CHAPTER 11

Development of Fundamental Movement: Manipulation Skills

KEY TERMS

Fundamental motor skills (FMS)
Motor competence
Environmental constraints
Intraskill sequences
Developmental sequences
Task constraints
Total body sequences
Component sequences
Individual constraints
Ipsilateral pattern
Contralateral patterns

CHAPTER COMPETENCIES

Upon completion of this chapter, the reader will be able to:

- Describe the developmental sequences for five manipulation skills.
- Observe a child perform a manipulation skill and identify the developmental stage of that child.
- Compare and contrast the total-body versus component approach to developmental sequences.
- Identify key individual, task, and environmental constraints acting on manipulation skills.
- Identify major gender differences in the acquisition of manipulation skills.
- Describe the characteristics of a proficient performer in manipulation skills.
- Devise a manipulative skill observation assessment checklist as an individual or group activity.

KEY CONCEPT

The childhood years should be focused on developing basic motor competence and efficient body mechanics in a wide variety of movement skills and situations.

Motor development is a complex process that occurs over the life span. Postural reflexes and the rudimentary movements of infants and toddlers provide children with practice in movement patterns and serve as the foundation for acquiring more voluntary motor skills during childhood.

According to the *phases and stages of motor development model*, after acquisition of these reflexes and rudimentary skills, children begin the development of these *fundamental movement patterns*, or **fundamental motor skills (FMS)**, as they are often described. Children are now able to explore the potential of their bodies as they move through space (*locomotion*), have increased control over their musculature in opposition to gravity (*stability*), and have an increasing ability to make controlled and precise contact with objects in their environment (*manipulation*).

Although childhood is focused on the acquisition of FMS, it is not important at this age for the child to focus on high degrees of skill in a limited number of movement situations. Rather, the focus of childhood should be on developing basic **motor competence** and efficient body mechanics in a wide variety of movement skills and situations.

From childhood and throughout adulthood, the various movement patterns that are learned, used, refined, and changed are influenced by different factors that can affect skill performance. Newell (1986) identified these factors as *constraints* and grouped them into task, environment, and individual (both functional and structural) demands. (See Chapter 2 for more detail on Newell's constraints.)

For example, as children grow in height and gain weight, such individual structural constraints can produce changes in their movement patterns. Overweight children often have difficulties hopping, jumping, and running, as they have limited strength to move their increased mass through space. **Environmental constraints** also impact performance. For example, surfaces such as grass or wood can affect the ability of a child to run with ease, or the size of a ball can influence a child's ability to catch with his or her hands. Likewise, task demands such as throwing for force or throwing for accuracy might call for a different movement pattern to be used to achieve the throwing task successfully. All of these constraints dynamically interact to impact the skill performance of individuals and help explain both *intravariability* (variability of skill performance between skills or within a specific skill for one individual) and *intervariability* (variability between children of a similar age) seen during childhood and over the life span. **FIGURE 11.1** provides an example of how environmental factors and the goal of a catching task act on or "constrain" the mover (along with his or her individual characteristics) and ultimately result in a movement outcome. While it is important to understand how constraints act on the child and result in a specific level of performance, what is more important to consider is the fact that both task and environmental constraints can be manipulated by teachers, coaches, and clinicians to promote the motor development of children.

CONCEPT 11.1

Individual, environmental, and task constraints influence a child's motor performance but can also be manipulated by teachers, coaches, and clinicians to promote the motor development of children.

In this chapter, we will examine the development of different FMS such as throwing, catching, and skipping. For each skill, we will first ask the question, *How do these skills emerge and develop?* In this area, we will focus on understanding the **intraskill (within a skill) developmental sequences** in the specific skill and summarize how a *proficient* mover might perform this skill as compared to an *initial* or inexperienced mover.

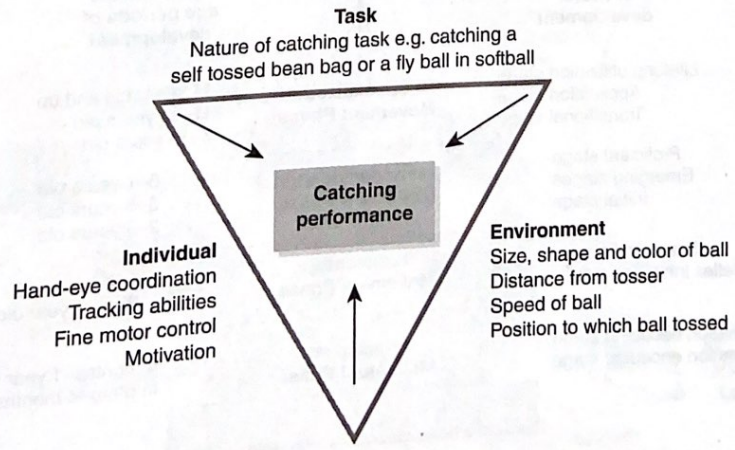


FIGURE 11.1 Constraints in action: A catching example.

Then we will examine what we know about how **environmental, individual,** and **task constraints** influence the performance of that skill.

Importance of Fundamental Motor Skills

The development of FMS is essential to achieving proficiency in various sports, games, and dances of a culture. They serve as the building blocks for efficient, effective movement and offer children ways to explore their environments and gain knowledge about the world around them. Developing FMS could be considered analogous to learning the letters or characters and sounds of an alphabet. These characters provide the basis for learning words (combined motor skills), which then allow children to produce sentences and paragraphs (specific sports skills and dance sequences) by restructuring the letters in various combinations. If basic understanding of characters and letters is not learned, children are handicapped in their language development. Likewise, in motor development, the ability to move easily in various combinations of FMS is compromised if children do not acquire basic motor competence during the early years.

FIGURE 11.2 illustrates how children should amass a broad base of FMS during early to middle childhood (approximately 3 to 7 years old). This base affords the children more possibilities (degrees of freedom) in their movement repertoires as it allows them more options in their movement responses. For example, a child who has had numerous opportunities to kick objects of various shapes, weights, and sizes while the objects were stationary or moving and while the child was also stationary or moving will develop a repertoire of movement patterns that may be used to respond to a wide variety of task demands. That child will then have those options available to him or her when participating in games such as soccer or American football that

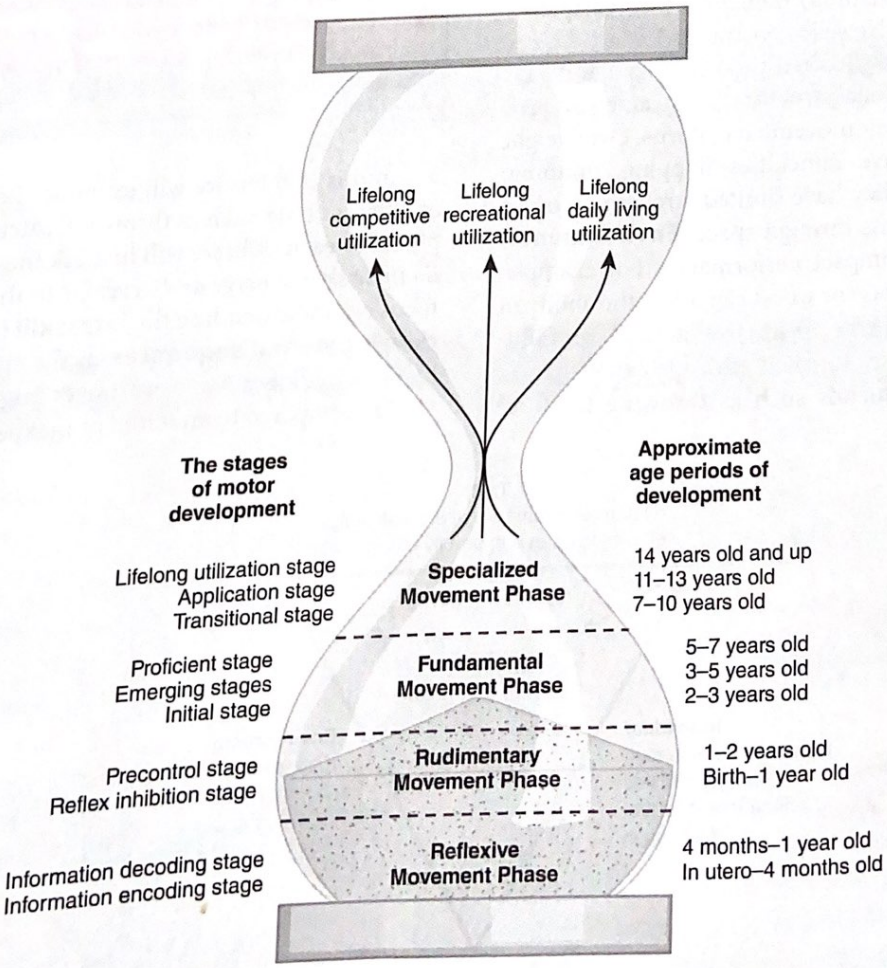


FIGURE 11.2 The phases and stages of motor development.

require different kinds of kicks and quick changes of position and direction in response to the movements of teammates or opponents. Children who develop motor competence in a wide variety of movement skills and situations will be more likely to be successful as they try their skills in the next step of the model, the specialized movement phase.

Developmental Trajectory Model

More recently, a conceptual model developed by Stodden and colleagues (2008) highlights the importance of FMS to engagement in lifelong physical activity. This model has received considerable attention and researchers across the globe are investigating the relationships proposed in the model.

Relationship Between Motor Competence and Physical Activity

At the heart of this model is a reciprocal and dynamic relationship between motor competence and physical activity (**FIGURE 11.3**). Motor skill competence is defined in terms of common FMS, specifically manipulative and locomotor skill patterns.

An underlying premise of this model is the common misconception that children "naturally" learn FMS. However, this premise is untrue; many children do not reach proficient levels in these skills and demonstrate the requisite motor competence to be able to apply these skills to sports and games across childhood and adolescence (Goodway & Branta, 2003; Goodway, Crowe, & Ward, 2003; Goodway, Robinson & Crowe, 2010). One of the interesting parts of this model is that the relationship between motor competence and physical activity changes across developmental time.

In the early childhood years, it is suggested that young children's opportunities to be physically active may drive their development of motor skill competence. A child with more access to physical activity will have more opportunities to develop her FMS, whereas a child with limited opportunities for physical activity will have correspondingly lower motor competence. These differences are most likely tied to factors such as access to a supportive environment for physical activity, engagement in instructional motor programs and activities, socioeconomic status, parental or sibling influences, and geographic climate, to name but a few. However, at this point in developmental time, the relationship between physical activity and motor competence is weak in early childhood and most likely has not yet had negative effects.

As children transition to middle childhood and adolescence, the relationship between physical activity and motor skill competence becomes more significant and will strengthen. Higher levels of motor skill competence offer a greater movement repertoire and more possibilities to engage in various physical activities, sports, and games. Children who are more highly skilled will most likely self-select higher levels of physical activity. For example, more skilled children are more likely to be active on the playground, play organized sports, and play sports or games for fun with their friends. These additional levels of physical activity provide the skilled child with further opportunities to advance

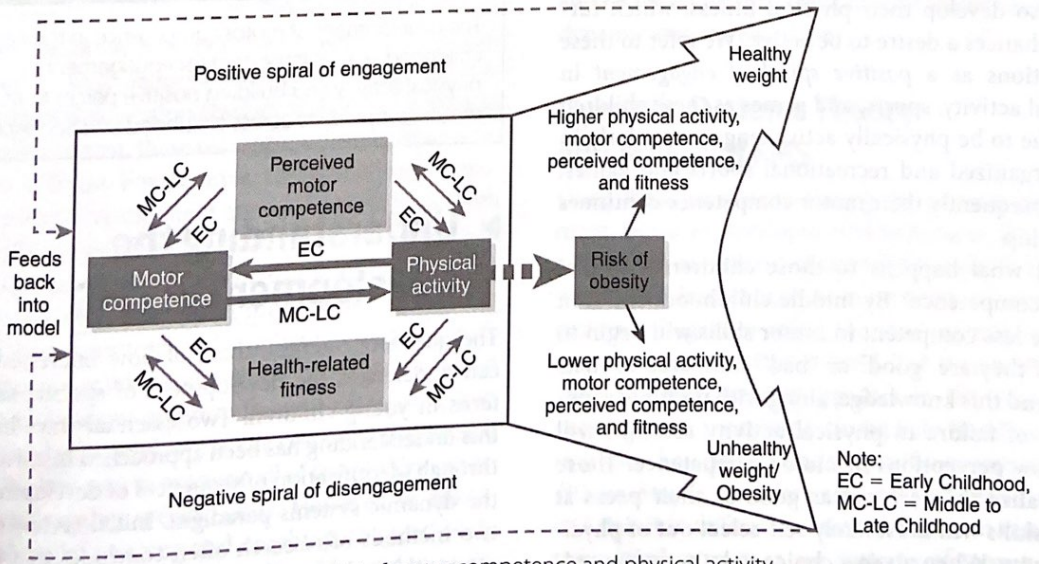


FIGURE 11.3 Developmental trajectory model of motor competence and physical activity.

Stodden, D. F., Goodway, J. D., Langendorfer, S. J., Roberton, M. A., Rudisill, M. E, Garcia, C., & Garcia L. E. (2008). A Developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. Quest, 60, 290–306.

his motor skills. The opposite is true for the child with lower motor skills, who, if given a choice to move or be sedentary, will most likely chose to be sedentary. The children with lower motor skills often are the ones sitting on the playground bench or inside using screens (e.g., television, video games, phone) on a sunny afternoon. As their bodies are largely sedentary, there is little prospect that their motor skills will improve, and the gap between the skilled, active children and the unskilled, inactive children becomes larger with time.

Perceived motor competence—that is, how children feel about how good they are at motor skills—is important. The relationship between motor competence and physical activity is mediated (influenced) by children's perceptions of their motor competence. In the early childhood years, children typically do not have the cognitive capacity to accurately judge if they are good at motor skills. When asked who is good at motor skills, nearly all children raise their hand and tell the adult they are "great." However, as children shift from Piaget's preoperations state of cognitive development to concrete operations, their capacity to accurately evaluate their motor competence improves. By this point in development, children who are more skilled in motor skills are also more likely to perceive themselves as competent and gain intrinsic pleasure from participating in sports and games. Moving is fun! Thus, higher levels of perceived motor competence and actual motor competence will drive higher levels of physical activity, which in turn will give children greater opportunities to become more motor competent. As children engage in more physical activity and motor skills, they also develop their physical fitness, which further enhances a desire to be active. We refer to these interactions as a *positive spiral of engagement* in physical activity, sports, and games as these children continue to be physically active, engage regularly in both organized and recreational sports and games, and subsequently their motor competence continues to develop.

But what happens to those children with less motor competence? By middle childhood, children who are less competent in motor skills will begin to know if they are "good" or "bad" compared to their peers, and this knowledge, along with multiple experiences of failure in physical activity settings, will drive low perceptions of motor competence. Those who realize they are not as good as their peers at motor skills will most likely self-select out of physical activity. When given a choice to be active or sedentary, such as on the playground, they will typically chose not to move, and if "required" to do physical activity, such as in a physical education class, they will engage at lower levels. Thus, low motor competence drives low physical activity levels, which minimizes a child's opportunities to improve motor competence.

Overall, low actual and perceived motor competence, along with limited physical activity, result in what Stodden et al. (2008) refer to as a *negative spiral of disengagement* from sports and games. That is, the child has limited motor competence, believes he or she is "not very good at sports," and thus chooses sedentary activities over physical activity—and as a result of sustained sedentary behavior is not physically fit.

As children move from middle childhood into adolescence, there is an increasing divide between those motor competent and active children who enjoy physical activity and their less motor competent and inactive peers who avoid it. As can be seen from this model, the development of FMS competence in the early childhood years is central to promoting a physically active lifestyle across childhood and into adolescence. In all of the models of motor skills development (e.g., the triangulated model, mountain of motor development, and the developmental trajectory model, reviewed elsewhere) the development of proficient patterns of FMS are essential if an individual is to develop a positive developmental trajectory to an active lifestyle across the lifespan.

CONCEPT 11.2

The development of motor competence in the early childhood years is important for engagement in physical activity and building positive perceptions of motor competence across childhood and adolescence.

Understanding the Development of FMS

The question emerges, then, of how interested adults can understand the development of specific skill patterns in young children. Two essential ways in which this understanding has been approached historically are through identification of sequences of development and the dynamic systems paradigm. Initial review of these two methods of research often concludes that the two are antithetical to each other. However, we contend that much can be gained by combining the two approaches.

Sequences of Fundamental Motor Skill Development

Developmental sequences have been a common way to examine the emergence of FMS. Motor development researchers (e.g., Branta, Halverson, Haubenstricker, Langendorfer, Roberton, Seefeldt, and Williams) have used this method to describe the typical patterns of behavior in specific skills such as throwing or kicking. This approach to motor skills is focused on the *process* of the movement or how the movement qualitatively looks instead of the quantitative *product* or outcome of distance, velocity, or time. Developmental sequences use either (a) the **total body sequences**, in which movements for the entire body are described, or (b) the **component sequences**, in which developmental sequences are identified for a segment of the body such as arms, trunk, or legs. In both approaches to developmental sequences, descriptions of movement patterns are placed in order from crude and inefficient patterns of movement to more mechanically efficient and proficient forms of movement. Each step or stage in the sequence describes the common patterns of movement performed by children as they learn FMS. Using this approach, children progressively move through the developmental sequences from less efficient patterns to more efficient patterns without any regression or skipping of stages.

Under a total body approach, one stage represents the performance of the entire body by the child at that moment in time. It is believed that body segments are linked together in a whole. In contrast, the component method describes how specific body segments change over time and how one body segment may be linked to another one. Both of these sequential approaches provide rich detail on how children develop and acquire these motor skill patterns and can be really valuable to the physical education teacher and coach. Although seemingly different, these two approaches are more similar than different. For example, the most common profiles seen in the component approach to FMS are often the specific stages identified by the total body approach. That is, the combinations of arm, trunk, and leg segmental sequence levels that appear most frequently together relate to the specific total body configuration stages. Both approaches are valid ways in which to assess change and track developmental progress. In some cases, such as in research and elite-level sports, the component approach may be the best way to examine all of the profiles exhibited when learning specific skills. However, in practical situations of teaching and coaching, the total body approach may be more easily and readily used to assess the motor skill development of children.

The total body and component stages were developed under core principles of stage theory (Roberton, 1978). These principles include the following:

- All children go through the same stages in the same order (*universal order*).
- Each stage shows a qualitatively different movement pattern from a previous stage.
- There is an *intransitive order* where stages cannot be reordered or skipped.
- Later stages grow out of earlier stages (known as *hierarchical integration*).
- Within a stage, behaviors mix and merge with previous behaviors, and thus there can be no regression in stages (*consolidation process*).
- An imbalance between an individual's mental structure and the environment stimulates the emergence of a new stage (*equilibration process*).

Although these principles have held true for many children, some children did not seem to follow them. It has become clear from motor development research (Garcia, 1994; Garcia & Garcia, 2002) that children are much more variable in their performance of FMS than stage theory might suggest. Three common weaknesses in stage theory were identified: (1) this linear approach did not account for regressions in performance that are often seen when the task changes, such as throwing for distance or accuracy; (2) stage theory did not account for children who reordered the sequence in which they learned skills or skipped over certain stages; and (3) this approach did not explain the process underlying why children shifted from one movement pattern to another. Recently, we have been able to account for these weaknesses in stage theory and reconceptualize developmental sequences using a dynamic systems paradigm.

Dynamic Systems Theory and Stages of FMS

Using dynamic systems theory, the patterns of movement found in developmental sequences are viewed as possible movement choices for the child. In other words, children choose from an array of movement patterns (stages) to select the most appropriate pattern to achieve the task at hand. The total body stages and the most common profiles in the component sequences are most likely strong behavioral attractors that may be selected under specific movement conditions. Strong attractors are ones that are so embedded that it is difficult to move that person out of that state. Weak attractors are patterns of movement we may see occasionally, but they are not as stable as

strong attractors and can more readily be changed by environmental and **individual constraints**. Using dynamic systems theory, there is no such thing as a "mature" or final stage, as the most efficient pattern will vary depending on the task at hand. For example, if you stand a child 5 feet from a wall and tell him or her to throw and hit the wall, he may select from any of the five possible stages of throwing to perform the task. Most likely the child will choose something like a "chop" throw (stage 1) or an "ipsilateral" throw (stage 3) because the task does not demand a forceful throw. However, if a child is 25 feet from the wall, most likely the child will show the most efficient pattern of performance of which he or she is capable, including arm wide up, a step with opposition, and a forceful throw (stage 5).

Reconceptualizing the stages of developmental sequences into various attractors allows motor development specialists to build upon previous knowledge and to extend the information in useful ways. If we reconceptualize the idea that stages of FMS development are common, stable patterns of movement that can be altered, we can manipulate environmental and task constraints to help move children into new attractors that are more beneficial to the demands of a specific task. Thus, our job as teachers and coaches is to assist children in developing a large array of movement patterns from which they can select in different context-specific activities or tasks.

CONCEPT 11.3

Developmental sequences can be identified for many FMS. These common patterns of movement are behavioral attractors that represent movement options from which a child can choose in a given movement context.

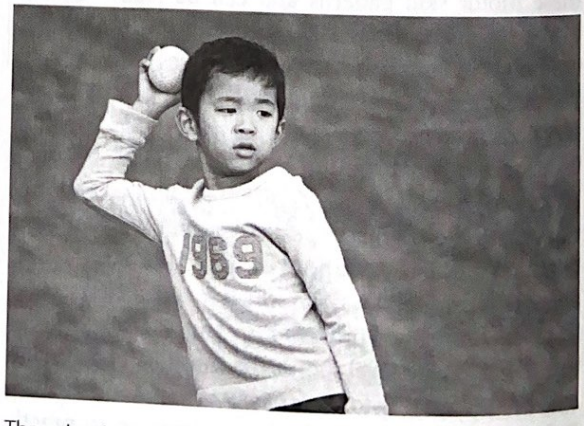
In the next section, we will examine the body of literature on manipulative skills using a dynamic systems approach. For each skill, we will identify the total body and component (where developed) developmental sequences. We will then describe what we know about the performance of a proficient and immature performer. We will conclude each skill with an examination of the factors that might influence the performance of the skill in terms of individual constraints, environmental constraints, and the nature of the task, considering implications for practitioners. We can break down the stages of FMS into *initial*, *emerging*, and *proficient phases of movement*. *Initial* movers are considered beginning learners and represent the first stage in a developmental sequence. The next phase is referred to as *emerging skills* and, depending on the developmental sequence, can consist of stages 2–4. The last phase is referred to as *proficient* and refers to a child who has efficient movement mechanics and is the last stage of FMS development. **TABLE 11.1** identifies the developmental total body sequences of five manipulative skills. For each stage, the words in italics provide a summary word or two in order to remember the stage, and below that is a description of the pattern of movement.

Manipulative Skills

Manipulative skills are a subset of skills that involve manipulating or controlling objects such as bats and balls. There are many manipulative skills, including throwing, catching, kicking, punting, striking, rolling, and bouncing/dribbling. For the purposes of this chapter, we will only review what we know about the first five skills and will not address rolling and bouncing.

Throwing

Throwing is one of the most functionally useful FMS as it is inherent in sports like baseball and softball and involved in sports such as basketball, soccer, and cricket. The throwing motion is also part of the patterns of sports skills such as the serve in tennis and volleyball, the overhead clear in badminton, and the spike in volleyball (Butterfield & Loovis, 1993; East & Hensley, 1985). In North America, being able to throw proficiently is important, as many of the activities that are played in schools and communities involve this critical skill (McKenzie et al., 1998). There are different types of throwing, such as the underhand throw, two-handed throw (as in a soccer



Throwing is one of the most analyzed fundamental movement skills due to its prevalence in a number of sports and recreational activities.

© ziggy_mars/Shutterstock

TABLE 11.1 Developmental Sequences of Five Manipulative Skills

Fundamental Motor Skill	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
	Initial Stage	*Emerging Stages*			*Proficient Stage*
Throw	*Chop* Front facing Vertical wind-up "Chop" throw Feet stationary No trunk rotation	*Sling Shot* Horizontal wind-up "Sling shot throw" Block rotation of trunk Follow-through across body	*Ipsilateral Step* Front facing High wind up Ipsilateral step Little trunk rotation Follow-through across body	*Contralateral Step* Sideways or front facing High wind up Contralateral step Little trunk rotation Follow-through across body	*Wind Up* Sideways Downward arc wind up Contralateral step Segmented trunk rotation Arm-leg follow-through
Catch	*Delayed Reaction* Delayed arm action Arms straight in front until ball contact, then scooping action to chest Feet stationary	*Hugging* Arms encircle ball as it approaches close to body Ball is "hugged" to chest Feet are stationary or may take one step	*Scooping* "To chest" catch Arms reach out & "scoop" under ball to trap it to chest Single step may be used to approach the ball	*Hand Catch* Catch with hands only Feet stationary or limited to one step	*Move to Ball* Catch with hands only Whole body moves through space in different directions
	Initial Stage	*Emerging Stages*		*Proficient Stage*	
Kick	*Stationary Push* Stationary Little/no leg wind up Foot "pushes" ball forward Step backward after kick (usually)	*Stationary Leg Swing* Stationary Leg wind-up to the rear Opposition of arms and legs during kick	*Moving Approach* Moving approach: 1 or multiple steps Foot travels in a low arc Arm/leg opposition Forward or sideward step on follow-through Forceful kick	*Leap-Kick-Hop* Rapid approach Backward trunk lean during wind-up Kicking leg way back behind body Leap (long last step) before kick Hop after kick	
Punt	*Yoking-Push* Stationary No leg wind-up: push Ball toss erratic (yoking) Push ball Steps back after kick	*Stationary Leg Swing* Stationary Leg wind-up to the rear Ball toss still erratic Forceful kick attempt Possible yoking	*Moving Approach* Moving approach into ball: 1 or multiple steps Possible arm/leg yoking Ball toss or drop Kicks ball forcefully	*Leap-Punt-Hop* Rapid approach Controlled drop Leap before ball contact (long last step) Kick forcefully Hop after ball contact	
Strike	*Chop Strike* Front facing tee or ball tosser "Chop" strike with bat from high to low Feet stationary	*Pushing* Body sideways to tee or ball tosser Horizontal push/swing of bat across body Block trunk rotation Feet stationary or single step	*Ipsilateral Step* Body sideways to tee or ball tosser Ipsilateral step (back foot steps across) Diagonal downward swing of bat	*Contralateral Step* Body sideways to tee or ball tosser Bat starts high by ear, elbows bent Contralateral step with weight transfer Segmented trunk rotation Wrist rollover on follow-through	

throw-in), and overhand throw. However, it is the overhand throw that has received the most attention in the motor development literature and is by far the most researched fundamental motor skill.

Prerequisites to Throwing

In order to be able to throw a ball efficiently, a child needs to be able to demonstrate a number of underlying capacities. The ability to demonstrate a long contralateral step is a hallmark of a skilled throw. The thrower also needs dynamic balance to resist the forces of throwing and a strong core from which to generate angular momentum. Upper body strength is important and for the highly skilled thrower there is a degree of fine motor skills in the positioning of the hand and the fingers on the ball at ball release.

Process Versus Product Approach to Throwing

Historically, researchers have examined throwing using a process and/or product approach. The product approach to throwing has looked at the outcome of the throw, such as distance thrown or speed of the throw. The process approach aims to understand the pattern of movement. However, a common belief in the motor development literature is that the development of efficient patterns of movement will result in better product outcomes such as greater distance and speed (Barrett & Burton, 2002). When we look to the elite-level athlete, we see that proficient throwers not only have good technique, but they can also throw long distances with speed; additionally, they can adjust their throwing patterns to the changing dynamics of the task and environment (Hamilton & Tate, 2002; Langendorfer & Roberton, 2002a). Throwing is considered a propulsive skill and as such can be broken down into three phases: wind-up, force production, and follow-through. **TABLE 11.2** outlines the characteristics of a proficient thrower.

TABLE 11.2 Characteristics of a Proficient Thrower

Wind-up

- Non-dominant shoulder faces target
- Throwing arm is brought back away from the body

Propulsion

- Long contralateral step
- Segmental rotation of the trunk where the hip rotates first, followed by the spine, shoulder, humerus, and forearm
- Humerus lags behind trunk and forearm lags behind humerus then arm whips through
- Straight arm at ball release

Follow-through

- Throwing arm follows through diagonally across the body
- Often step forward after follow through

Development of the Overarm Throw

Throwing is a complex gross motor skill that involves the interaction of different body parts coordinating with each other to apply sophisticated biomechanical principles in action resulting in the transfer of significant force to the ball. Major League Baseball pitchers are considered expert throwers, and some can throw a ball at more than 160 kilometers per hour. Yet it is clear that young children do not throw like this. So, how do throwing skills emerge and develop?

Monica Wild (1938) was one of the earliest researchers in throwing, analyzing the throwing patterns of 32 children ages 2 to 12 years. Her most novice throwers (stage 1 in Table 11.1) were 2 or 3 years old and used a front-facing throw, stationary feet, and no trunk rotation (Wild, 1938). By 6 to 7 years of age, children demonstrated more proficient patterns (stage 4 in Table 11.1), could step with a contralateral pattern (that is, opposite arm and foot moving forward), and had trunk rotation. Since these early days, other researchers have added immensely to our understanding of the complex world of throwing. Researchers at Michigan State University developed a total body approach to throwing (Seefeldt, Reuschlein, & Vogel, 1972) in contrast to their counterparts at Wisconsin (and then Bowling Green State University), who used a component approach to the developmental sequences (Roberton & Halverson, 1984).

Total Body Developmental Sequences of Overarm Throwing

Table 11.1 and **FIGURE 11.4** show the five-stage developmental sequence of throwing (Seefeldt, Reuschlein, & Vogel, 1972), similar to Wild's work. The initial stage of throwing (stage 1) is inefficient with a front-facing, stationary base of support, hip flexion, and chopping arm action to generate force. In stage 2, children stand sideways and "slingshot" the ball across their body. By stage 3, children step and throw, but on the ipsilateral foot (the foot on the same side as the throwing arm). It is not until stage 4 that a child takes a contralateral step (the leg opposite the throwing arm moves forward) and begins the journey to more proficient throwing. By stage 5,

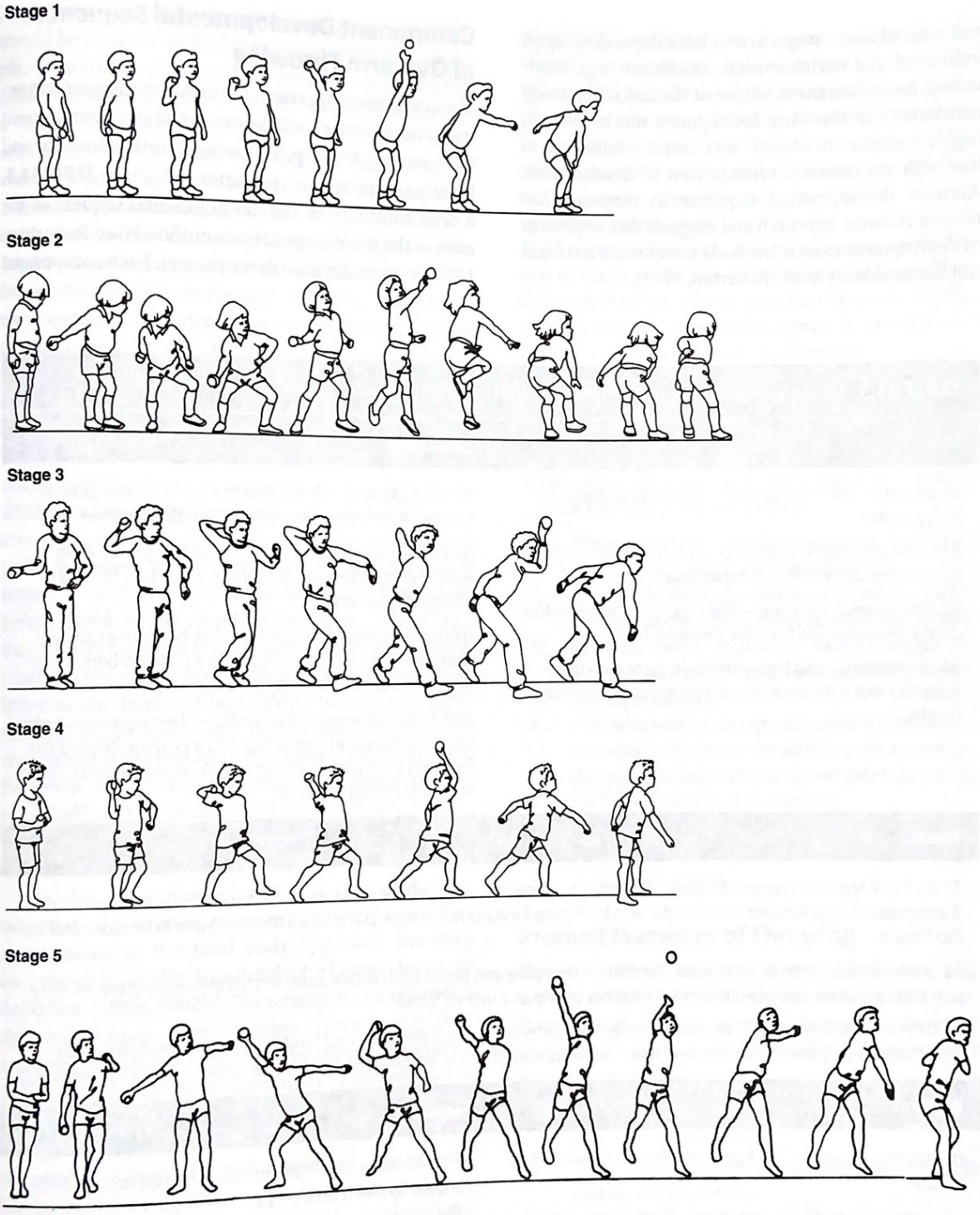


FIGURE 11.4 Developmental sequences of throwing.

Reprinted with the permission of Dr. Crystal Branta and the Michigan State University Motor Performance Study.

the child has acquired the preparatory movements and force dynamics of a proficient thrower. These throwing stages have demonstrated preliminary validation via a mixed-longitudinal sample of children (Haubenstricker, Branta, & Seefeldt, 1983).

Garcia and Garcia (2002) longitudinally tracked six children ages 2 to 5 years across 2 years and analyzed 3,469 throws. Their findings concurred with a dynamic systems approach to skill development showing that children moved back and forward between adjacent

and non-adjacent stages across time depending upon individual and environmental constraints (e.g., motivation, body awareness, nature of the task). The study concluded that throwing development was individual, highly variable, nonlinear, and context sensitive, in line with the dynamic systems view of development. Another developmental sequence in throwing has taken a different approach and suggests that sequences of development exist at the body component level and not the total body level (Roberton, 1977).

Component Developmental Sequences of Overarm Throwing

The component approach to throwing suggests throwing development should be examined at the component level; namely, the step, backswing, trunk, humerus, and forearm components (Roberton, 1977). In **TABLE 11.3**, a brief summary of the developmental sequences for each of the five components is outlined (see Roberton, 1977 for more detailed descriptions). Each component

TABLE 11.3 Component Developmental Sequences of the Overarm Throw

Step	Backswing
S1 *No Step*—The child throws from the initial stationary foot position. S2 *Homolateral (ipsilateral) Step*—The child steps with the foot on the same side as the throwing hand. S3 *Contralateral, Short Step*—The child steps with the foot on the opposite side from the throwing hand. S4 *Contralateral, Long Step*—The child steps with the opposite foot a distance of over half the child's standing height.	B1 *No Backswing*—The ball in the hand moves directly forward to release from the arm's original position. B2 *Elbow and Humeral Flexion*—The ball moves away from the intended line of flight to a position behind or alongside the head. B3 *Circular Upward Backswing*—The ball moves away from the intended line of flight to a position behind the head via a circular overhead movement. B4 *Circular, Downward Backswing*—The ball moves away from the intended line of flight to a position behind the head via a circular, down-and-back motion, which carries the hand below the waist.

Trunk
T1 *No Trunk Action or Forward-Backward Movements*—Only the arm is active in force production. If trunk action occurs, it accompanies the forward thrust of the arm by flexing forward at the hips. Sometimes there is trunk extension prior to hip flexion. T2 *Upper Trunk Rotation or Total "Block" Rotation*—The spine and pelvis both rotate away from the intended line of flight and then simultaneously begin forward rotation, acting as a unit or "block." T3 *Differentiated Rotation*—The pelvis precedes the upper spine in initiating forward rotation. The thrower twists away from the intended line of ball flight and then begins forward rotation with the pelvis while the upper spine is twisting away.

Humerus	Forearm
H1 *Humerus Oblique*—The humerus moves forward to ball release. H2 *Humerus Aligned But Independent*—The humerus moves forward to ball release in a plane horizontally aligned with the shoulder, forming a right angle between humerus and trunk. H3 *Humerus Lags*—The humerus moves forward to ball release horizontally aligned, but at the moment the shoulders (upper spine) reach front facing, the humerus remains within the outline of the body (as seen from the side).	F1 *No Forearm Lag*—The forearm and ball move steadily forward to ball release. F2 *Forearm Lag*—The forearm and ball appear to "lag" behind the shoulder. F3 *Delayed Forearm Lag*—The lagging forearm delays reaching its final point of lag until the moment of front facing.

Data from Roberton, M. A. (1977). Stability of stage categories across trials: implications of stage theory of overarm throwing development. *Journal of Human Movement Studies, 3*, 49–59.

has three or four steps (equivalent to stages). A child would be rated on each of the components. For example, an initial performer who would be a total body approach stage 1 "chop thrower," would demonstrate a Step-1, Backswing-1, Trunk-1, Humerus-1, Forearm-1 (1-1-1-1-1) with no step, no backswing or trunk rotation, and a humerus that is oblique with a forearm that has no lag. This 1-1-1-1-1 action is equivalent to the "chopping" action of stage 1 in the total body approach, where almost all of the throwing action comes from the arm. However, the component approach provides a more sophisticated analysis of the biomechanical factors occurring in forceful throws than the total body approach. For example, the component approach distinguishes between a short (S3) and long (S4) contralateral step, recognizing that proficient throwers take a long contralateral step when they throw for force (Langendorfer & Roberton, 2002a). Additionally, the component approach examines the mechanics of the trunk action and differentiates between "block" (hips, trunk, and shoulders rotate as a block) and "differentiated" (hips rotate before trunk before shoulder) rotation. The same is true for the humerus (upper arm) and forearm action where in the component approach the importance of humeral lag (humerus lags behind the shoulder) and forearm lag (forearm lags behind the humerus) are recognized in the production of force (Langendorfer & Roberton 2002a). Thus, an efficient thrower, such as a baseball pitcher, would demonstrate S4, B4, T3, H3, F3 (see Table 11.3). All of these actions result in significant force being imparted to the ball.

In the component approach, it is important to note that all components are not perfectly correlated as suggested in the total body approach, but they are also not totally independent (Langendorfer & Roberton, 2002a, 2002b). For example, just because a child moves from a Step-1 to Step-2 (no step to ipsilateral step), it does not mean that the other components such as trunk will change accordingly (Langendorfer & Roberton, 2002a). Within the component approach, change in component levels can occur at different rates and at different times for different components. Although the component approach was developed under a stage theory perspective, the probabilistic view of dynamic systems theory works well with this approach. The component sequences outline the wide variety of possible configurations (behavioral attractors) of throwing performance and show that children can demonstrate different configurations of body components based upon individual, task, and environmental constraints (Hamilton & Tate, 2002). Langendorfer and Roberton (2002b) found that of the possible 27 configurations of component levels, only 14 were demonstrated, indicating that there are certain profiles or behavioral attractors in throwing that represent common patterns of throwing movement. It is important to remember that certain components are closely related and other components cannot be seen together. For example, if a child has a S2 (ipsilateral/homolateral step), it is not possible for the child to rotate the trunk, the only possible configuration of trunk would be a T1 (no trunk rotation). Thus, although there are a lot of possible movement configurations with the component approach, in reality, we tend to see similar patterns of movement.

Both total body and component sequences of development provide valuable information for teachers and coaches. Using developmental sequences allows teachers and coaches to assess and track the development of throwing in their children. Teachers can use a five-step process to do this:

1. Observe and evaluate the developmental level of the child (e.g. stage 3 ipsilateral step).
2. Identify the desired performance (desired attractor) for the child to perform (contralateral step).
3. Consider what individual factors might be influencing the child (e.g. balance, ability to step with opposition).
4. Consider how to manipulate aspects of the environment to promote the skill (e.g. tie a scarf on the opposite leg and put a foot print down on for the opposite foot to step on).
5. Watch the child perform the task and modify it to make it more difficult or easier based upon your observations.

Product Measures of Throwing

Distance thrown, accuracy of the ball thrown, and velocity or speed of the ball are common product measures used to evaluate overarm throwing proficiency. Two major outcomes are known about these product measures of throwing:

1. There are distinct gender differences in outcome measures of throwing.
2. There are age-related increases in outcome measures of throwing.

Constraints in Throwing

Newell (1984) suggests that motor performance is a product of the interaction between and among individual, task, and environmental constraints. **TABLE 11.4** identifies key individual, environmental, and task constraints in the throwing literature. The development of throwing is not linear or prescriptive; rather,

TABLE 11.4 Individual, Task, and Environmental Constraints in Throwing

Constraints in Throwing		
Individual	**Task**	**Environmental**
Gender	Accuracy	Size of target
Age	Force	Distance from target
Biological	Throw stationary or on the run	Instruction
		Cultural impact

it is dynamic and variable in nature. It is important that teachers understand this critical point. As teachers select tasks for their students, these teachers can often elicit a more advanced pattern of throwing by considering individual constraints and changing the task and environmental constraints to demand such a performance. Thus, the selection of appropriate tasks becomes an important role in order for teachers to promote throwing development.

Individual Constraints in Throwing

Individual constraints are factors that are internal to the individual. In throwing, the two major areas of individual constraints that have been examined are gender and age. However, a few studies have examined other biological factors in throwing. Southard (2002) experimentally "advanced developmental age" by manipulating the mass of 5- to 12-year-old children's arm segments (humerus and forearm) to approximate the relative mass of an adult arm. Results showed that the adult mass condition improved the throwing performance of more immature throwers. Southard suggested that changes in relative mass of upper limb segments as a result of normal growth and development may, in part, be a contributing factor to the development of more advanced throwing patterns over time. Stodden, Langenderfer, Fleisig, and Andrews (2006a, 2006b) conducted a biomechanical analysis of throwing, categorizing participants by throwing proficiency on the component sequences. They found boys were more likely to have more advanced movement mechanics (higher attractor profiles) than girls. Interestingly, step length significantly predicted ball velocity, demonstrating the link between process (pattern of movement) and product (velocity) in throwing.

Relative to gender and age, boys outperform girls at every age and in every category of throwing (Butterfield & Loovis, 1993; Garcia & Garcia, 2002; Halverson & Roberton, 1979; Langenderfer & Roberton, 2002a, 2002b; Roberton & Konczak, 2001; Sakurai & Miyashita, 1983; Thomas & Marzke, 1992). The gender differences found in throwing are the largest for any fundamental motor skill (Nelson et al., 1991; Thomas & French, 1985; Williams, 1996). The effect size at 4 years of age is three times as great (1.5 vs. 0.5) for boys as girls and continues to increase in strength through adolescence to an effect size above 3.0 (Thomas & French, 1985). Not only do girls start behind in throwing, this deficit continues to increase throughout the school-age years and has implications to teaching physical education. Butterfield, Angell, and Mason (2012) showed similar gender and age findings with children ages 5 to 14 years. Throwing demonstrated rapid improvements up to ages 9 to 10, but beyond this the rate of improvement slowed dramatically or even declined. Boys outperformed girls at all ages. At the younger ages (4–7 years), boys and girls had low probabilities of demonstrating a mature pattern of throwing. By 10 years of age, 78.8% of the boys compared to only 47.0% of the girls had achieved a mature throwing pattern. Given that at this age many physical education programs have shifted from instructing skills to teaching sports, it seems likely that girls' lack of throwing proficiency will persist into middle and high school, impacting their ability to participate effectively in sports that involve throwing.

Angell et al. (2018) conducted a longitudinal study of throwing and striking where 280 boys and girls in grades K–8 (ages 4–15) were tested three times per year for 5 years on the Test of Gross Motor Development (TGMD-2). The authors were interested in how children changed in their performance across time and analyzed individual growth curves across these time points. As anticipated, children improved their throwing across age and boys outperformed girls, reinforcing the notion that girls may be disadvantaged in sports involving throwing. At age 5 years girls and boys had similar throwing patterns. But boys rapidly improved their throwing skills, plateauing at 10 years, whereas girls' throwing skills improved more slowly, peaking at age 12. As with prior studies, girls had a much less likelihood of demonstrating a mature form than boys. The authors were also interested in whether body mass index (BMI) influenced throwing performance; however, it was not found to be correlated with throwing performance. The authors concluded that biology might be a leading factor in the development of throwing.

Gender differences are categorized as an individual constraint because of the biological factors associated with them. **FIGURE 11.5** shows age-related gender differences in throwing (Seefeldt & Haubenstricker, 1982). By stage 5, the typical boy is 63 months whereas the typical girl is 102 months (a difference of more than 3 years).

Thomas and colleagues (1994) found that gender differences for throwing distance were three times the size of gender differences for other tasks. Morris, Williams, Atwater, and Wilmore (1982) found that 5- to 6-year-old girls were similar to 3- to 4-year-old boys in throwing for distance, highlighting the large gender differences. A meta-analysis of 21 throwing studies (5 accuracy, 11 distance, and 5 velocity) reported that boys' performance was 1.5 standard deviations greater than girls' starting as early as ages 4 to 7 years when throwing for force and distance (Thomas & French, 1985). By age 12 years, the boys were 3.5 standard deviations ahead of the girls for throwing speed. Halverson and colleagues (1982) and Roberton and colleagues (1979) also reported gender differences for velocity that continued to increase with age. Halverson et al. (1982) calculated a yearly rate of change of velocity for both boys and girls. Boys increased 5 to 8 ft/sec/year, in contrast to the girls, who only changed 2 to 3 ft/sec/year in kindergarten to second grade, and 2 to 4.5 ft/sec/year from third to seventh grade (Halverson et al., 1982; Roberton et al., 1979). Runion, Roberton, and Langenderfer (2003) undertook an interesting study. They evaluated the throwing velocities of 50 13-year-old boys and girls and compared them to a 1979 sample of 13-year-olds. The theory was that with the increase in youth sports, particularly for girls, the more recent participants would outperform the data collected 30 years ago. Overall they found that boys' and girls' throwing velocities had not improved from 1979 to 2003 and that gender differences still persisted in favor of boys in both cohorts.

Gender differences in throwing have also been reported for countries other than the United States. Sakurai and Miyashita (1983) found significant gender differences in Japanese children ages 5–9 years. Pan and Lu (2001) indicated that Chinese boys' performance on overhand throw for accuracy and distance was better than girls' from age 7–12 years. Other work has found that German males outperformed their female counterparts in throwing form and velocity (Ehl et al., 2005). A study of 6-, 8-, and 10-year-old

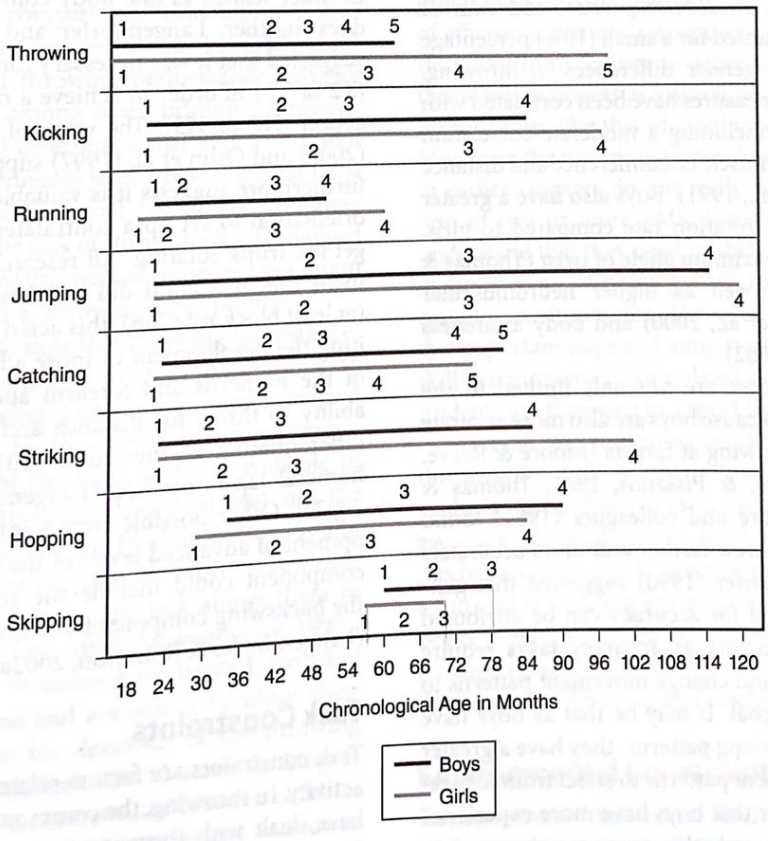


FIGURE 11.5 Age-related changes in the FMS of children.

Seefeldt, V., & Haubenstricker, J. (1982). Patterns, phases, or stages: An analytical model for the study of developmental movement. In J. A. S. Kelso & J. E. Clark (Eds.), The Development of Movement Control and Co-ordination (pp. 309–318). New York: John Wiley & Sons.

Aboriginal Australian children also demonstrated gender and age differences, with boys throwing faster than girls and 10-year-olds faster than 6-year-olds (Thomas et al., 2010). However, Aboriginal boys and girls were more similar in ball velocities and kinematics (motion of bodies) than U.S. girls and boys. Aboriginal girls threw with greater velocities than U.S., German, Japanese, and Thai girls, while boys were similar across cultures. It was hypothesized by the authors that in the Australian Aboriginal culture, there may be a greater cultural emphasis on a girls' ability to throw than in the other cultures. Another study of three international cultures (Australia, Japan, and Thailand) by Sakurai, Chentanez, and Elliott (1998) also suggested cultural differences may account for their findings on throwing distance between girls and boys ages 7–11 years. Boys and girls demonstrated similar patterns in throwing for distance than children in the U.S., with girls throwing substantially shorter distances than boys. However, children from Australia and Japan threw greater distances than Thai children. It was suggested that sports such as cricket and baseball, which are a dominant part of the Australian and Japanese cultures, might account for these findings.

Nelson et al. (1986) found that biological factors of joint diameters, shoulder/hip ratio, and sum of skinfolds only accounted for a small (10%) percentage of the variance in gender differences in throwing. Specific biological measures have been correlated with gender differences including a moderate correlation between boys' arm muscle circumference and distance thrown (Nelson et al., 1991). Boys also have a greater external-to-internal rotation rate compared to girls, who have a lower maximum angle of twist (Thomas & Marzke, 1992), as well as higher neuromuscular coordination (Yan et al., 2000) and body awareness (Garcia & Garcia, 2002).

Gender differences are not only limited to the force of the throw, because boys are also more accurate than girls when throwing at targets (Moore & Reeve, 1987; Moore, Reeve, & Pissanos, 1981; Thomas & French, 1985). Moore and colleagues (1981) found kindergarten boys threw farther and more accurately than girls. Langendorfer (1990) suggested that gender differences found for accuracy can be attributed to environmental factors as accuracy tasks require the ability to adapt and change movement patterns to meet the accuracy goal. It may be that as boys have more advanced throwing patterns, they have a greater repertoire of movement patterns to select from to meet the task demands, or that boys have more experience at throwing and can apply this experience in a variety of different conditions (Langendorfer, 1990).

Overall, gender differences in both product and process measures of throwing have implications for the physical education teacher or coach. If girls are significantly worse than boys in throwing at all ages, it is important that the physical education teacher and coach ensure that sports and games involving throwing do not naturally advantage boys. Modification of rules and playing areas may be necessary.

Other individual factors of interest include age. Langendorfer and Roberton (2002a, 2002b) identified how throwing performance changed across age by describing common attractor profiles (common patterns of movement) and attractor pathways (shifting from one pattern of movement to another) for the development of throwing at different ages. Attractor profiles describe the overall throwing pattern for specific components, and attractor pathways describe the shifting patterns from one throwing pattern to another across time. The strongest attractors for children for the trunk, humerus, and forearm component were (refer back to Table 11.3):

- 5–6 years: 1-1-1 or 2-1-1 or 2-2-1 or 2-2-2
- 7 years: 2-3-2 or 2-1-1 or 2-2-2

Attractor profiles have been found to be linked. In other words, as one body component changes, so does another. Langendorfer and Roberton (2002a) suggested that it was necessary for the trunk to rotate (T2 or T3) in order to achieve a more advanced arm action (H2 or H3). The work of Garcia and Garcia (2002) and Oslin et al. (1997) supports this view, and furthermore suggests it is valuable to use a sideways orientation to set up a contralateral step in order to get the trunk rotating. All researchers were in agreement that if a child did not have a rotating trunk (at least block rotation), this acted as a constraint limiting the development of more advanced movements of the humerus and forearm and subsequently the ability to throw for distance and velocity. However, differentiation of the trunk (T3) may appear after humeral lag is reached (Langendorfer & Roberton, 2002a). Other possible factors influencing the development of advanced levels of the trunk and humerus component could include the relationship between the backswing component and arm component levels (Langendorfer & Roberton, 2002a).

Task Constraints

Task constraints are factors related to the goal of the activity. In throwing, the commonly investigated areas have dealt with throwing for accuracy versus force. From a constraints perspective, the task or goal of the activity has a powerful influence on the throwing

pattern we demonstrate. For example, if a child is placed 35 feet from a wall and told to hit the wall with a tennis ball, most likely, he or she would select a throwing pattern with wind-up, contralateral step, trunk rotation, humeral and forearm lag, and follow-through. That is, the child would choose the most mechanically efficient pattern he or she was capable of performing for the task at hand. However, if the same child were placed 10 feet from a wall and told to throw the ball at the wall, most likely she would demonstrate a chopping motion with the arm and no step or trunk action. That is, the task demands do not require significant force, and thus a different pattern of throwing would be selected. In this manner, children may demonstrate different patterns of throwing depending on the task demands. When tasks vary in their goal (such as accuracy versus force), throwing performance changes in relation to the intended goal.

Oliveira and Manoel (2002) examined throwing in a group of 7-year-old boys and girls. They reported more advanced throwers threw farther than less advanced throwers, but there was no difference in accuracy. Roberton (1987) determined that the task constraints of force and accuracy influenced product scores. She reported velocity was reduced by one developmental year when comparing a "throwing hard" condition versus an accuracy condition. However, there was little change in throwing performance between force and accuracy among more primitive throwers. Langendorfer (1990) determined that males improved close to one developmental level when changing from an accuracy goal to a force goal. Lorson and Goodway (2007) determined the task of "throwing hard" changed the step component of throwers as compared to a group that did not receive the "throwing hard" prompt.

It is interesting to note that throwing for distance/force versus throwing for accuracy only seems to influence the throwing patterns of more advanced performers. It may be that more advanced throwers have a variety of throwing patterns available to them and are able to select those that best suit the task demands (Langendorfer, 1990; Roberton, 1987). Advanced throwers often seem to select more primitive patterns of throwing if the task allows them to do so (Hamilton & Tate, 2002; Langendorfer, 1990). Yet more primitive throwers have limited throwing options to select from and are unable to adjust their throwing patterns to the demands of the throwing task. Molina and Stodden's (2018) study looking at variability in throwing performance between children and adult performers at maximum speeds and lower levels of performance (sub-maximal speeds) suggests similar findings. Children and less skilled throwers are more variable, even at maximum speeds. Overall, they conclude that teachers and coaches should remove accuracy constraints and focus on force production.

The majority of throwing studies have looked at throwing in an isolated task. One interesting study in 6-, 9-, and 12-year-old children compared throwing for distance, running, and a combined task requiring the child to run then throw for distance (Gimenez et al., 2012). The researchers used a component approach to analyze the throwing and running patterns. For the combined task of run-and-throw, they broke the task down into running, a transition phase in which the child was getting the body in a position to throw (they identified 5 stages to the transition phase), and then throwing. Gimenez et al. (2012) created an index of efficiency that represented the child's ability to translate the speed of the run into the force of the throw. They calculated this index of efficiency by comparing throwing speed in the individual task to throwing speed in the run-and-throw task. As might be expected, there were age differences in the ways the different age groups integrated running and throwing. Younger children had a lower index of efficiency (mostly negative) meaning they could not translate the speed from the run efficiently into the throw. In contrast, the oldest group (12-year-olds) had a higher and positive index of efficiency, demonstrating they could effectively use the speed from the run to generate more force in the throw with a smooth transition between the two skills. More studies like this of combined FMS are needed. Moreover, the models of motor development discussed in earlier chapters do not really address this integration of two or more FMS. Good physical educators understand that they need to shift from teaching FMS in isolation to combining FMS in increasingly more complex environments. However, too often we skip this important stage and jump straight from teaching a skill like throwing in an isolated skill station to having students use throwing in a sport like baseball.

Overall, the consensus on throwing tasks is that throwing for force is a better task to develop a more sophisticated pattern of movement than throwing for accuracy. As children are developing their throwing mechanics they should practice throwing for force in a fun and motivating environment. Later, as children begin to develop more advanced throwing mechanics they should begin to combine both running and throwing and throwing and catching.

Environmental Constraints

Environmental constraints deal with those factors external to the individual. Environmental constraints include the manipulation of the throwing environment

such as the distance to be thrown, the size of the target and the type of the target. They also include the size of the ball and sociocultural influences such as opportunities to practice throwing and differential effects of instruction.

There is little empirical evidence with respect to sociocultural influences on throwing; however, there has been some discussion of these factors in the literature. For girls, factors such as the limited number of advanced female throwers to imitate and less support from parents to throw may have an impact on their throwing performance and account for the gender differences found in throwing (East & Hensley, 1985; Nelson et al., 1986; Thomas & French, 1985). Organized activities, such as youth sport, could be another contributing environmental factor. Research suggests that boys tend to participate in more organized throwing experiences such as baseball (Butterfield & Loovis, 1993; Halverson et al., 1982; Thomas & Marzke, 1992) and that differences exist in the quality of throwing opportunities (Butterfield & Loovis, 1993). Garcia and Garcia (2002) suggest that young girls respond differently than boys in instructional throwing environments. In their study of preschoolers, girls were motivated to throw to please the teacher and to receive positive feedback, stickers, smiles, and encouragement. In contrast, boys were more intrinsically motivated by improving their own skill and competing against other boys; this was particularly true for the more skilled throwers.

The size, shape, and mass of the ball are factors that may influence the throwing pattern (Southard, 1998). Teachers and coaches can manipulate environmental factors to improve throwing performance. For example, baseball coaches have increased the mass of the baseball in training as a tool to increase ball velocity in pitchers (DeRenne, Tracy, & DunnRankin, 1985). Although there is little empirical literature in this area, those who frequently teach throwing to children know that ball size and shape influences the pattern of throwing. A few researchers have found that the size of the ball influences the mechanics of the throw (Burton, Greer, & Wiese, 1992; Burton, Greer, & Wiese-Bjornstal, 1993). This is particularly true for young children, and instructors need to be aware of the relatively smaller size of their hands to the ball size. For example, throwing a softball might seem like a good task to an adult, but it is clear that the hand size of younger-age elementary school children is too small to grip a softball appropriately. Burton et al. (1992) suggest there may be an optimal ball size to hand size in throwing tasks.

Other factors such as how far a child must throw, or the size of the target that it is thrown to, can influence the pattern of the throw. Hamilton and Tate (2002) examined the influence of three different throwing distances (scaled to height: 2, 4, and 6 times body height) and three different target sizes (3, 5, and 7 feet square) on the throwing performance of 26 third-grade children. They found more advanced step, trunk, and humerus body components were demonstrated when the children had to throw longer distances. No significant effects were found for target size, although the investigators acknowledged their targets may have been too big and did not require high levels of accuracy. The manner in which skilled throwers adapt their throwing patterns to the distance thrown was evident in a study of the throwing patterns of collegiate baseball throwers (Barrett & Burton, 2002) and elementary school-age children (Lorson & Goodway, 2008). Barrett and Burton found that players altered their throwing patterns depending on how far they needed to throw. When throwing into base from the infield, an ipsilateral step was often seen, whereas throws from the outfield required more advanced throwing components. Lorson & Goodway (2008) examined gender differences in the throwing form of children playing a throwing game before and after instruction. They found differences between the pretest and after instruction for boys' throwing form on the trunk and forearm components and for girls' throwing form on the step and trunk components. The improvement after instruction and gender differences were similar to those found in a controlled practice context.

A significant environmental constraint is the influence of instruction on throwing performance. There is a growing body of work in this area and some innovative and effective methods to teach children to throw that have significant implications for teachers and coaches. It seems particularly important to develop effective instructional practices for girls as research has found persistent gender differences in throwing performance with many studies showing that these gender differences persevere after instructional intervention (Browning & Schack, 1990; Dusenberry, 1952; Garcia & Garcia, 2002; McKenzie et al., 1998; Thomas et al., 1994).

Early work by Dusenberry (1952) found a 3-week instructional program resulted in both genders improving distance thrown, but boys threw farther than girls with the same amount of training. In contrast, Halverson and colleagues (Halverson & Roberton, 1979; Halverson, Roberton, Safrit, & Roberts, 1977, 1979) found no improvements in throwing velocity between groups (throwing instruction, a movement program without throwing instruction, and a comparison group) for an 8-week throwing program. However, a subsequent review of the developmental level

in throwing components reported more advanced patterns of forearm lag, trunk action, stepping action, and spinal rotation in the throwing instruction group (Halverson et al., 1979). McKenzie and colleagues (1998) showed that throwers in a school program designed to enhance physical activity performed significantly better on distance and accuracy tasks in throwing compared to students in a regular physical education program. Again, this may speak to throwing practice opportunities versus the actual nature of the throwing instruction.

A number of studies have considered the role and knowledge of the teacher in throwing instruction. Graham and colleagues (1991) compared the influence of a trained physical educator to a classroom teacher on the qualitative and quantitative outcomes in throwing of 60 first- and third-graders' performance over 3 years. Interestingly, this study found that students taught by the classroom teacher were more skilled in throwing than throwers who were instructed by a trained physical educator. Although these findings may seem surprising, it may be that the classroom teacher's more "recess-like" physical education had more throwing activities overall, including more forceful throwing opportunities such as dodgeball. In contrast, the physical education specialist may have concentrated more on the development of all motor skills, not just throwing (Graham et al., 1991). A study by Walkwitz and Lee (1992) found that improving the throwing content knowledge of teachers through a motor development orientation improved teacher behaviors, which resulted in a significant impact on the stepping patterns of children. Cohen, Goodway, and Lidor (2012) found that when a teacher was trained to evaluate a child's developmental level, then provided feedback aligned to the developmental level of throwing (aligned development feedback), improvements in ball velocity and throwing body components were found compared to how the teacher had typically taught throwing. Clearly, if a teacher can accurately evaluate the throwing skill and provide appropriate feedback, children will improve their throwing. However, it may be that students can achieve the same outcome as the teacher in the Cohen et al. (2012) study. Another study by Alstot (2018) found that children as young as first through third grades could accurately undertake peer assessments of throwing, which lends possibilities that children could peer coach each other on throwing and enhance each other's skill. Alstot (2018) also found that using a token economy (incentive) to motivate children to improve their throwing resulted in better throwing performance.

Other studies have looked at the nature of throwing cues and feedback provided within the instructional environment. Fronske and colleagues (1997) were the first to use critical cues to help third- and fifth-graders with immature throwing patterns improve on throwing distance and the step and backswing component. The findings revealed that the use of cues improved throwing distance and form (step and arm) more than for a group that did not receive specific instruction. Oslin and colleagues (1997) used a specific presentation of cues called component specific instruction to improve throwing performance of 22 children ages 3–6 years. Overall, component-specific instruction increased throwing efficiency, but there was no difference between a force production sequence or forward chaining sequence. Lorson and Goodway (2007) used critical cues and task constraints of a forceful throw to bring about changes in developmental levels and ball velocity of second- and third-grade students.

A comparison of a traditional approach to teaching throwing compared to a biomechanical–developmental approach to throwing instruction with 34 kindergartners showed the importance of developing efficient biomechanical movement in throwing (Stodden & Rudisill, 2006). The biomechanical approach focused on the exploitation of hypothesized control parameters that promote optimal energy transfer through the kinetic link system (Stodden et al., 2006a, 2006b). Specifically, instruction focused on generating linear and angular momentum of the trunk and center of mass in addition to optimal preparatory positioning of the humerus, forearm, and wrist to promote energy transfer during the throwing motion. The results of this study showed that the instructional strategy integrating biomechanical concepts was more effective in promoting certain aspects of the throwing skill. This study was also the first to show a reduction in gender differences in throwing arm components. Gender differences in ball velocity were not reduced, which may indicate that additional intervention time was needed to more effectively reorganize coordination and interactions among segments to change ball speed.

Lorson followed up the Stodden study by investigating the influence of three instructional strategies taught by physical education teachers on the throwing performance of 105 first- and second-grade children (Lorson, 2005; Lorson & Goodway, 2008). The three instructional approaches were: (1) the biomechanical approach developed above by Stodden (Stodden & Rudisill, 2006); (2) a critical cue group emphasizing three critical cues ("laser beams" for sideways orientation, "long step," and "twist and throw hard"); and (3) a traditional group utilizing the cues ("side to target," "arm way back," and "throw hard") suggested by a major elementary physical education textbook

(Graham, Holt-Hale, & Parker, 2007). The results from this study found the biomechanical approach was more successful than the other two approaches in promoting change in the humerus and forearm. No differences were found between the groups for the step and trunk component, as well as ball velocity. Significant gender differences were present at the pretest and remained at the posttest with boys' throwing performance and velocity greater than those of girls. Lorson added the unique aspect of looking at the application of throwing performance to a game situation (Lorson & Goodway, 2008). The step, trunk, and forearm components in a throwing game were correlated with body component levels during practice. Overall, these findings suggest that any of the three strategies improved throwing performance, with the biomechanical approach the most useful tool to help develop the humerus and forearm components.

Other studies have focused on resistance training related to improving throwing performance. Maddigan, Beh, & Belfry (2014) found that strength training using elastic resistance bands resulted in greater throwing velocities than a control group and recommended that coaches could use such an approach to improve their athlete's throwing speed. Szymanski (2012) conducted a review of literature on resistance training approaches to improve throwing. The review concluded that there was no best resistance training approach. If players had less experience, general resistance training could increase throwing velocity. But for more elite players (high school, college), off-season resistance training demonstrated improvements in throwing velocity.

In summary, a review of the throwing literature suggests that:

- Valid developmental sequences exist for throwing that can be at the level of the overall body (total body) or at the level of individual body components (component approach).
- Gender differences are present in throwing, with boys better than girls both in terms of the processes (patterns of movement) and products (velocity and distance) of throwing.
- Children exhibit variable, nonlinear, and context-sensitive emergence of throwing behaviors in line with a dynamic systems approach. That is, children's throwing performance can be highly variable based upon the environment and task factors.
- Individual, task, and environmental constraints influence throwing performance.
- Throwing instruction positively impacts the performance of the overarm throw.
- Process measures of throwing are more sensitive to instruction than product measures such as velocity.
- A variety of instructional approaches including models, critical cues, and the biomechanical approach yield significant effects on throwing performance.
- A long contralateral step is important in order to begin rotating the trunk on the legs.
- The biomechanical approach seems to have the best results in impacting the humerus and forearm components of the throw.
- Resistance training helps promote improvements in throwing velocity.
- Gender differences present prior to the interventions persist across the intervention; even though girls get better from instruction, they do not catch up to boys at the end.
- During initial instruction of the overarm throw, the focus should be on throwing for force to evoke the most mature pattern.

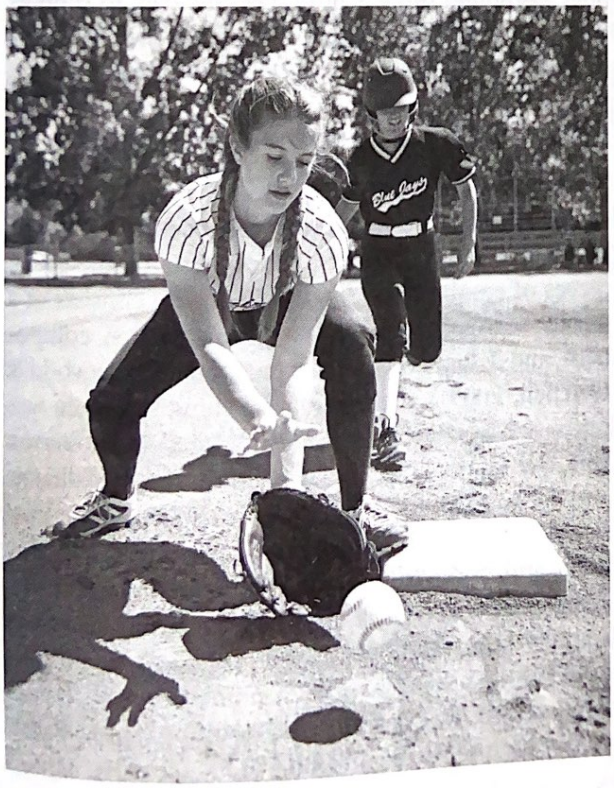
INTERNATIONAL PERSPECTIVES

Motor Skills in Children: Are We a Product of Our Sports Culture?

The data in Figure 11.4 provide a guideline about the age at which 60% of the children tested could perform a particular skill at a specific stage. These data were collected on children in the Midwestern part of the United States. However, we know from a constraints perspective that environmental factors influence the emergence of motor skills in children. That is, the type of sports to which children are exposed will influence the development of those motor skills that are in the sport culture. Get in a group and select a country whose popular sports are familiar to you (e.g., U.K., Japan, Australia, Germany, China). Now think about similarities and differences of the sports culture in this country compared to the U.S. sports culture. Take a look at the chart in Figure 11.4 and discuss how these data might look different for boys and for girls in these two countries. Do you think that you will see different data for the two countries? In what skills? And in what genders? What role do you think sports cultures play in the development of children's motor skills?

Catching

Like throwing, catching is also a commonly used skill in sports, games, and lifetime activities. It is a manipulative skill whose goal is to retain possession of the object. The kind of catch performed is dependent on the task and environmental demands such as the position and velocity of the ball in the air, the shape and size of the ball, and the trajectory of the ball. As a result, catching can be done with one hand or two. In catching's more primitive form, young children learn to catch balloons, large balls or beach balls, and beanbags with their arms and hands. As children progress through elementary school, they become better able to catch balls of different sizes, shapes, and velocity with one and two hands. They also learn to catch within the parameters of their body and later catch balls high above the head or to the side of the body. At the elite sports level, we see amazing feats of catching where individuals intercept the ball in seemingly impossible situations. From the outfielder in baseball who catches a ball while flying horizontally through the air, to the receiver who miraculously leaps higher than a defender to catch a football, these athletes demonstrate an uncanny ability to adapt their body dynamics to intercept a ball. Many sports such as basketball, baseball, softball, rugby, and American football rely on proficient catching skills in order to play the game. There is a fairly large body of literature on catching to inform the physical education teacher and coach. For the purposes of this chapter, we will only examine the literature on two-handed catching.



The fundamental movement skill of catching serves as the foundation for later specialized skills such as fielding in baseball/softball.

Prerequisites to Catching

Children need to possess several skills in order to be able to catch a ball, including eye-hand coordination, the ability to track an object with the eyes and consistently anticipate and intercept this object, perceptual awareness, and fine manipulation of the fingers to the flight dynamics of the object. The *proximo-distal* law of developmental direction is relevant to the emergence of catching behaviors. This law states that children learn to gain control of their body from the midline out to their hands. The law is seen in action in the development of catching behaviors as children first learn to catch by trapping the ball to their chest then become able to catch a ball tossed to their chest with their hands, and finally can catch a moving ball in the air. It is not until children can catch a ball on the move with their hands that they are ready to apply catching skills to the arena of games and sports.

Proficient Catchers

There are many kinds of catching, but the two that have received the most attention in the developmental literature are two-handed catching and one-handed catching. Many of the major motor development scholars agree on the characteristics of a proficient catcher (Gabbard, 2004; Gallahue & Ozmun, 2006; Haywood & Getchell, 2006; Payne & Isaacs, 2008) and these characteristics can be found in **TABLE 11.5**. Skilled catchers are seen in many sports across the world, from the fast reactions of the first baseman in baseball and the wicket keeper in cricket to the precision of the wide receiver catching an American football while flying through the air. Skilled catchers are central to the success of many sports.

In contrast, we have all observed an initial catcher. Often, he or she turns the head to the side, closes the eyes, and leans away from the incoming ball for fear of being hit in the face. He or she does not track the ball's flight, and the arms and hands make little or no adjustments to the spatial characteristics of the ball, just responding at the last moment as the ball comes toward the body. The fingers tend to stay rigid and the arms and hands do not "give" into the ball. If the ball is tossed with force, it will frequently bounce out of the outstretched hands,

TABLE 11.5 Characteristics of a Proficient Catcher

Proficient catchers demonstrate the following:

Preparation for Catching

- Track the ball with the eyes
- Align body with incoming flight characteristics of object
- Feet slightly apart
- Prior to catch, arms relaxed at side or slightly in front

Reception of the Object

- Hands move to intercept the object—fingers adjust to precise spatial characteristics of the object (fingers up for high ball, down for low ball)
- Arms "give" on contact to absorb the force
- Fingers grasp object in well-timed simultaneous action
- Body weight transferred from front to back

assuming the ball connects with them. The timing of the catching motion is out of sync with the ball flight, and many children demonstrate balance difficulties once they have received a forcefully thrown ball. If the ball is small, it is rarely caught; if the ball is large, such as a playground ball, the children will trap it against their chest using their arms. Inexperienced catchers such as these do not possess the necessary skills to be able to successfully apply catching to the games and sports arena. Sadly, many parents and coaches do not consider these factors as they make decisions about their child's ability to engage in organized sport. In many community-organized sports leagues, children with poor catching skills are placed in positions such as first base, where they cannot possibly meet the demands of the task asked of them. From a developmental perspective, these children would be much better off practicing their catching skills with parents, siblings, and peers, rather than engaging in miserable experiences in organized sports where the child's developmental level does not match the task demands.

Development of Two-Handed Catching

Developmental sequences of catching are available for both the total body (Haubenstricker, Branta, & Seefeldt, 1983) approach and the component (Roberton & Halverson,1984) approach to catching.

Total Body Developmental Sequence of Two-Handed Catching

Table 11.1 and **FIGURE 11.6** illustrate the five-stage sequence of catching a ball. The first stage of this sequence mirrors the description of the inefficient catcher above with arms rigidly out in front, head often turned to the side and little to no tracking of the ball. The child progresses to hugging (stage 2), then scooping (stage 3) a larger ball. Stage 2 and 3 are often hard to discriminate for the inexperienced observer but the stage 2 hugger tends not to track the ball very well and often waits until the ball comes close to the body before hugging it to the chest. In contrast, the more advanced stage 3 catcher will see the ball earlier and lean into ball flight to scoop the ball out of the air. It is not until stage 4 that the child can hand catch a ball tossed to the trunk (he would miss a ball tossed outside of the parameters of the body). By stage 5, the child can now move her body to catch the ball. The stages for catching have undergone preliminary validation in a mixed longitudinal sample (Haubenstricker, Branta, & Seefeldt, 1983). Given these stages, parents, teachers, and coaches need to recognize that a child is not ready to engage in team sports or games involving catching until she reaches stage 5.

The catching data in Figure 11.5 reveal that catching is one of the few skills where girls are ahead of their male counterparts. Girls show stage 4 behaviors around 60 months, whereas boys reach this stage 12 months later at 72 months. The proficient (stage 5) stage of catching is reached at 76 months for girls and 82 months for boys. Although there is little scientific data to support this view, it is believed that the girl's earlier-maturing central nervous system may account for these data.

Component Developmental Sequence of Two-Handed Catching

A component developmental sequence for catching exists that is the product of an integration of several pieces of empirical work. This sequence consists of a 4-step arm component, 3-step hand-action component, and 3-step body-action component (Haywood & Getchell, 2009). The original catching sequence was proposed by Harper (1973) and cited by Roberton and Halverson (1984). Later, Strohmeyer, Williams, and Schaub-George (1991) used a mixed longitudinal sample to attempt to validate these sequences. The hand and body components were validated, but the arms were not. Thus, a modified arm component was adapted from Haubenstricker, Branta, and Seefeldt (1983) and added to the Strohmeyer et al. (1991) hand and body components, resulting in the three-component sequence in **TABLE 11.6**.

Constraints in Catching

There are many individual, task, and environmental constraints that influence the performance of catching, as shown in **TABLE 11.7**.

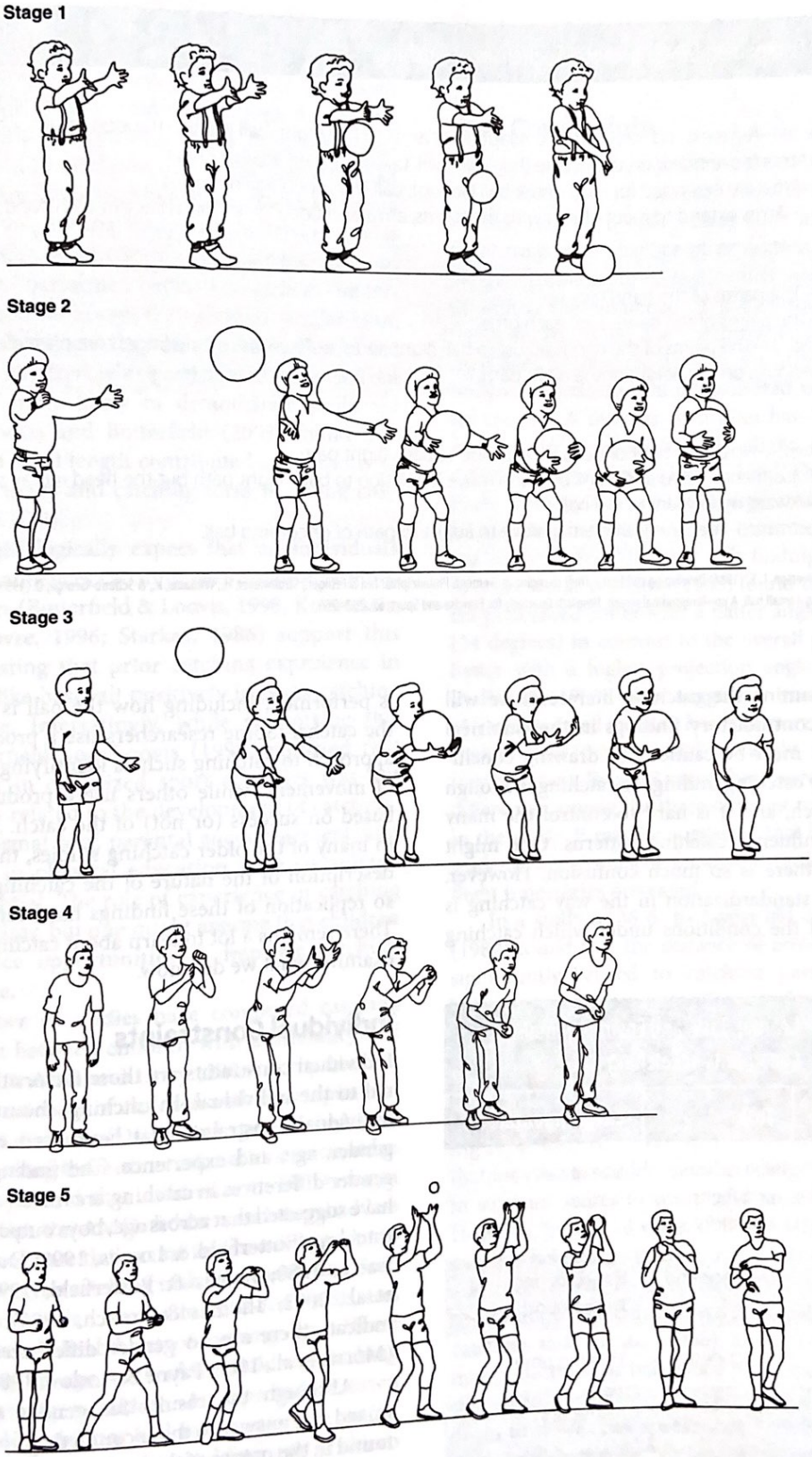


FIGURE 11.6 Developmental sequences of catching.

Reprinted with the permission of Dr. Crystal Branta and the Michigan State University Motor Performance Study.

TABLE 11.6 Component Developmental Sequences of Catching

Arm

A1 *Little Response*—Arms extend forward, little adaption of arms to ball flight; ball is often trapped against chest.
A2 *Hugging*—Arms move sideways to encircle (hug) the ball; ball is trapped against chest.
A3 *Scooping*—Arms are extended forward under ball (scoop); ball is trapped against chest.
A4 *Arms "Give"*—Arms extend to meet object with the hands; arms and body "give"; ball is caught with hands.

Hands

H1 *Palms Up*—The palms of the hand face up.
H2 *Palms In*—The palms of the hands face each other.
H3 *Palms Adjusted*—The palms of the hands adjust to ball flight and size. Thumbs or little fingers are placed close together, depending on the height of the flight path.

Body

B1 *No Adjustment*—No adjustment of body in response to ball's flight path.
B2 *Awkward Adjustment*—Arms and trunk begin to move in relation to ball's flight path but the head remains erect, creating an awkward movement to the ball.
B3 *Proper Adjustment*—Feet, trunk, and arms move to adjust to path of oncoming ball.

Roberton, M. A., & Halverson, L. E. (1984) Developing children – Their changing movement. Philadelphia: Lea & Febiger.; Strohmeyer, H., Williams, k., & Schaub-George, D. (1991), Developmental sequences for catching a small ball: A pre-longitudinal screen, Research Quarterly for Exercise and Sport, 62, 257–266.

As we examine the catching literature, we will find a lot of contradictory findings in the empirical literature. We must be cautious in drawing conclusions from the catching findings as catching is a tough task to research, and it is hard to control the many factors that influence catching patterns. One might wonder why there is so much confusion. However, there is little standardization in the way catching is evaluated and the conditions under which catching is performed, including how the ball is delivered to the catcher. Some researchers use a process-oriented approach to catching such as identifying the patterns of movement, while others use a product approach based on success (or not) of the catch. Additionally, in many of the older catching studies, there was little description of the nature of the catching conditions, so replication of these findings has been impossible. There remains a lot to learn about catching, but let us examine what we do know.

TABLE 11.7 Learner, Task, and Environmental Constraints in Catching

Individual	Task	Environmental
Gender	Ball location and flight trajectory	Size of ball
Age	Distance and height	Ball color and background
Experience	Ball speed	Viewing time
Body parameters		Instruction
Disability		Focus of attention

Individual Constraints

Individual constraints are those factors that are internal to the individual. In catching, the major areas of individual constraints that have been examined are gender, age, and experience. The findings relative to gender differences in catching are mixed. Some studies have suggested that across age, boys outperform girls in catching (Butterfield & Loovis, 1998; DuRandt, 1985; Isaacs, 1980; Loovis & Butterfield, 1993; McKenzie et al., 2002; Thomas & French, 1985), while others indicate there are no gender differences in catching (Morris et al., 1982; Payne & Koslow, 1981).

Although the results for gender appear to be mixed, the answer to these conflicting findings may be found in the nature of the catching task set for the children and the way the authors identified a successful or proficient catching pattern. Morris and colleagues (1982) suggested that age was a more important factor

than gender in children ages 3 to 6 years. Other work agreed with this finding, indicating that as a child got older (4–8 years), catching performance increased (DuRandt, 1985), and that chronological age was more influential on catching scores than other factors (DuRandt, 1985). Loovis, Butterfield, and Bagaka (2008) examined catching behaviors across time in a multicohort longitudinal design of children in grades K–8, 2–8, and 4–8. In contrast to other literature on catching, boys performed better than girls in the initial K–8 cohort, although they showed similar slow, steady growth trajectories over the nine years of the study. Also, children who participated in organized sports were more likely to demonstrate proficient catching. Loovis and Butterfield (2003) found that age, sex, and hand length contributed significantly to catching accuracy and catching form in young children (grades K–2).

We might logically expect that an individual's experience influences catching performance. A number of studies (Butterfield & Loovis, 1998; Kourtessis, 1994; Lefebvre, 1996; Starkes, 1986) support this view, suggesting that prior catching experience in ball sports like baseball positively impacts catching performance. Interestingly, while supporting this view, Butterfield and Loovis (1998) reported that engagement in organized sport activities was not significantly related to the development of catching. Rather, informal play, parental encouragement, and instruction in physical education were considered more influential. The role of experience in catching is far from clear, but one might assume that children need practice opportunities to improve catching performance.

A number of studies have compared catching performance between children with a disability and those without. Astill and Utley (2006) compared the two-handed catching of children with developmental coordination disorder (DCD) and age matched controls (AMC) using three-dimensional kinematic video analysis. They found that children with DCD caught fewer balls than the AMC children and they had less ability to coordinate their arms and hands to adapt to the demands of the catching task. Kourtessis and Reid (1997) found similar results for children with and without physical disabilities of varying ages. There was a finding for age, with older children catching better than younger children. As expected, children with physical disabilities had lower scores in catching than typically developing children and children who were ambulatory with a physical disability had better scores than those who were not ambulatory. However, when the children's knowledge of catching was assessed, no difference was found between the children with a physical disability and those without.

Task Constraints

Task constraints are factors related to the goal of the activity. In this section we will examine studies that deal with task factors such as ball location, flight trajectory, distance of projection, and effects of height of interception. McConnell and Wade (1990) examined the influence of a ball projected to different locations on the catching skills of 108 children ages 5–10 years. Tossing a ball too close to the body or too far away was associated with unsuccessful catches. A number of studies have examined the relationship between a ball's flight trajectory and catching performance (Bruce, 1966; DuRandt, 1985). Early work by Bruce (1966) suggested there was no relationship between two ball trajectories and catching performance. However, this finding is in contrast to other work. Williams (1968) found unskilled catchers performed better with a flatter angle of projection (34 degrees) in contrast to the overall group that did better with a higher projection angle (44 degrees). DuRandt (1985) also suggested younger children (4 years) seemed to catch low trajectory balls best, and slightly older (6 years) children caught medium trajectory balls best. By age 8 years, there were no significant differences among the three different trajectories used in the study. It may be suggested that by age 8 years, students are proficient enough to adjust to varying flight trajectories presented.

In a study of 36 6- to 7-year-old children, Payne (1982) found that the distance of projection was not significantly related to catching performance, but ball size was. In contrast, other scholars (Belka, 1985; McConnell & Wade, 1990) found that catching success was greater for near distances as opposed to intermediate and far distances. Again, the contradictory findings in this area probably lie in the ways in which catching behaviors were evaluated. Belka (1985) suggested that for younger children, a chest-height catch resulted in superior scores to waist- and knee-height catches. However, by age 10 years, children were proficient in varying heights of interception such as chest, waist, and knee height. The speed a ball is tossed also affects the nature of the coincidence-anticipation part of the catching task. Bruce (1966) found catching performance declined as ball speed increased from 25 feet/second to 33 feet/second. However, slowing the toss down to slower ball speeds may not be the answer, as young children are often inaccurate with these slower speeds. They tend to move too early to anticipate the ball (Haywood, Greenwald, & Lewis, 1981; Isaacs, 1983).

Environmental Constraints

Environmental constraints deal with those factors external to the individual. Environmental constraints include ball size, ball color and background color, viewing times, and the influence of instruction and focus on catching. Many teachers will select a larger ball to catch when working with young children. Early work by Smith (1970) supported this view, indicating larger balls were easier to catch. Smith tied this rationale to the young child's lack of ability to track the ball and less skill in the fine motor control aspect of the task. Other studies using the outcome of the catch as the means of assessment (e.g., whether the hands made contact with the ball or whether they maintained control of the ball) supported this notion, showing that children catch larger balls more successfully than smaller balls (Payne, 1985; Payne & Koslow, 1981). In contrast, some studies have shown that smaller balls result in better catching performance (Isaacs, 1980; Wickstrom, 1983). The rationale behind this work is that children were forced to use their hands to catch a small ball, but with bigger balls they could resort to hugging the ball into their chest. Clearly, when a teacher changes the size of the ball to be caught, she influences the catching pattern used. We believe that if children are incapable of catching a smaller ball, then a larger ball should be used to build success and motivation. Once children can catch a ball with their hands, the teacher should systematically decrease the size of the ball.

Another factor that influences catching is ball color and background. Morris (1976) found overall, blue and yellow balls were caught more readily than white balls, and specifically that 7-year-olds catch blue balls against a white background best. As children get older, the influence of color diminishes. Isaacs (1980) reported an interesting finding relative to ball color: a child caught his preferred color ball more successfully than other color balls.

Children need to visually track a ball to catch it, thus the amount of time they have to view the ball influences catching performance. Research has found that as viewing time decreases, so does the success of catching the object (Whiting, Gill, & Stephenson, 1970). Other work has suggested that older children better predict the position of the ball in the air for interception when viewing time is short (Lefebvre & Reid, 1998).

One of the major environmental constraints that influences catching performance is instruction. Given the critical nature of catching in a wide variety of sports and games, we know relatively little about the impact of instruction on catching performance. However, those studies that have been conducted report that instruction positively impacts both the product and process aspects of catching performance (Goodway, Rudisill, & Valentini, 2002; Graham, 1991; McKenzie et al., 1998; Toole & Arink, 1982).

Toole and Arink (1982) compared the influence of movement education as opposed to traditional instruction on the motor skill performance of catching, throwing, striking, and kicking in first-grade children. The catching skill improved more from the traditional instructional approach as compared to the movement education approach. The authors suggested that the command style of instruction with demonstration and specific instructions probably accounted for this improvement. A couple of studies have compared the influence of physical education specialists to trained classroom teachers on FMS performance of children, including the skill of catching (Graham, 1991; McKenzie et al., 1998). Both studies found that instruction improved catching skills, but there was no difference between physical education specialists and trained classroom teachers. In the McKenzie et al. study (1998) catching gain scores for boys were significantly greater than those of girls, although the curriculum had a small to moderate effect on the skill improvement. In Graham's (1991) study, children improved the process and product aspects of catching across the three years as one might expect; again, there were no differences by program.

A study by Goodway, Rudisill, and Valentini (2002) is one of the few studies to take a developmental approach, using developmental sequences to examine the influence of instruction on catching development in preschoolers and kindergartners. Intervention 1 with disadvantaged preschoolers used a direct-instruction approach. Intervention 2 with developmentally delayed kindergartners used a mastery motivational climate approach to teach the intervention. Prior to the intervention, "hugging" and some "scooping" behaviors were most common for the participants in Intervention 1. The older children in Intervention 2 demonstrated more variability in their catching performance, as might be expected with an older age group. Both Intervention 1 and 2 resulted in significant pre- to postintervention changes in the arm component for the children in the intervention groups. In Intervention 1, 75% of the intervention group improved at least one level, and in Intervention 2, 68% of the intervention group improved one level. Different patterns of change were found between the interventions for the body and hand components. It was suggested that the differing task constraints in the two interventions, in the form of cue words and instructional tasks, shaped or constrained the emergence of catching behaviors. That is, the children

responded to what was taught and emphasized in the specific intervention. The authors concluded that instruction improves catching performance for preschool and kindergarten-age children. The instructional time allocated for catching was 120 minutes in Intervention 1 and 60 minutes in Intervention 2, showing that catching performance can be impacted in a relatively little amount of instructional time.

A more recent series of interesting studies about quiet eye (QE) has emerged as a feature of expertise in catching and throwing skills (e.g. throw a ball at a wall and catch it off the wall). Quiet eye refers to the tracking gaze or final fixation point of gaze in a task (e.g., focused on tracking a ball in flight or gaze is focused on a target prior to throwing at it). It is believed that QE provides a critical period where sensory information can be analyzed and integrated into a movement plan (Miles et al., 2017). Some of the earlier work in this area (Wilson et al., 2013) found differences in the duration of QE predicted differences in throwing and catching performance. Children who were better catchers and caught more balls had earlier and longer QE durations (e.g., focused their eyes on the target and on ball flight) than children who were less coordinated. Furthermore, tracking gaze duration on the ball prior to catching predicted the relationship between catching ability and catching performance. Following this work the authors (Miles et al., 2014) taught lower-coordinated children how to use QE strategies that mimicked more skilled performers. Children who received quiet eye training (QET) significantly increased their QE duration in both the throwing and catching part of the task and also improved their catching performance (from 48% to 70% success) compared to a control group. Miles and colleagues (2017) conducted a follow up QE intervention study and added a long-term retention test six weeks after the QET to determine the long-term impact of QET on catching and throwing skills. Not only did the QET group have longer QE duration on both the catching and throwing aspect of the task, they also had better catching outcomes immediately following the QET and 6 weeks later at the retention test. This interesting series of work has implications to the physical education teacher, suggesting that teachers need to direct their children's attention to both focusing on the target prior to throwing *and* focusing on the ball in flight in order to enhance catching skills.

Similar to the studies above, Abdollahipour and Psotta (2017) examined the difference between an internal and external focus on the catching skills of children. In the internal focus (IF) condition, children concentrated on their hands as they caught the ball. In the external focus (EF) condition, children concentrated on the ball. In the Control condition, there were no focus instructions. The results from this study support the findings of the QE studies where catching performance was better in the EF (focused on the ball) than the IF condition, suggesting that an external focus of attention may be more beneficial in an interceptive catching skill in children.

In summary, a review of the catching literature suggests the following:

- Valid developmental sequences exist for catching.
- Gender differences are present in stages of catching with girls (typically) better than boys.
- Individual, task, and environmental constraints influence catching performance.
- Instruction positively impacts the performance of catching with the emergence of catching development shaped by the nature of the intervention.
- Focusing the gaze of the performer on the ball in flight helps enhance catching performance.

Kicking

Kicking is a ballistic skill that is a form of striking with the foot. Many sports use variations of kicking, but the most popular sport that relies on kicking skills is soccer, or football as it is called in much of the world. Soccer has become a worldwide sport played by millions of people in over 200 countries played by approximately 265 million players. Around the world, kicking is used in other organized sports such as American football and rugby, and also in cultural activities such as sepak tekraw, hackey-sack, or shuttlecock.

Prerequisites to Kicking

Children need a number of capacities in order to be able to kick. Foot-eye coordination is most critical and is impacted by the cephalo-caudal law (head to



Learning how to dribble a soccer ball begins with the fundamental movement skill of kicking.

© Ariel Skelley/DigitalVision/Getty Images

toe) of development. In the beginning, young children have little "understanding" of where their feet are and struggle to make coordinated contact with the ball, and thus often kick from a stationary position. Kicking requires dynamic balance, with the child needing to manage their center of gravity as he or she moves over the stability leg (the weight-bearing leg) in more advanced kicking. Overlock (2004) found a significant relationship between static and dynamic balance ability and kicking. Kicking also requires more sophisticated perceptual-motor skills and multi-limb coordination in more skilled kickers. For heavier children, the child's strength to weight ratio might impact the child's ability to bear his or her body weight on one leg.

Despite the large number of people around the world using kicking skills, relatively little is known about the development of the skill and the individual, task, and environmental constraints associated with kicking. The one skill that has limited research on it is place kicking, a form of kicking in which the child kicks a ball placed on the ground. It is believed that place kicking is a foundational skill that, once mastered, enables children to apply their kicking skills to other skills such as foot dribbling and passing.

Proficient Kickers

As for all of the other fundamental motor skills, proficient kickers apply biomechanical principles to maximize the performance dynamics of the kick. Proficient kickers are able to adjust the force, distance, trajectory, and type of kick to changing task dynamics in order to accomplish the goal of the task. If you watch a professional soccer game, you will see a soccer player perform hundreds of variations of kicks from soft touches where the ball is lightly kicked a few feet to forceful kicks where the ball is driven halfway down the field. The type of kick performed depends on the force and position of the ball, when it is received, and also the intended outcome of the kick. In kicking, there is a stabilizing leg that bears body weight and a manipulative leg that contacts the ball (Gabbard, 2004). Like throwing, kicking has been viewed both from a process (pattern of movement) and product (outcome of movement, e.g. velocity) perspective.

There are three parts to a proficient place kick: preparatory action, force production, and follow-through. The characteristics of a proficient kicker are reported in **TABLE 11.8**.

Unlike skilled kickers who have preparatory, force production, and follow-through actions, initial kickers tend to show a single motion that lacks the power-producing aspects of the proficient kick. Most likely due to poor dynamic balance and eye-foot coordination, less skilled kickers tend to stand behind the ball in a stationary position. They push the ball forward with a flexed leg, and have no observable rear leg swing, and there is little, if any, motion of the upper body and the arms. Obviously, with a motion as primitive as this, the child is unable to adapt the kick to sports and games or other more complex environments.

TABLE 11.8 Characteristics of a Proficient Kicker

Preparatory Action
Continuous motion into the ball
Long last step (or leap) before the ball
Stabilizing foot beside or slightly behind ball
Trunk slightly leaned back
Force Production
Manipulative leg starts back with knee flexed
Forceful forward swing of leg with sequential inertia—thigh rotates first followed by lower leg
Leg straightens as it makes contact with ball
Trunk leans back at contact
Follow-through
Manipulative leg travels vigorously forward and upward, often causing the stability leg to come off the ground and perform a hopping pattern (this dissipates force)
Trunk leans backward
Arms in opposition to legs to counter the rotatory forces of leg

Development of Kicking

Only one group of researchers has identified a four-stage developmental sequence for kicking performance (Haubenstricker et al., 1981). Table 11.1 and **FIGURE 11.7** portray the developmental sequence of kicking a ball.

In stages 1 and 2, the child is stationary behind the ball and the kick has little functional utility; the child often demonstrates a loss of balance as he or she kicks the ball. It is not until stage 3 that the child can perform a continuous movement into the ball with a step-kick pattern or short run and kick. In this stage, the child begins to develop more force by getting the manipulative leg behind the trunk for force production. By stage 4, the child has added a long last step or leap into the ball to enable positioning of the manipulative leg behind the body, then create a powerful leg drive to contact the ball and follow-through actions to dissipate the force generated from the powerful kick.

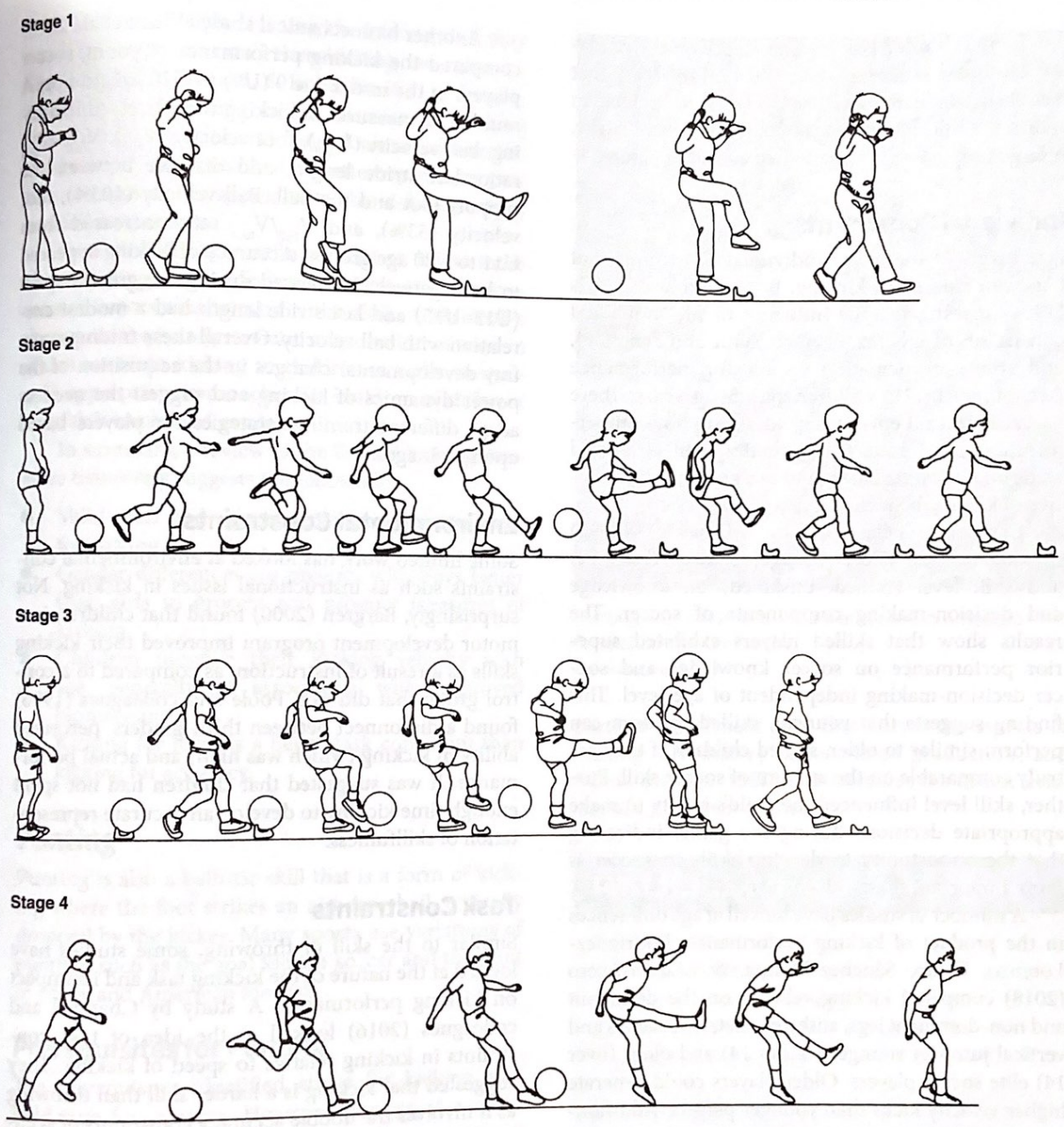


FIGURE 11.7 Developmental sequences of kicking.

Reprinted with the permission of Dr. Crystal Branta and the Michigan State University Motor Performance Study.

Figure 11.5 shows the age at which 60% of girls and boys perform a particular stage of kicking. Early (stage 1) kicking behavior emerges around 20 months for boys and girls. At this point boys begin to be in advance of girls, a trend that increases with age. In these early stages, children will often alternate their kicking foot, and dominance of one foot over the other has yet to be determined by the child (Gabbard, 2004). Gabbard (2004) suggests that humans are innately drawn to stabilize on their left side, leaving the right side as the manipulative limb, and that this shift to right-footedness occurs toward middle childhood. Interestingly, the incidence of left-footedness is consistent across the life span (Gabbard & Iteya, 1996). By stage 3, there is a marked difference between boys who acquire this stage of kicking at 54 months and girls who do not reach it until 74 months. The final stage of kicking takes a long time to emerge at 87 months for boys and 99 months for girls. Gender differences favoring boys are not only found in process measures such as developmental stages, they are also found in product measures such as distance kicked, and these differences increase with age (DeOreo & Keogh, 1980).

There is limited empirical evidence on the fundamental motor skill of kicking. Much of the work that has been conducted has been relative to kicking in sports, specifically the arena of elite soccer and rugby. A large proportion of it is biomechanical in nature.

Individual Constraints

Age is one of the major individual constraints that has been studied in kicking. Butterfield and Loovis (1994) investigated the influence of the individual constraints of age, sex, balance (static and dynamic), and sports participation on kicking performance (technique) in 716 children ages 5–14 years. There was a significant effect for gender, with boys outperforming girls (grade 6 boys better than girls) and static and dynamic balance were significantly predictive of kicking behaviors.

Campos, Gallagher, and Ladewig (1995) investigated the effects of age (8–10 and 12–14) and skill level (skilled, unskilled) on knowledge and decision-making components of soccer. The results show that skilled players exhibited superior performance on soccer knowledge and soccer decision-making independent of age level. This finding suggests that younger, skilled children can perform similar to older, skilled children if they are truly comparable on the amount of soccer skill. Further, skill level influenced the child's ability to make appropriate decisions during the game, indicating that the opportunity to develop skills in soccer is more important than a child's age.

A number of studies have looked at age differences in the product of kicking performance. Rodríguez-Lorenzo, Olmo, Sánchez-Molina, & Martín-Acero (2018) compared kicking velocity on the dominant and non-dominant legs, anthropometric variables and vertical jump in younger (under 14) and older (over 14) elite soccer players. Older players could generate higher velocity kicks than younger players. Additionally, vertical jump tests and anthropometric measurements were associated with kicking ball velocity. The findings from this study suggest individual factors like age, body structure, and muscular power may be related to kicking velocity.

A kinematic study by Bransdorfer (1999) examined the relationship between kicking kinematics and skill level in 20 3- to 8-year-old children. The results reported knee flexion at contact for all four stages of skill level of players. Also, there was a segmental relationship between deceleration of the thigh and acceleration of the shin in skilled (stage 4) kickers as predicted. Some evidence of this relationship was also found in stage 3 kickers.

Another biomechanical study (Vieira et al., 2018) compared the kicking performance of young soccer players in the under age 9 (U9) to U20 age groups. A number of measures of kicking were assessed including: ball velocity (V_{ball}), foot velocity (V_{foot}), V_{ball}: V_{foot} ratio, last stride length, and distance between the support foot and the ball. Ball velocity (103%), foot velocity (53%), and V_{ball}/V_{foot} ratio increased from U11 to U20 age groups. Accuracy of kicking appeared to be negatively influenced during the growth spurt (U13–U15) and last stride length had a modest correlation with ball velocity. Overall these findings portray developmental changes in the acquisition of the power dynamics of kicking and suggest the need to adapt different training strategies for players based upon their age.

Environmental Constraints

Some limited work has looked at environmental constraints such as instructional issues in kicking. Not surprisingly, Bargren (2000) found that children in a motor development program improved their kicking skills as a result of instruction, as compared to a control group that did not. Poole and colleagues (1996) found a disconnect between third-graders' perceived ability in kicking (which was high) and actual performance. It was suggested that children had not spent enough time kicking to develop an accurate representation of skillfulness.

Task Constraints

Similar to the skill of throwing, some studies have looked at the nature of the kicking task and its impact on kicking performance. A study by Chappell and colleagues (2016) looked at the idea of task constraints in kicking relative to speed of kicking. They suggested that kicking is a harder skill than throwing as it involves the double accuracy constraints of accurately contacting the ball with the foot and producing an accurate goal-directed kick. Thus, such task complexity may influence the speed of a kick, variability in kicking speed and resultant accuracy. Young adults (N = 28; 18- to 25-year-olds) kicked a playground ball at various percentages (50–100%) of their maximum speed at a wall target analyzing speed variability and spatial error. Speed variability decreased as the speed of the kick got closer to maximum. The findings from this study did not support the speed-accuracy tradeoff with a "band width" effect where kicking at higher speeds (70–79% of max) resulted in greater accuracy than lower speeds (59% or less). Overall these findings suggest that kicking at higher speeds

(e.g., kick hard) while learning the kicking skill may result in better outcomes than kicking for accuracy. Similarly, Mally, Battista, & Roberton (2011) demonstrated that increasing target distance in kicking (resulting in a harder and faster kick to achieve the task) with children resulted in better movement pattern changes in the approach to the kick, leg swing, and follow-through.

Overall, there is a definite need to know more about kicking and the individual, task, and environmental factors that constrain the skill. Additionally, there needs to be a systematic examination of ways in which we teach kicking to children in order to evaluate appropriate approaches for children of different ages, skill levels, and gender.

In summary, a review of the limited kicking literature tentatively suggests the following:

- Valid total body developmental sequences exist for kicking.
- Gender differences are present, with boys better than girls in process and product measures of kicking.
- Children increase their kicking velocity with age, generally in association with improved biomechanics.
- Kicking for force is a better task constraint than kicking for accuracy.

Punting

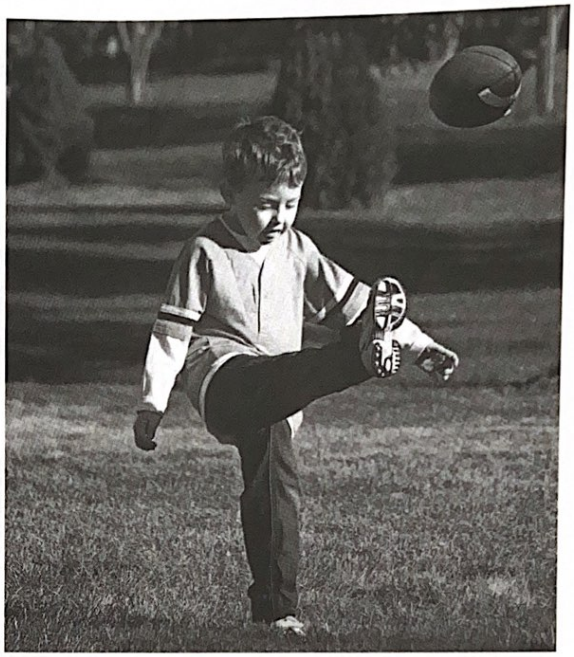
Punting is also a ballistic skill that is a form of kicking where the foot strikes an airborne ball, typically dropped by the kicker. Many sports use variations of punting, such as the goal kick in soccer and the punt in rugby and American football.

Prerequisites for Punting

The prerequisites identified above for kicking also hold true for punting. However, punting is a more complex skill than kicking in that the player must drop the ball to his or her foot in order to punt it. Thus, punting requires eye-hand-foot coordination, a significant degree of balance, and perceptual motor abilities involving multi-limb coordination. As with kicking, there is little or no empirical evidence to guide the teacher and coach in the learning process.

Proficient Punters

Punting follows many of the biomechanical principles of kicking in order to maximize the power-producing dynamics of the punt. Proficient punters can punt the ball with precision to a specific location on a field and also punt for distance. There are three parts to a proficient punt that mirror the aspects of kicking: preparatory action, force production, and follow-through. **TABLE 11.9** identifies the characteristics of a proficient punter.



Punting is a fundamental skill that is used in American football, soccer, and rugby.

© lissart/E+/Getty Images

TABLE 11.9 Characteristics of a Proficient Punter

Preparatory Action
Arms extended in front of trunk
Continuous motion into the ball
Long last step (or leap) before the kick
Trunk slightly leaned back
Force Production
Manipulative leg is back with knee flexed
Forceful forward swing of leg with sequential inertia—thigh rotates first followed by lower leg
Leg straightens as it makes contact with ball
Ankle extended at ball contact
Trunk leans back
Follow-through
Arms move to side and then move in opposition to kicking leg
Manipulative leg travels vigorously forward and upward, often causing the stability leg to come off the ground and perform a hopping pattern (this dissipates force)

The performance of an initial or inexperienced punter is very similar to that of a poorly skilled kicker. Initial punters (Seefeldt & Haubenstricker, 1978) often start from a stationary position, as moving into the ball is too complex for such an inexperienced punter. Novice punters tend to toss the ball up into the air rather than drop it onto their foot, and demonstrate a pattern where they raise their manipulative leg in tandem with their arms (a pattern known as yoking). The manipulative leg does not have a rear-leg swing, and the trunk and arms have little action. In contrast, experienced punters are able to transfer the power created from the movement into the ball into ball velocity and distance demonstrating much more sophisticated biomechanics.

Development of Punting

Roberton (1984) hypothesized a component sequence for punting consisting of a four-step "ball release phase: arm component," three-step "ball-contact phase: arm component," and three-step "ball-contact phase: leg action component." This approach was not validated. The same group of researchers that developed a sequence for kicking also developed a total body four-stage sequence for punting (Seefeldt & Haubenstricker, 1978). Table 11.1 and **FIGURE 11.8**

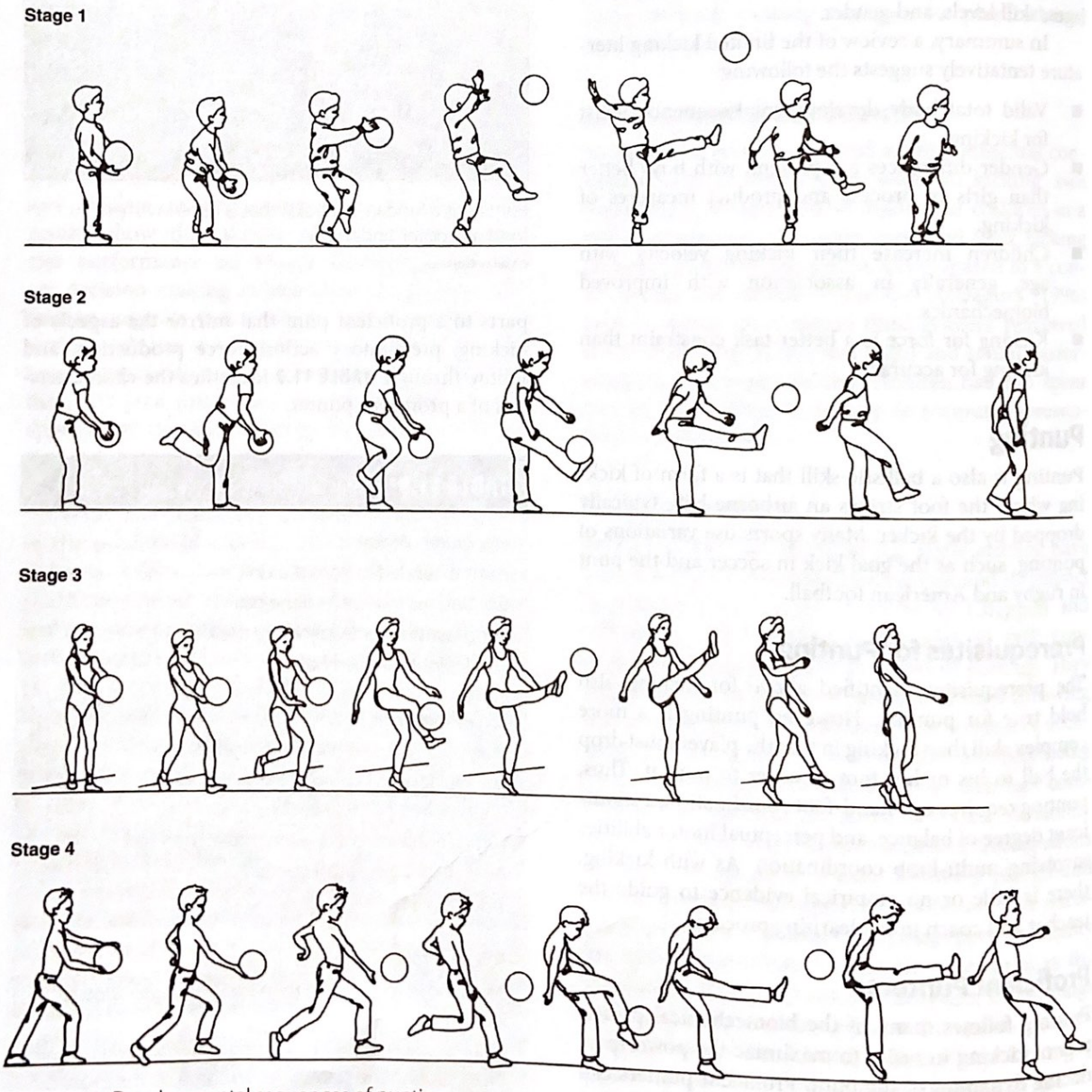


FIGURE 11.8 Developmental sequences of punting.

Reprinted with the permission of Dr. Crystal Branta and the Michigan State University Motor Performance Study.

illustrate the four stages of punting a ball for force. Except for dropping the ball, they mirror the stages of kicking. Stages 1 and 2 are stationary, and it is not until stage 3 that the child can step and drop the ball. By stage 4, the child has added the necessary power dynamics to produce a forceful punt that can be used productively in sports and games. There are no age and stage data available for punting, although experience with children suggests that kindergarten-age children are still at the rudimentary stages, and typically it is not until later elementary school or middle school that you might see a more proficient punt from the average child. Although we do not empirically know if gender differences exist with punting, one might suspect that they do, given these data on kicking.

There is almost no empirical data on the punting skills of children. A small number of studies have looked at various aspects of punting in elite sports like Australian-rules football and American football. The only study found on punting with children examined the influence of two instructional approaches (teacher- versus learner-rotated format) on the punting skills of fifth-grade children. Both approaches were valuable in teaching punting to children; however, the learner-rotated format was most profitable for low-ability children (Goldberger & Gerney, 1990).

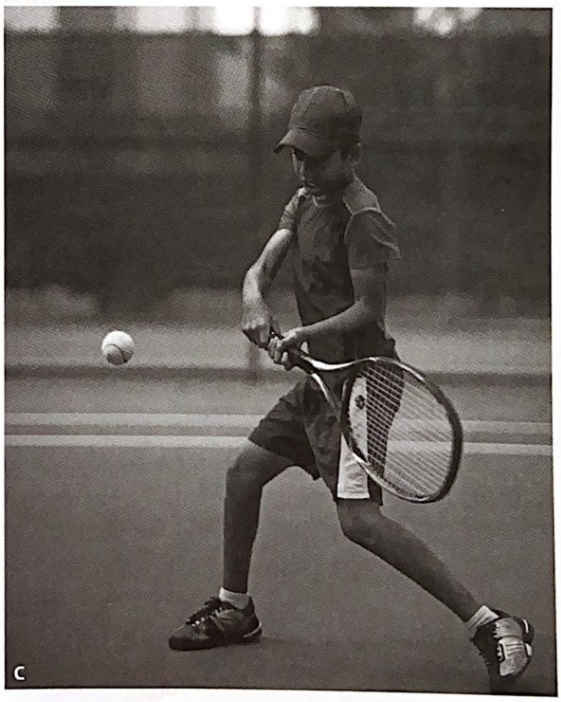
In conclusion, the developmental sequences on kicking and punting are very similar and teachers can apply their knowledge from one to the other. It makes sense that children should have developed basic competence in kicking skills (e.g., stage 3) before beginning to focus on putting which is a much harder coordination task. Kicking and punting skills are important to teach, especially ensuring that girls get plenty of opportunity to practice and develop their skills due to the gender differences found in kicking favoring boys. There is a strong professional body of literature, mostly in the soccer coaching journals, that has much to share about what coaches "know" (from experience) about teaching kicking. However, we know almost nothing about this skill empirically. The area of kicking and punting is wide open to empirical investigation.

Striking

Striking is a ballistic, propulsion skill that takes on many forms in many sports and is taught across the school-age physical education curriculum. There are several forms of striking, such as sidearm, underarm and overarm, one-handed, and two-handed. The kind of striking selected is, in part, influenced by the task demands such as the position of the object in the air and other environmental and task-oriented constraints. In its primitive form, young children strike balloons and







The fundamental movement skill of striking is an important factor for successful participation in softball/baseball, golf, and tennis.

(A) © A.PAES/Shutterstock; (B) © Doubletree Studio/Shutterstock; (C) © Anshu Ajitsaria/Moment Open/Getty Images

balls with their hands, body parts, and short paddles. They can strike with one hand or two. As they progress through elementary school, they learn one-handed striking in table tennis, two-handed striking with a bat (batting), and other sport-specific forms of striking such as a forearm in badminton (sidearm strike) and a volleyball serve (overarm strike). Striking is an essential skill in many lifetime activities such as badminton, tennis, squash, racquetball, volleyball, baseball, and softball. As such, one would think that we might know a lot about the development of this important skill, but the reality is we know relatively little.



DEVELOPMENTAL DILEMMA

To Play or Not to Play: That Is the Question!

Jose and Yolanda are 4-year-old fraternal twins born prematurely. Both children are small for their age but love being involved in motor skills and are begging their mother to let them join the local T-ball league that many of their friends are in. Jose runs at stage 3 and throws, catches, and strikes at stage 2. Yolanda runs at stage 4, throws and catches at stage 5, and strikes at stage 4. Their mother is worried about whether T-ball is "right" (developmentally appropriate) for her two children. There are two T-ball leagues in her community. One is very competitive. The coaches of these teams train the children very intensely three times per week and have games once weekly in preparation for travel baseball/softball. The other league is recreational and coached by parents, many of whom are not knowledgeable about the sport or children. In this league, the children meet 30 minutes before the game to warm up and practice skills and then have one game per week. As you are the physical education teacher of her older children, Jose and Yolanda's mother approaches you to ask the following questions:

- Are Jose and Yolanda on target with their motor skills?
- Should children of this age be playing organized sports like T-ball?
- Do Jose and Yolanda have the necessary skills to be in T-ball?
- If I decide to sign them up for a league, which one should I choose?
- What can I do with them at home to work on their skills?

Go back and review your developmental stages for running, striking, throwing, and catching. Discuss what it takes to participate in T-ball in terms of fundamental motor skill competence. Then consider how you would respond to Jose and Yolanda's mother. Would you have the same answer for each child?

Prerequisites to Striking

There are several factors that are important to being able to strike an object. Eye-hand (bat) coordination is critical, as is the ability to track the object with the eyes and consistently intercept an object. One motor development principle that is pertinent here is the proximodistal (development proceeds from the midline to the furthest part of the body or implement) law of developmental direction. That is, children learn to control their body from the midline out to the most distal (furthest away) part of the body. In striking a balloon with the hand, the hand is most distal to the body and hard to control in young children. However, when we put a bat in a child's hand, the end of the bat is now most distal and places a significant burden on the child to know where in three-dimensional space the bat is positioned. We have often seen a preschool or kindergarten-age child swing a bat at a stationary ball on a tee and miss the ball. The adults watching often wonder how a child can miss an object that is stationary. But for the young child, this is a complex and challenging task for which the child must comprehend the distal end of the bat, then struggle in the precise task of making the end of the bat contact the ball. If a child repeatedly misses the ball with the bat, the child needs to use a shorter bat, "choke up" on the bat, or use his or her hand as a bat in order to reduce the demands of the task. Other prerequisites to striking include the dynamic balance necessary to step and swing the bat with force, along with the core strength needed to segmentally rotate the trunk. As individuals progress to become skilled strikers, they can make amazingly accurate judgments and perform precise movements in short periods of time, as evidenced by Major League Baseball players.

Proficient Strikers

Proficient strikers are able to adjust the position of the body, arm, and implement (racket or bat) to meet the incoming object, connect with it, and impart a specific amount of force to the object to precisely place it on the playing field or court. Thus, striking is both a reception skill (receive the ball) and a projection skill (impart force to send the ball away). For example, the skilled badminton player can powerfully place the birdie right to the edge of the service line, or complete a soft touch and "drop shot" the birdie carefully over the net. In the same manner, skilled batters can connect with a curveball pitched at more than 160 kilometers per hour and place the ball on the field in order to advance the runner to the next base. Sidearm striking and batting share many similar characteristics, especially in the force production part of the movement. Where

TABLE 11.10 Characteristics of a Proficient Striker

Sidearm Striking	Batting
Preparatory Action	*Preparatory Action*
Swinging bat back in a horizontal plane	Body oriented sideways with weight on back leg
Body oriented sideways	Step and weight shifts forward as hands go back
Force Production Action	*Force Production Action*
Long contralateral step into hit	Contralateral step into hit
Swinging through a full range of motion	Swinging through a full range of motion
Differentiated trunk and hip rotation to contribute rotary forces	Differentiated rotation to contribute rotary forces
Extending arms just before contact	Combining backswing, step, pelvic rotation, trunk rotation, arm swing, ball contact, and follow-through to maximize forces
Combining backswing, step, pelvic rotation, trunk rotation, arm swing, ball contact, and follow-through to maximize forces	Extending arms just before contact
Follow-Through Action	*Follow-Through Action*
Arm comes across body	Wrists roll
Body moves across base leg	Bat swings across body
	Weight shifts to front foot

there are differences, they are in the preparatory and follow-through actions. **TABLE 11.10** identifies the characteristics of a proficient striker. Similar to other ballistic skills, there are three parts to proficient striking incorporating the preparatory action, force production action, and follow-through action.

The performance of the unskilled or initial batter is very similar to the "chopping" motion of poorly skilled throwers. Initial strikers often face the object they are trying to strike, have an overarm pattern of chopping, and swing the implement from high to low with flexion and extension of the arm and no step. The arms and wrist are often rigid, making it challenging to adjust the angle of the bat/racket to the oncoming object. Sometimes in initial striking, the timing of the child's swing can be out of sync with the flight of the object. In contrast, skilled batters stand sideways to the object and demonstrate a powerful coordination of the step, hip, trunk, shoulder, and arm components to impart force to the ball.

Development of Two-Handed Striking (Batting)

Only one group of researchers has identified developmental sequences for striking with a bat (Seefeldt & Haubenstricker, 1982). Table 11.1 and **FIGURE 11.9** show the four-stage sequence of striking with a bat. Figure 11.5 shows the age at which 60% of girls and boys perform a particular stage of striking. Initial (stage 1) striking behavior emerges around 20 months with little differences among gender. By stage 3 (emerging strikers) boys are in advance (43 months) of girls (49 months). There is then a long period of time before the emergence of proficient stage 4 behaviors: 87 months for boys and 102 months for girls.

These data in Figure 11.5 are supported by other data in the literature on striking. Espenschade and Eckert (1980) suggest that sidearm striking becomes apparent by approximately 36 months. Harper and Struna (1973) studied longitudinal changes in one-handed striking of two children across a year. This work showed that as children developed in their striking skills, they developed more of a sidearm swing, contralateral step, and spinal and pelvic rotation. Wickstrom's (1968) study of 33 preschool children ages 21 to 60 months showed that the younger children (younger than 30 months) used an overarm swing to contact a suspended ball. With some feedback, they shifted to a sidearm pattern, and by four years, their pattern resembled that of an adult. Loovis and Butterfield (1995) investigated the relationship of age, sex, balance, and sport participation on the development of sidearm striking by 717 children ages 4–14 years. Development of mature striking was associated with sex; boys performed better at all grades except in

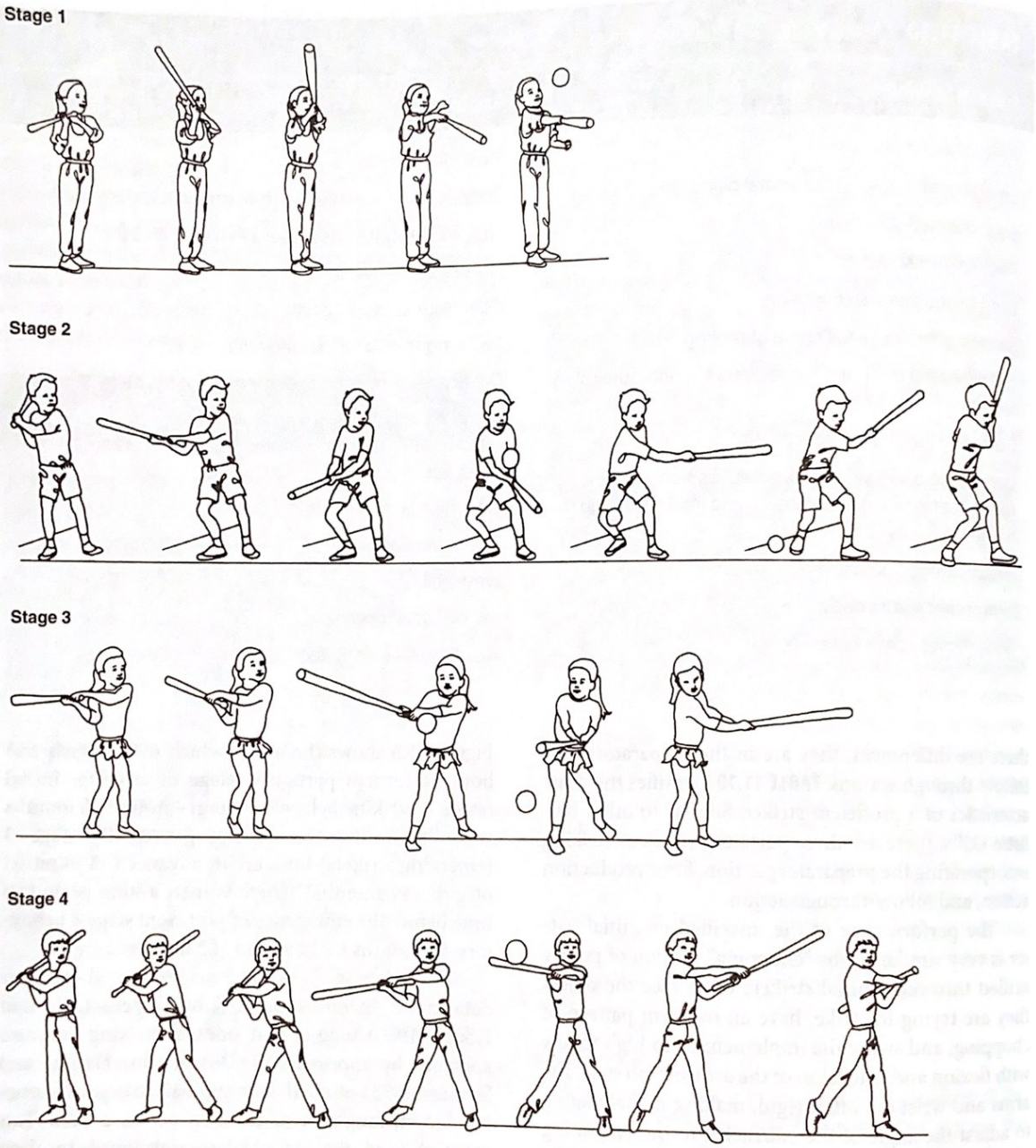


FIGURE 11.9 Developmental sequences of striking.

Reprinted with the permission of Dr. Crystal Branta and the Michigan State University Motor Performance Study.

grade 5, where the percentage of girls showing a mature sidearm-striking pattern approximated that of boys.

Other work on striking has hypothesized a component approach to striking patterns. Langendorfer (1987) and Messick (1991) used cross-sectional analysis to propose component developmental sequences for overarm striking. Langendorfer proposed eight component sequences based on observation of 1- to 10-year-olds that included the trunk, humerus, forearm, leg, pelvic range of motion, spinal range of motion, elbow angle, and racket action. In contrast, Messick proposed elbow angle, trunk, and racket sequences based on observations of 9- to 19-year-olds performing overhand tennis serves. Neither of these sequences has been validated longitudinally.

More recently Miller, Vine, and Larkin (2007) developed a striking assessment called the Miller Amalgamated Striking Instrument (MASI) using the total body sequences and the principles underlying component developmental sequences. The MASI had

10 components with 3 levels of efficiency in each component. In assessing 161 children ages 6–7 or 9–10 years on 6 trials of striking the ball for distance, the MASI found a significant correlation between process measures (performance on the MASI) and product measures (distance of ball hit). As with throwing, it appears that as the mechanics of the striking movement improve, so does the ability to translate that into product outcomes like the distance a ball is struck. Additionally, the authors suggest that product measures of striking, like striking for distance, may be simple and fast ways to evaluate striking performance to infer better striking mechanics.

There is little empirical work on striking development with many of the studies that have investigated striking actually having a different focus. Wegman (1999) investigated the influence of three practice models (repetitions, random, and combined) on the acquisition of striking in 54 girls in fourth grade. Performance significantly improved for all three groups, but the repetitions group performed better than the other two groups at the end of practice. A contextual interference effect in retention was shown for racket striking, in which the random group was significantly better than the repetitions and combined groups. This finding was attributed to the open nature of the striking skill and prior experience of participants. Johnson and Ward (2001) showed that classwide peer tutoring (students helping students) with third-grade children in a striking unit resulted in fewer total practice trials, more correct trials, and a higher percentage of correct trials than in a baseline condition. Additionally, the intervention was effective for high- and low-skilled girls, and children could accurately (90%) determine one another's performance in striking. Bram and Feltz (1995) examined the effects of batting feedback on motivational factors and batting of young baseball players. The study concluded that contact average may be more appropriate feedback for young players (compared to batting average) as it is less ambiguous and is based on a more realistic definition of success. French, Spurgeon, and Nevett (1995) proposed a study to examine differences in cognitive and skill execution components of game performance in 159 young baseball players with varying levels of expertise. The results indicated that baseball skill execution during game play maximally discriminated expertise levels.

A couple of studies have been conducted on affordances in striking. Davids, Bennett, and Beak (2002) looked at children's sensitivity to haptic (a sense of touch) information in perceiving affordances of a tennis racket for striking a ball. The findings concluded that children could demonstrate reliable preference for a tennis racket to optimally afford striking to a maximum distance in advance of performing a strike. The nonvisual condition was most reliable, suggesting that haptic information was more important in the absence of vision. Additionally, as time progressed, so did the children's affordances. Gagen (2002) found that racket size and child strength measures significantly predicted 59% of the variance in speed and control of striking a tennis ball. She concluded that reaching a critical ratio of racket size to striker size is needed to force a striker to reorganize the movement pattern.

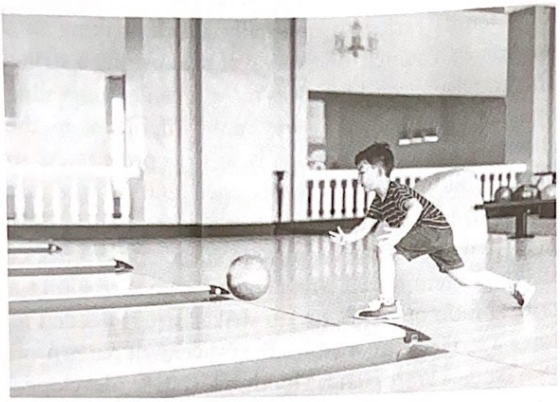
Tsuda, Ward, and Goodway (2018) developed an evidenced-based content knowledge packet for beginning tennis developing 14 instructional task sequences for upper elementary students. The content knowledge packet was unique in that it used a developmental focus to transition students from learning discrete skills like a forehand in isolation, to learning to apply those skills in more complex environments and ultimately developmentally appropriate games. The tasks in the knowledge packet were underpinned by Rink's (2012) four stages of game development model and the concept of content development.

The world of striking is varied with little empirical evidence to guide the teaching-learning process. Teachers need to consider the developmental level of the child in order to determine appropriate striking tasks. Roberton and Halverson (1984) suggest the need to scale the size and weight of the implement to the child. Much of the literature agrees that children need a sideways orientation, a long contralateral step into the object transferring weight to the front foot, good power dynamics in the swing, and follow-through. The area is ripe for research for investigators interested in striking and the individual, task, and environmental factors that influence the pattern of the strike.

Two other skills are worth mentioning, but they do not have developmental stages associated with them, they are rolling and hand dribbling (bouncing). However, when we observe these stages we definitely see differences between novice and more skillful performers.

Rolling

Rolling the ball is a useful skill in children's games and translates later into different kinds of bowling. Although rolling a ball is not part of many team sports, it does develop performance elements that can be applied in other skills. For example, in a more proficient performers, a child will step with opposition to roll the ball. This same step and weight transfer can be applied in underhand and overhand throwing and even a forehand in tennis.



Rolling is a fundamental movement skill used often in recreational activities.

© Saksit Kuson/EyeEm/Getty Images

Prerequisites to Rolling

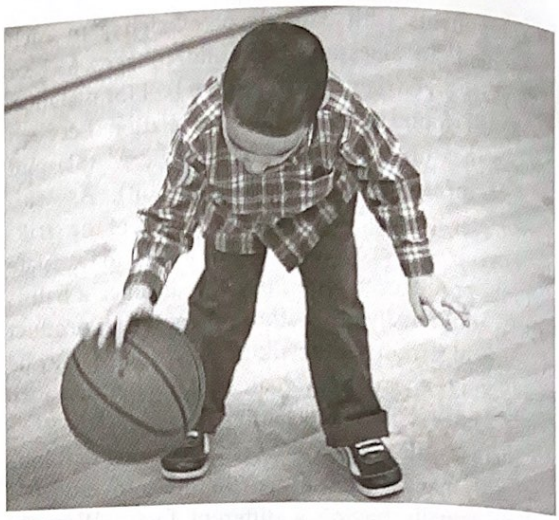
The main prerequisite to rolling a ball is the ability to be able to weight transfer with the opposite foot. This is a challenge for our younger performers. Dynamic balance and lower leg strength, along with the capability to stabilize the core as the child steps and lunges, are also important. In our younger performers, we see deficits in balance and **contralateral patterns**, often resulting in a child who faces the target with legs wide apart, bends down at the waist, and rolls the ball forward. As children become more capable of a contralateral step, they frequently struggle to stabilize the core and keep the shoulders facing the target. Thus, as their arms swing behind the body their shoulders turn and the ball often gets thrown forward rather than rolled close to the ground.

Characteristics of a Proficient Roller

The proficient roller has a smooth contralateral pattern, with a long lunge and the ball being released close to the ground. **TABLE 11.11** shows the characteristics of a proficient roller.

TABLE 11.11 Characteristics of a Proficient Roller

Preparatory Action
Start front facing with feet together
Preferred arm swings backward behind body, shoulders facing forward
Force Production
Long contralateral step forward resulting in lunge
Arm swings forward
Trunk bends at the waist
Ball released close to the ground so ball does not bounce



Developing the rhythmic timing of ball bouncing is key when learning how to dribble a basketball.

© Allen Donikowski/Moment/Getty Images

Hand Dribbling/Bouncing

Bouncing is a fundamental motor skill often called hand dribbling. It is used extensively in the sport of basketball. Dribbling typically starts with stationary dribbling, but as a child gains in skill, he or she can begin to dribble while moving. As children gain greater skills, dribbling becomes integrated with different kinds of passes and movements.

Prerequisites to Hand Dribbling/Bouncing

Hand dribbling requires that children understand how to impart force to the ball. Additionally the child needs to stabilize the core and have a significant degree of fine motor control. In a beginning dribbler, the child does not understand the necessary amount of force to impart to the ball and often the ball starts high, and gradually gets lower and lower as they don't push the ball hard enough. Most beginning dribblers have little control over the ball as they "slap" the ball with a firm wrist and flat hand or have "noodle arm" where their arm and hand are loose and have little force.

Characteristics of a Proficient Stationary Dribbler

TABLE 11.12 shows the characteristics of a proficient dribbler.

Putting Fundamental Motor Skills into Games and Sports

One of the major criticisms of the FMS literature is that few scholars have looked at the FMS in more complex environments, especially during sports and games.

TABLE 11.12 Characteristics of a Proficient Stationary Dribbler

Uses one hand to dribble the ball
Pushes the ball down with the fingertips
Ball bounces consistently about hip height
Position of the ball is controlled

From a pragmatic standpoint there is a disconnect between teaching an isolated FMS, and ultimately being able to use that skill functionally within a sport. One model of game development has attempted to conquer this issue of transitioning FMS into sports and games. Rink's stages of game development model (2012) provides a framework for teachers to plan instructional tasks that systematically develop children's competence from performing a discrete FMS to putting that skill into game play with the focus on how skills are used in games rather than the technical aspect of the skill. Rink (2012) model consists of four stages:

Stage 1 – Developing control of the object. In this stage, teachers focus on the child developing the ability to control an object and/or control his/her body with an object. As a child develops control of the object, he or she will shift from stationary to moving objects and from stationary to moving receivers. Obviously, in this stage, the child must also focus on the technical aspects of the skill, but these aspects are situated within the notion of control. Three types of actions are included (Rink, 2012):

1. *Sending actions* means the child can control the placement of an object and the force of the object to an intended place.
2. *Receiving actions* mean the child can obtain possession/control of an object with varying degrees of speed, direction of level.
3. *Carrying and propelling actions* means the child can maintain possession of the object while moving in more complex environments such as different pathways and speeds.

Stage 2 – Complex control and combinations of skills. This stage is similar to stage 1, where mastery and control of the object is important. However, in this stage, the practice conditions become increasingly more complex and include factors such as combination skills, imposing rules and playing areas, passive defenders, and cooperative games. These activities primarily aim to develop mastery of controlling the object.

Stage 3 – Beginning offensive and defensive strategies. In stage 3, there is a shift from technical skills to tactical play, and an understanding of the skill within the context of offensive and defensive roles. The assumption at this stage is that the technique of the skill is adequately developed so that it does not take the child's entire attentional focus and the child can begin to focus on the tactical elements of using the skill in a sport or game.

Stage 4 – Complex game play. The start of this stage is variable and can begin when children begin to understand offensive and defensive roles. During this stage the teacher is focused on helping the children keep the flow of the game going in order to "learn" the game. In the early phase of this stage, rules can be modified, and playing areas and team size can be decreased.

In our view, the critical stages Rink's (2012) model are stages 2 and 3 where children are slowly taking their FMS from an isolated and de-contextualized environment into a more complex, and sport-contextualized context. It is that shift from isolated FMS practice to more game-like practice that often results in learning struggles in children. Although there is little empirical evidence for this model, it does seem to be a good framework from which to take isolated FMSs into the world of games. More research needs to be conducted to examine the best instructional approaches in which to do this.

Summary

Children demonstrate developmental sequences in the acquisition of FMS during childhood. It was originally believed that children moved through these developmental sequences starting with the initial phase of movement being inefficient. As a child progressed through the developmental sequences, he or she increasingly became more mechanically proficient and better able to apply these skills in sports and games. More recently, we have taken this knowledge of developmental sequences and reconceptualized them using a dynamic systems and constraints perspective. The qualitatively different patterns of movement seen in the developmental sequences are believed to represent behavioral attractors or common ways of moving for the skill as children progress through learning the skill. Children may choose from these behavioral attractors in a movement situation, and the movement selected

will depend on the interaction of constraints imposed by the individual, environment, and task. Total body and component sequences have been proposed for five manipulation skills. Knowledge of the developmental sequences and the constraints acting on the skill better prepare the teacher, coach, or clinician to design developmentally appropriate movement experiences for children. Additionally, using Rink's stages of game developmental model may help the teacher take isolated and de-contextualized FMS and slowly put them into increasingly more complex environments.

Questions for Reflection

1. What role does FMS development play in the physical activity of children?
2. How would you break the negative spiral of disengagement in a low-skilled child?
3. Explain how the relationship between motor competence and physical activity changes from early childhood to middle childhood and adolescence.
4. Compare and contrast the total body approach and component approach to developmental sequences. How are they similar and how are they different?
5. Select catching or throwing and compare and contrast the total body or component sequences. How are these sequences similar and different? Which one is best?
6. Explain how stages of FMS are viewed within dynamic systems theory.
7. Select one of the five manipulative skills and summarize the individual, task, and environmental constraints influencing the skill.
8. In the skill above, identify how you could manipulate environmental or task constraints to make the task easier or harder for a child.
9. If you were a teacher or a researcher of throwing, what assessment would you use to track the development of throwing skills and why?
10. Take one of the manipulative skills and design an instructional activity for each of the 4 levels of Rink's stages of game development model.

Critical Readings

Branta, C., Haubenstricker, J., & Seefeldt, V. (1984). Age changes in motor skills during childhood and adolescence. *Exercise and Sport Science Review, 12*, 467–520.

Clark, J. E., & Metcalfe, J. S. (2002). The mountain of motor development: A metaphor. In J. E. Clark & J. H. Humphrey (Eds.), *Motor Development: Research and Review*, Volume 2 (pp. 62–95). Reston, VA: NASPE Publications.

Gallahue, D. L., & Cleland, F. (2003). *Developmental Physical Education for Today's Children*. (4th ed.). Champaign, IL: Human Kinetics.

Rink, J. (2012). *Teaching Physical Education for Learning*. (6th ed.). New York, NY: McGraw-Hill.

Roberton, M. A. (1978). Stages in motor development. In M. V. Ridenour (Ed.), *Motor Development: Issues and Applications*. Princeton, NJ: Princeton Book Company.

Stodden, D. F., & Goodway, J. D. (2007). The dynamic association between motor skill development and physical activity. *Journal of Physical Education, Recreation and Dance, 78*, 33–49.

Thelen, E. (1995). Motor development: A new synthesis. *American Psychologist, 50*, 79–95.

References

Abdollahipour, R., & Psotta, R. (2017). Is an External Focus of Attention More Beneficial Than an Internal Focus to Ball Catching in Children? *Kinesiology, 49*(2), 235–241.

Alstot, A. E. (2018). Accuracy of a Peer Process Assessment Performed by Elementary Physical Education Students. *Physical Educator, 75*(5), 739–755.

Angell, R. M., Butterfield, S. A., Tu, S., Loovis, E. M., Mason, C. A., & Nightingale, C. J. (2018). Children's Throwing and Striking: A Longitudinal Study. *Journal of Motor Learning & Development, 6*(2), 315–332.

Astill, S., & Utley, A. (2006). Two-Handed Catching in Children with Developmental Coordination Disorder. *Motor Control, 10*(2), 109–124.

Bargren, M. (2000). The effects of a children's motor skill development program on preschool children's motor skills. Unpublished doctoral dissertation, University of Oregon, Eugene, OR.

Barrett, D. D., & Burton, A. W. (2002). Throwing patterns used by collegiate baseball players in actual games. *Research Quarterly for Exercise & Sport, 73*(1), 19–27.

Belka, D. E. (1985). Effects of selected sequencing factors on the catching process of elementary school children. *Journal of Teaching in Physical Education, 5*(1), 42–50.

Bram, A. D., & Feltz, D. L. (1995). Effects of batting performance feedback on motivational factors and balling performance in youth baseball. *Perceptual & Motor Skills, 81*, 1367–1378.

Bransdorfer, A. F. (1999). A kinematic analysis of the developmental sequence of kicking using a direct and angled approach (Doctoral dissertation). Retrieved from Microform Publications, University of Oregon. 1998. http://kinpubs.uoregon.edu.proxy.lib.ohio-state.edu/

Browning, C. K., & Schack, F. K. (1990). Effects of instruction on throwing performances of sixth grade girls. *The Physical Educator, 47*, 144–152.