issue of integrating skills also raises some theoretical questions that are difficult to tackle. What are the limits by which to define where one skill ends and another begins? Can a skill be treated like a module, in the sense that it can be used to build very different complex skills? What is the nature of a module? How are they integrated? Connolly (1973) addressed some of these questions when looking at how young children acquire manipulative hand skills. He stated that we should first identify these modules and ask about their nature and about the syntax rules involved in their integration. Manoel, *et al.* (2002) proposed a model of modules in graphic skills, which are seen as action programs with invariant and variable features. The invariant features are maintained when the module is integrated with another module; the variable features allow many modifications in the module in order to facilitate integration. Manoel, Dantas, Gimenez, and Oliveira (2011) have also found some evidence that 10-year-old children formed memory modules in order to ease the acquisition of a complex graphic skill. The next step would be to turn these ideas into operational concepts to investigate modularity in fundamental movement skills.

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APPENDIX

Developmental Sequence for Each Component in the Three Phases of the Combined Task

Developmental sequence: running phase
- Arm action component
  - Step 1. Static beside the body
  - Step 2. Alternate action
  - Step 3. Arm holding the ball is over the shoulder but below the head
  - Step 4. Arm holding the ball is over the shoulder at head height during the entire running path
  - Step 5. Alternate action followed by a backswing arm movement holding the ball at head height near the throwing zone
- Trunk action component
  - Step 1. Facing the throwing zone
  - Step 2. Sideways to the throwing zone
  - Step 3. Gradual rotation from facing the throwing zone to sideways
- Leg action component
  - Step 1. Alternate step
  - Step 2. Crossed step
  - Step 3. Lateral step
  - Step 4. Alternate step followed by crossed step

Developmental sequence: transition phase
- Step 1. Stop
- Step 2. Stop and leap
- Step 3. Leap and stop
- Step 4. Leap
- Step 5. Wide crossed step

Developmental sequence: throwing phase
- Arm action component
  - Step 1. Next to the trunk
  - Step 2. Over the shoulder and away from the throwing zone
- Trunk action component
  - Step 1. Facing the throwing zone
  - Step 2. Sideways to the throwing zone
  - Step 3. Gradual rotation away and back to the throwing zone
- Leg action component
  - Step 1. In parallel
  - Step 2. Without arm-leg opposition
  - Step 3. With arm-leg opposition