

DEVELOPMENT OF FUNDAMENTAL MOVEMENT: MANIPULATION SKILLS

KEY TERMS

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

CHAPTER COMPETENCIES

Upon completion of this chapter you should 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. If you reflect back to the *phases and stages of motor development model* shown in chapter 3, you will see that the next step in the model is the fundamental movement phase. As the journey into childhood begins, children begin the development of these *fundamental movement patterns* or **fundamental motor skills** (FMS), as they are often known. 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 for the child at this age 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 4 for more detail on Newell's constraints). For example, as children grow in height and gain

weight, such individual structural constraints can affect changes in their movement patterns. Overweight children often have difficulties hopping and 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 impact 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 interact to impact the skill performance of individuals and help explain both *intravariability* (variability of skill performance between/within different skills for one individual) and *intervariability* (variability between children of a similar age) seen during childhood and over the life span. Figure 11.1 provides a catching example of how environmental factors and the goal of the task act on 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 task and environmental constraints can be manipulated by teachers, coaches, and clinicians to promote the motor development of children.

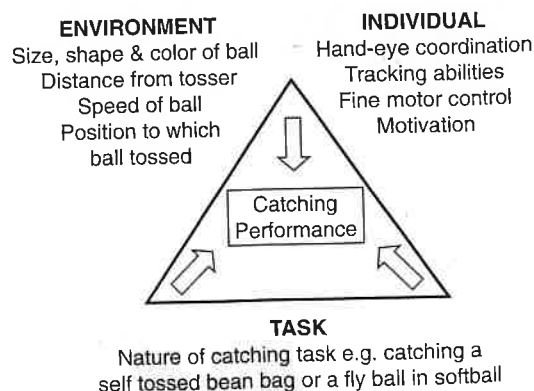


Figure 11.1

Constraints in Action: A Catching Example



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 and the next one on locomotor skills 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 developmental sequences in the specific skill. After this we will summarize how a *proficient* mover might perform this skill as compared to an *initial* or inexperienced mover. 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 letters or characters 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.

In Chapter 3, Figure 3.1, Phases and Stages of Motor Development, 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 her when participating in games such as soccer or football that 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.

More recently a conceptual model developed by Stodden and colleagues (2008) highlights the importance of FMS to engagement in lifelong physical activity. At the heart of this model is a reciprocal and dynamic relationship between motor competence and physical activity (see Figure 11.2). Motor skill competence is defined in terms of common FMS, specifically manipulative and locomotor skill patterns. An underlying premise of this model is a common misconception that children "naturally" learn FMS. However, this is not true; 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, young children's physical activity patterns may drive their development of motor skill competence.

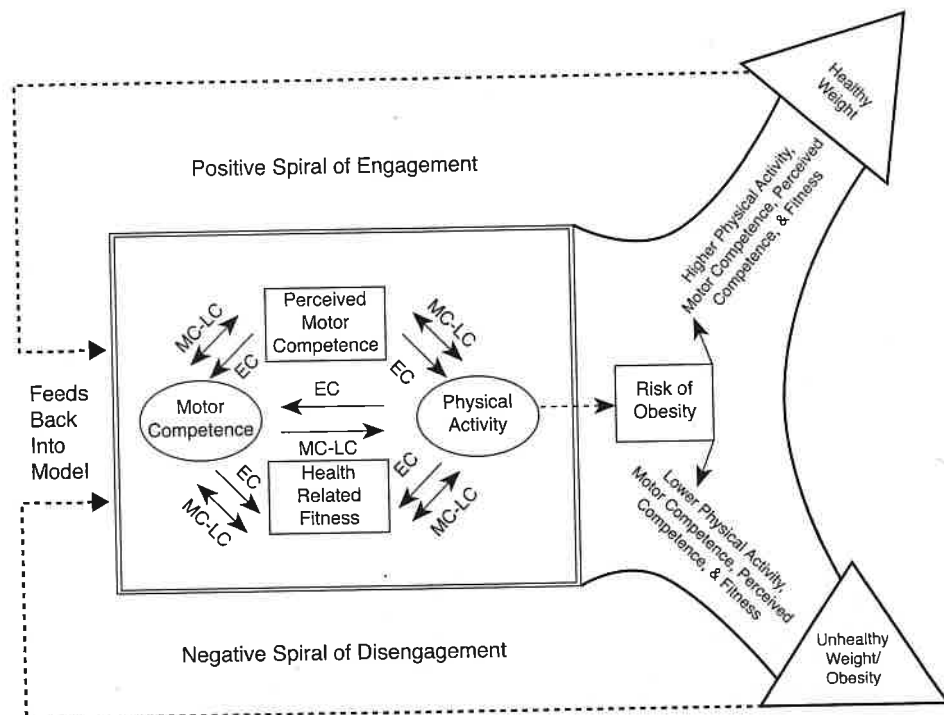


Figure 11.2
Synergistic Model of Motor Competence and Physical Activity

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 an environment for physical activity, engagement in instructional motor programs/activities, socioeconomic status, parental/sibling influences, and climate, to name but a few. However, at this point in developmental time the relationship between physical activity and motor competence is weak and has most likely 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. Children who are more skilled are also more likely to perceive themselves as competent and gain intrinsic pleasure from participating in sports and games. 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 competent. We refer to these interactions as a *positive spiral of engagement* in sports and games as these children keep engaging in sports and games and keep getting more competent. But what happens to those less competent children? By middle childhood children who are less competent in motor skills will most likely self-select out of physical activity when given a choice or engage at lower levels if required to do physical activity such as in a physical education class. Thus low motor competence drives low physical activity levels, which minimizes a child's opportunities

to improve motor competence. To compound this effect, by middle childhood children possess the cognitive capabilities to accurately assess their motor competence compared to same-age peers. They 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. Thus, low actual and perceived motor competence, along with limited physical activity, result in what the authors refer to as a *negative spiral of disengagement* from sports and games. That is, the child has limited motor competence, believes she is "not very good at sports," and thus chooses sedentary activities over physical activity. 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.



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, 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** whereby movements for the entire body are described, or (b) the **component sequences** where 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. Although seemingly different, these two approaches are more similar than different. For example, the most common profiles seen in the component approach to fundamental motor skills 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 sport, 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 (Robertson, 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 these principles.

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. In more recent years 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" movement pattern, as the most efficient pattern will vary depending on the task at hand. For example, if you stand a child five feet from a wall and tell him 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 she is capable (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.



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. In the sixth edition of this text three stages of FMS development were described: *initial*, *elementary*, and *mature*. In this edition we have modified these terms slightly. *Initial* movers are considered beginning learners and represent the first stage in a developmental sequence. The next stage is referred to as *emerging* and depending on the developmental sequence can consist of stages 2–4. The last stage is referred to as *proficient* and refers to a child who has efficient movement mechanics. 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 tennis serve, 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 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.

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 form, 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 & Robertson, 2002a). Table 11.2 outlines the characteristics of a proficient thrower.

Development of the Overarm Throw

Throwing is a complex gross motor skill that involves the interaction of different body parts

TABLE 11.1 Developmental Sequences of Five Manipulative Skills

Fundamental Motor Skill	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
	<i>Initial Stage</i>		<i>Emerging Stages</i>		<i>Proficient Stage</i>
Throw	<i>Chop</i> Vertical windup "Chop" throw Feet stationary No spinal rotation	<i>Sling Shot</i> Horizontal wind-up "Sling shot throw" Block rotation Follow-through across body	<i>Ipsilateral Step</i> High windup Ipsilateral step Little spinal rotation Follow-through across body	<i>Contralateral Step</i> High windup Contralateral step Little spinal rotation Follow-through across body	Windup Downward arc windup Contralateral step Segmented body rotation Arm-leg follow-through
Catch	<i>Delayed Reaction</i> Delayed arm action Arms straight in front until ball contact, then scooping action to chest Feet stationary	<i>Hugging</i> Arms encircle ball as it approaches Ball is "hugged" to chest Feet are stationary or may take one step	<i>Scooping</i> "To chest" catch Arms "scoop" under ball to trap it to chest Single step may be used to approach the ball	<i>Hand Catch</i> Catch with hands only Feet stationary or limited to one step	<i>Move to Ball</i> Catch with hands only Whole body moves through space
Kick	<i>Initial Stage</i>		<i>Emerging Stages</i>		<i>Proficient Stage</i>
	<i>Stationary Push</i> Little/no leg windup Stationary position Foot "pushes" ball Step backward after kick (usually)	<i>Stationary Leg Swing</i> Leg windup to the rear Stationary position Opposition of arms and legs	<i>Moving Approach</i> Moving approach Foot travels in a low arc Arm/leg opposition Forward or sideward step on follow-through	<i>Leap-Kick-Hop</i> Rapid approach Backward trunk lean during windup Leap before kick Hop after kick	
Punt	<i>Yoking-Push</i> No leg windup Ball toss erratic Body stationary Push ball/step back	<i>Stationary Leg Swing</i> Leg windup to the rear Ball toss still erratic Body stationary Forceful kick attempt	<i>Moving Approach</i> Preparatory step(s) Some arm/leg yoking Ball toss or drop	<i>Leap-Punt-Hop</i> Rapid approach Controlled drop Leap before ball contact Hop after ball contact	
Strike	<i>Chop Strike</i> "Chop" strike-bat Feet stationary	<i>Pushing</i> Horizontal push/swing Block rotation Feet stationary/stepping	<i>Ipsilateral Step</i> Ipsilateral step (back foot steps across) Diagonal downward swing	<i>Contralateral Step</i> Contralateral step Segmented body rotation Wrist rollover on follow-through	

TABLE 11.2 Characteristics of a Proficient Thrower

Proficient throwers demonstrate the following:

- 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
- Forearm lags behind humerus
- Throwing arm follows through across body

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 aged 2 to 12 years. Her most novice thrower (stage 1) was 2–3 years old with a front facing throw, stationary feet, and no trunk rotation (Wild, 1938). By 6.5 years of age children demonstrated more proficient patterns (stage 4), could step with a contralateral (opposite arm to foot) pattern, 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 (Robertson & Halverson, 1984).

Total Body Developmental Sequences of Overarm Throwing

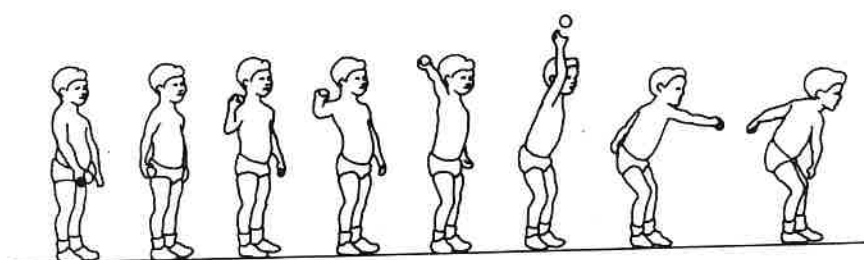
Table 11.1 and Figure 11.3 show the five-stage developmental sequence of throwing (Seefeldt, Reuschlein, & Vogel, 1972), similar to Wild's work. The initial stage of throwing (stage 1) is inefficient with a stationary base of support, front facing, and hip flexion and chopping arm action to generate

force. By stage 3 children step and throw but on the ipsilateral foot (same foot and arm). It is not until stage 4 that a child takes a contralateral step (opposite arm to leg) and begins the journey to more proficient throwing. By stage 5 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).

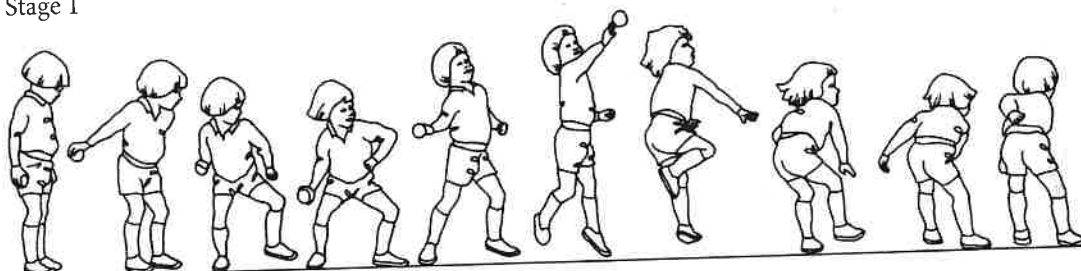
Garcia and Garcia (2002) longitudinally tracked six children aged 2 to 5 years across two years and analyzed 3,469 throws. Their findings concurred with a dynamic systems approach showing that children moved back and forward between adjacent and nonadjacent stages across time depending upon individual and environmental constraints (e.g., motivation, body awareness). 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 (Robertson, 1977).

Component Developmental Sequences of Overarm Throwing

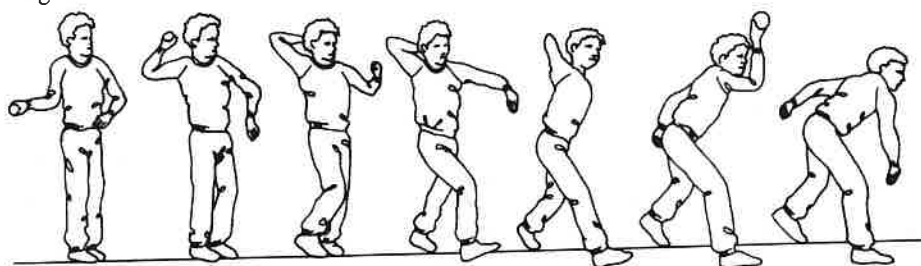
The component approach to throwing suggests throwing development should be examined at the component level; namely, the step, backswing, trunk, humerus, and forearm components (Robertson, 1977). In Table 11.3 a brief summary of the developmental sequences for each of the



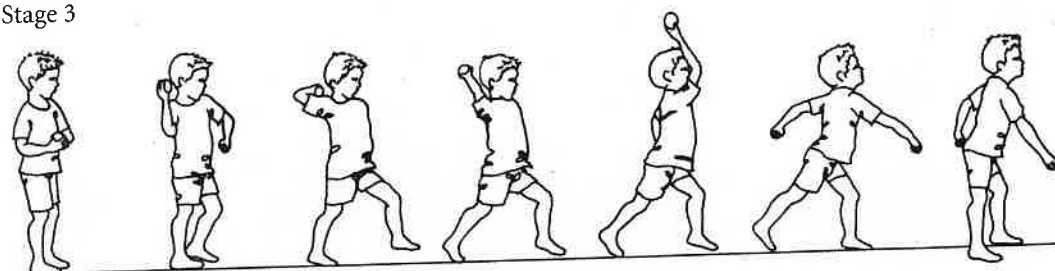
Stage 1



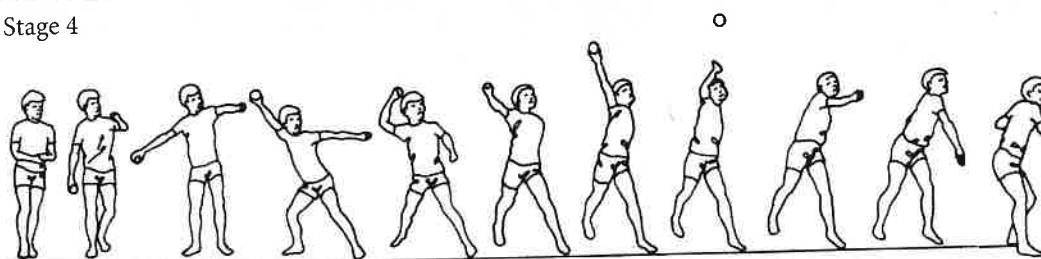
Stage 2



Stage 3



Stage 4



Stage 5

Figure 11.3

Developmental Sequences of Throwing

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TABLE 11.3 Component Developmental Sequences of the Overarm Throw

Step	Backswing
S1 <i>No Step</i> —The child throws from the initial stationary foot position.	B1 <i>No Backswing</i> —The ball in the hand moves directly forward to release from the arm's original position.
S2 <i>Homolateral Step</i> —The child steps with the foot on the same side as the throwing hand.	B2 <i>Elbow and Humeral Flexion</i> —The ball moves away from the intended line of flight to a position behind or alongside the head.
S3 <i>Contralateral, Short Step</i> —The child steps with the foot on the opposite side from the throwing hand.	B3 <i>Circular Upward Backswing</i> —The ball moves away from the intended line of flight to a position behind the head via a circular overhead movement.
S4 <i>Contralateral, Long Step</i> —The child steps with the opposite foot a distance of over half the child's standing height.	B4 <i>Circular, Downward Backswing</i> —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 <i>No Trunk Action or Forward-Backward Movements</i> —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 <i>Upper Trunk Rotation or Total "Block" Rotation</i> —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 <i>Differentiated Rotation</i> —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 <i>Humerus Oblique</i> —The humerus moves forward to ball release.	F1 <i>No Forearm Lag</i> —The forearm and ball move steadily forward to ball release.
H2 <i>Humerus Aligned But Independent</i> —The humerus moves forward to ball release in a plane horizontally aligned with the shoulder, forming a right angle between humerus and trunk.	F2 <i>Forearm Lag</i> —The forearm and ball appear to "lag" behind the shoulder.
H3 <i>Humerus Lags</i> —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).	F3 <i>Delayed Forearm Lag</i> —The lagging forearm delays reaching its final point of lag until the moment of front facing.

5 components is outlined (see Robertson, 1977 for more detailed descriptions). Under each component there are between 3 and 4 steps. A child would be rated on each of the components. For example, an initial performer 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 action is much akin 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 & Robertson, 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 rotates 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 & Robertson 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 & Robertson, 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 & Robertson, 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 Robertson (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.

Both total body and component sequences of development provide valuable information for teachers. Using developmental sequences allows teachers 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.
2. Identify the desired performance (desired attractor) for the child to perform.
3. Consider what individual factors might be influencing the child.
4. Consider how to manipulate aspects of the environment to promote the skill.
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 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.

TABLE 11.4 Individual, Task, and Environmental Constraints in Throwing

Constraints in Throwing		
Individual	Task	Environmental
• Gender • Age • Biological	• Accuracy • Force	• Size of target • Distance from target • Instruction

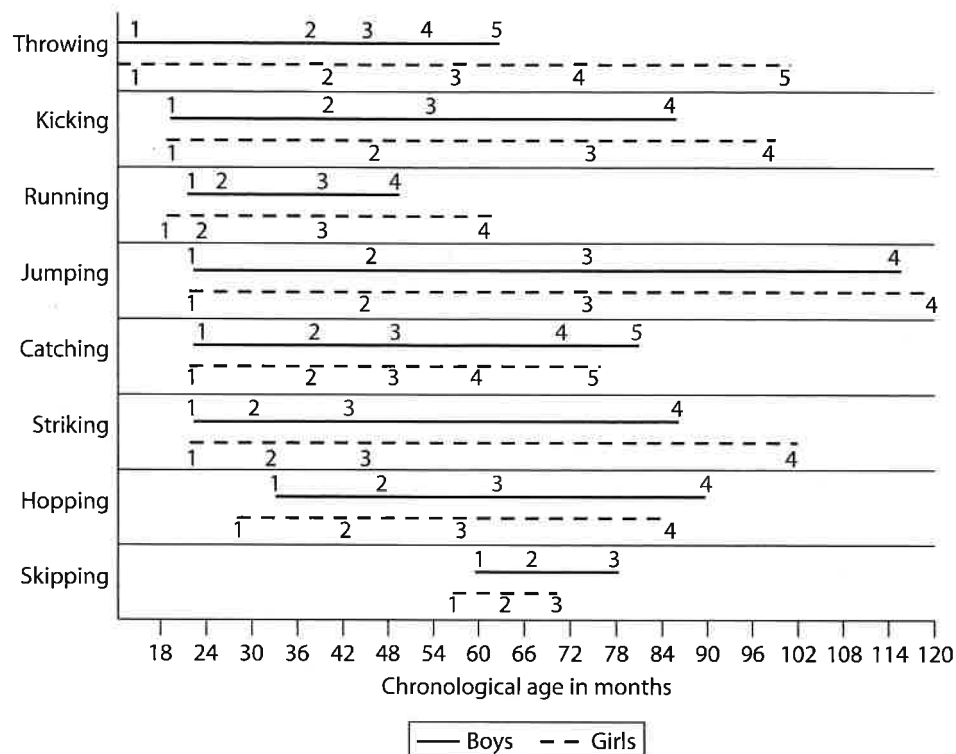
Individual Constraints in Throwing

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) manipulated the mass of 5–12-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, Langendorfer, Fleisig, and Andrews (2006a,b) 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 & Robertson, 1979; Langendorfer & Robertson, 2002a, 2002b; Robertson & 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). Gender differences are categorized as an individual constraint because of the biological factors associated with them. Figure 11.4 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 5–6-year-old girls were similar to 3–4-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 Robertson 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; Robertson et al., 1979). Runion, Robertson, & Langendorfer (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

**Figure 11.4**

Age-Related Changes in the FMS of Children

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 aged five to nine 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 Aboriginal Australian children also demonstrated gender differences with boys throwing faster than girls and 10-year-olds faster than 6-year-olds (Thomas, Alderson, Thomas, Campbell, & Elliot, 2010).

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' greater external to internal rotation rate versus girls having less of a maximum angle of twist (Thomas & Marzke, 1992); neuromuscular coordination (Yan et al., 2000); and body awareness (Garcia & Garcia, 2002).

Gender differences are not only limited to forceful throws 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 conditions (Langendorfer, 1990).

Overall, gender differences in both product and process measures of throwing have implications for the physical educator or coach. If girls are significantly worse than boys in throwing at all ages, it is important that the physical educator 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 Robertson (2002a, 2002b) identified how throwing performance changed across age by describing common attractor profiles and attractor pathways 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 Robertson (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 in addition, 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. However, differentiation of the trunk (T3) may appear after humeral lag is reached (Langendorfer & Robertson, 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 & Robertson, 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 was capable of demonstrating 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 he 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 was 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.

Manoel and Oliveira (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. Robertson (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; Robertson, 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.

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 and the size 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 females, 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, & Dunn-Rankin, 1985). Although there is little empirical literature in this area, those of us 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; we 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 aged elementary children is too small to grip the ball appropriately.

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-aged 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' on the trunk and forearm components and for girls' 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 three-week instructional program resulted in both genders improving distance thrown but boys threw further than girls with the same amount of training. In contrast, Halverson and colleagues (Halverson & Robertson, 1979; Halverson, Robertson, 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 eight-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, Robertson, Safrit, & Roberts, 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 three 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 (in press) found that when a teacher was trained to deliver aligned development feedback based upon throwing component sequences, improvements in ball velocity and throwing body components were found compared to what the teacher did naturally.

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 aged 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 more recent innovative approach to throwing instruction with 34 kindergartners compared a biomechanical-developmental approach to a traditional approach to teaching 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,b). 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 (Lorson, 2005; Lorson & Goodway, 2008) 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. 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.

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

- Valid developmental sequences exist for throwing.
- Gender differences are present in throwing, with boys better than girls.
- Children exhibit variable, nonlinear, and context-sensitive emergence of throwing behaviors in line with a dynamic systems approach.
- 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.
- 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). 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, 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. At the elite sports level we see amazing feats of catching where individuals intercept the ball in seemingly impossible situations. 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.

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 proximodistal 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 sports.

Proficient Catchers

There are many kinds of catching but the two that have received 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 11.8. 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 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. 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, assuming the ball connects with them. The timing of the catching motion is out of synch 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 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 sport 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 (Robertson & Halverson, 1984) approach to catching.

Total Body Developmental Sequence of Two-Handed Catching

Table 11.1 and Figure 11.5 illustrate the five-stage sequence of catching a ball. The first stage of this

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

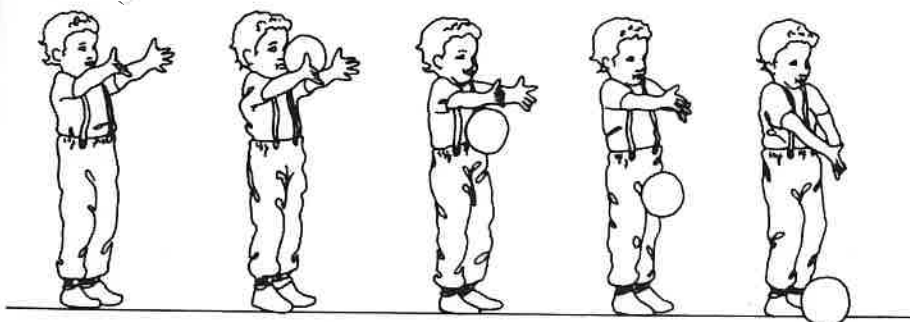
- Hands move to intercept the object—fingers adjust to precise spatial characteristics of the object (fingers up for high ball, down for low ball)
- Arms "give" on contact to absorb the force
- Fingers grasp object in well-timed simultaneous action
- Body weight transferred from front to back

sequence mirrors the description of the inefficient catcher above. The child progresses to hugging (stage 2), then scooping (stage 3) a larger ball. 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 his 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 involving catching until she reaches stage 5.

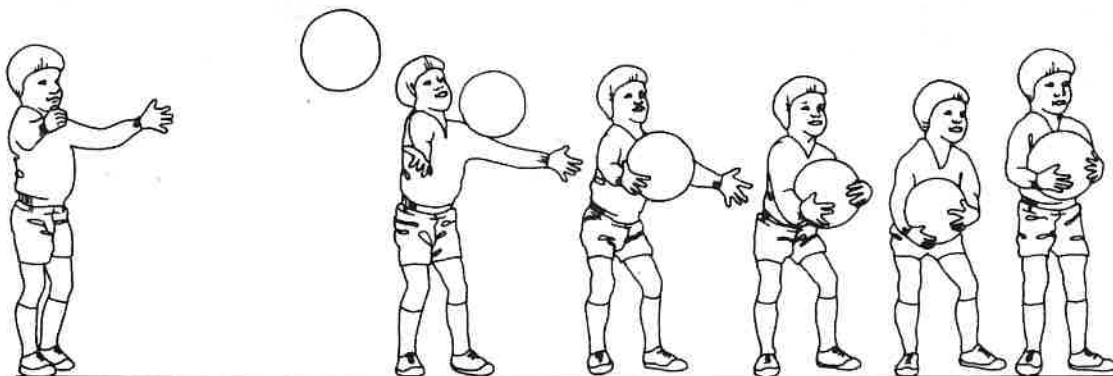
The catching data in Figure 11.4 reveal that catching is one of the few skills where girls are ahead of their male counterparts. Girls show stage 4 behaviors around 60 months, whereas boys reach this stage 12 months later at 72 months. The proficient (stage 5) stage of catching is reached at 76 months for girls and 82 months for boys.

Component Developmental Sequence of Two-Handed Catching

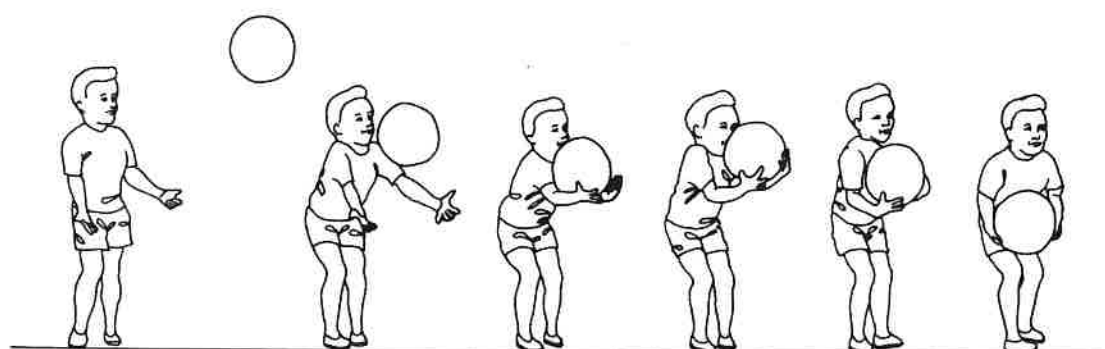
A component developmental sequence for catching exists that is the product of an integration of several pieces of empirical work. This sequence consists of a 4-step arm component, 3-step hand-action component, and 3-step body-action component (Haywood & Getchell, 2009). The original catching sequence was proposed by Harper (1973) and cited by Robertson 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.



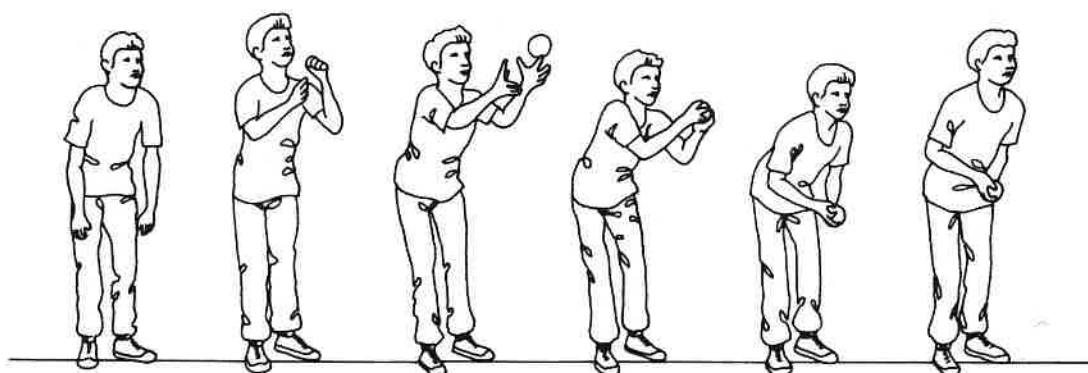
Stage 1



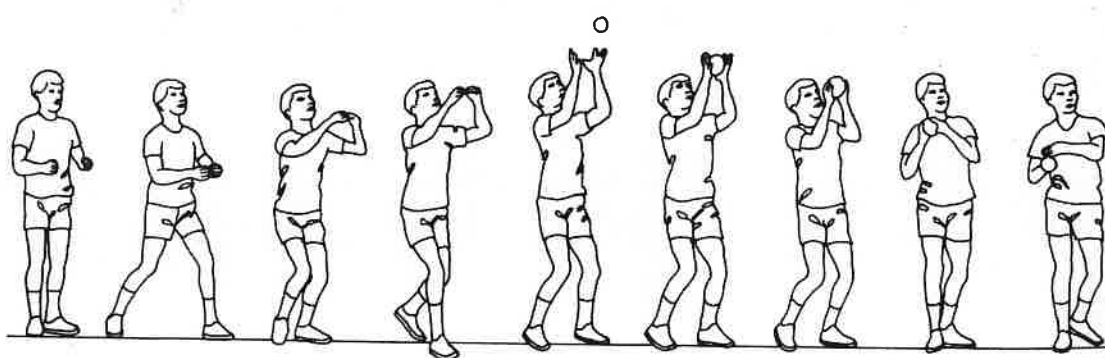
Stage 2



Stage 3



Stage 4



Stage 5

Figure 11.5

Developmental Sequences of Catching

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Constraints in Catching

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

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

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.

TABLE 11.7 Individual, Task, and Environmental Constraints in Catching

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

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. 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.

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 aged 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.

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 aged 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°) in contrast to the overall group that did better with a higher projection angle (44°). 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 6–7-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, Greewalh, & 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 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 impact 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 influence 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-aged 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.

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 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.

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 204 countries. 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.

In order to be able to kick children need to possess eye-foot coordination, balance, and perceptual motor abilities. Overlock (2004) found a significant relationship between static and dynamic balance ability and kicking. Despite the large number of people around the world using kicking skills, there is relatively little 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 where 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 football game, you will see a football 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).

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

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. Less skilled kickers tend to stand behind the ball in a stationary position, 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.

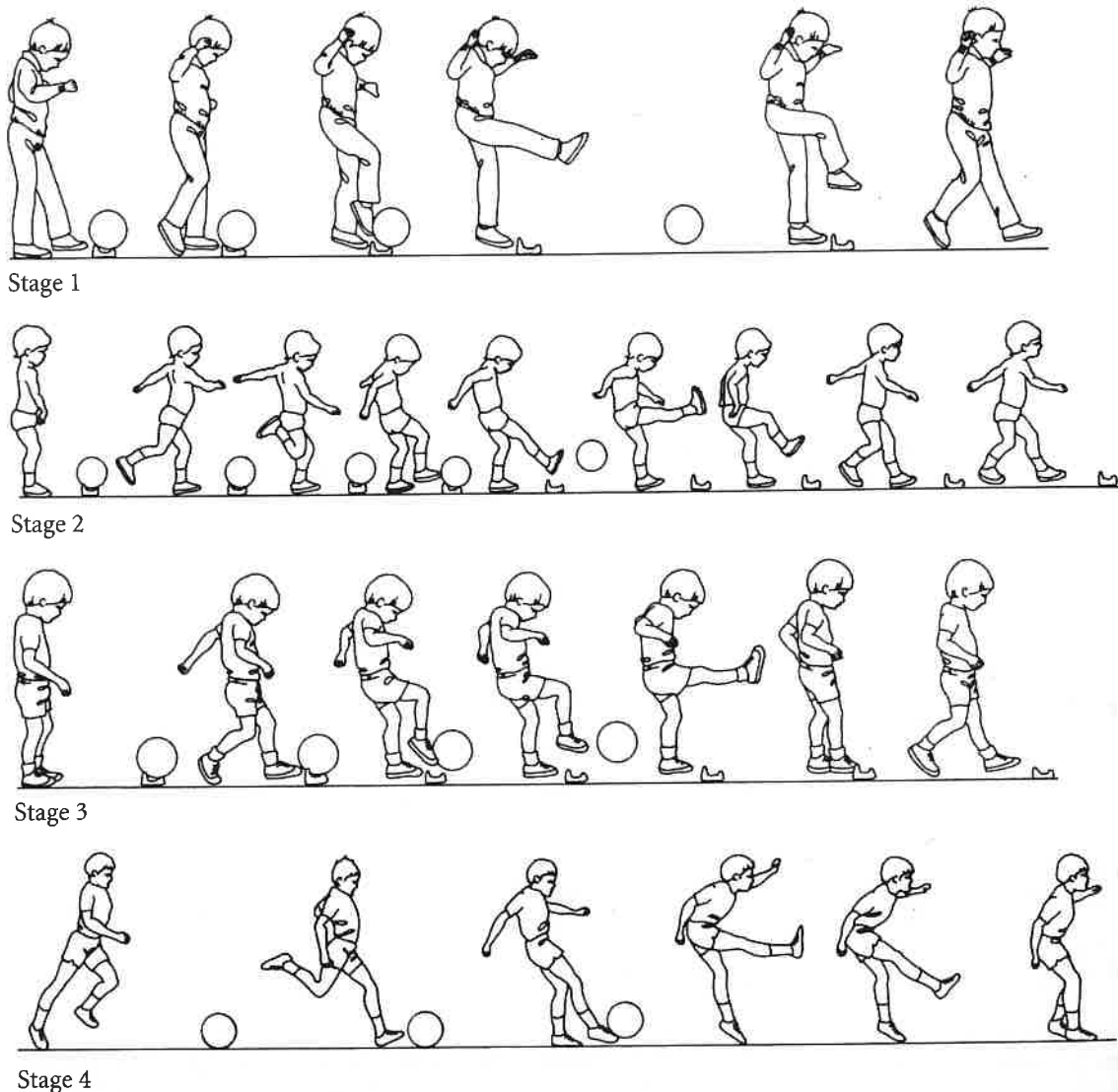
Development of Kicking

Only one group of researchers has identified a four-stage developmental sequence for kicking performance (Haubenstricker, Seefeldt, Fountain, & Sapp, 1981). Table 11.1 and Figure 11.6 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. 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, a powerful leg drive to contact the ball, and follow-through actions to dissipate the force generated from the powerful kick.

Figure 11.4 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 footedness 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

**Figure 11.6**

Developmental Sequences of Kicking

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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 kicking; much of it is biomechanical in nature and from Europe. Gámez and colleagues (2004)

compared the three-dimensional kicking kinematics of 8–10-year-old experienced football players to adult data in the literature. Overall, children had less peak hip, knee, and ankle velocity than adults (speed of limb segments). The timing of the velocity of limb segments also differed between children and adults. Another kinematic study by Bransdorfer (1999) examined the relationship

between kicking kinematics and skill level in 20 3–8-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.

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.

A number of studies have looked at individual factors influencing kicking. Butterfield and Loovis (1994) investigated the influence of individual constraints of age, sex, balance (static and dynamic), and sports participation on kicking in 716 children aged 5–14 years. Sex (grade 6 boys outperformed girls) and static and dynamic balance were significantly predictive of kicking behaviors. 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.

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 equated 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.

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. 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. Punting requires eye-hand-foot coordination, balance, and perceptual motor abilities. 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.

The performance of an initial or inexperienced punter is very similar to that of a poorly skilled kicker. Inefficient punters (Seefeldt & Haubenstricker, 1978) often start from a stationary position, 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.

Development of Punting

Robertson (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

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)

“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 11.7 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-aged children are still at the rudimentary stages, and typically it is not until later elementary 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.

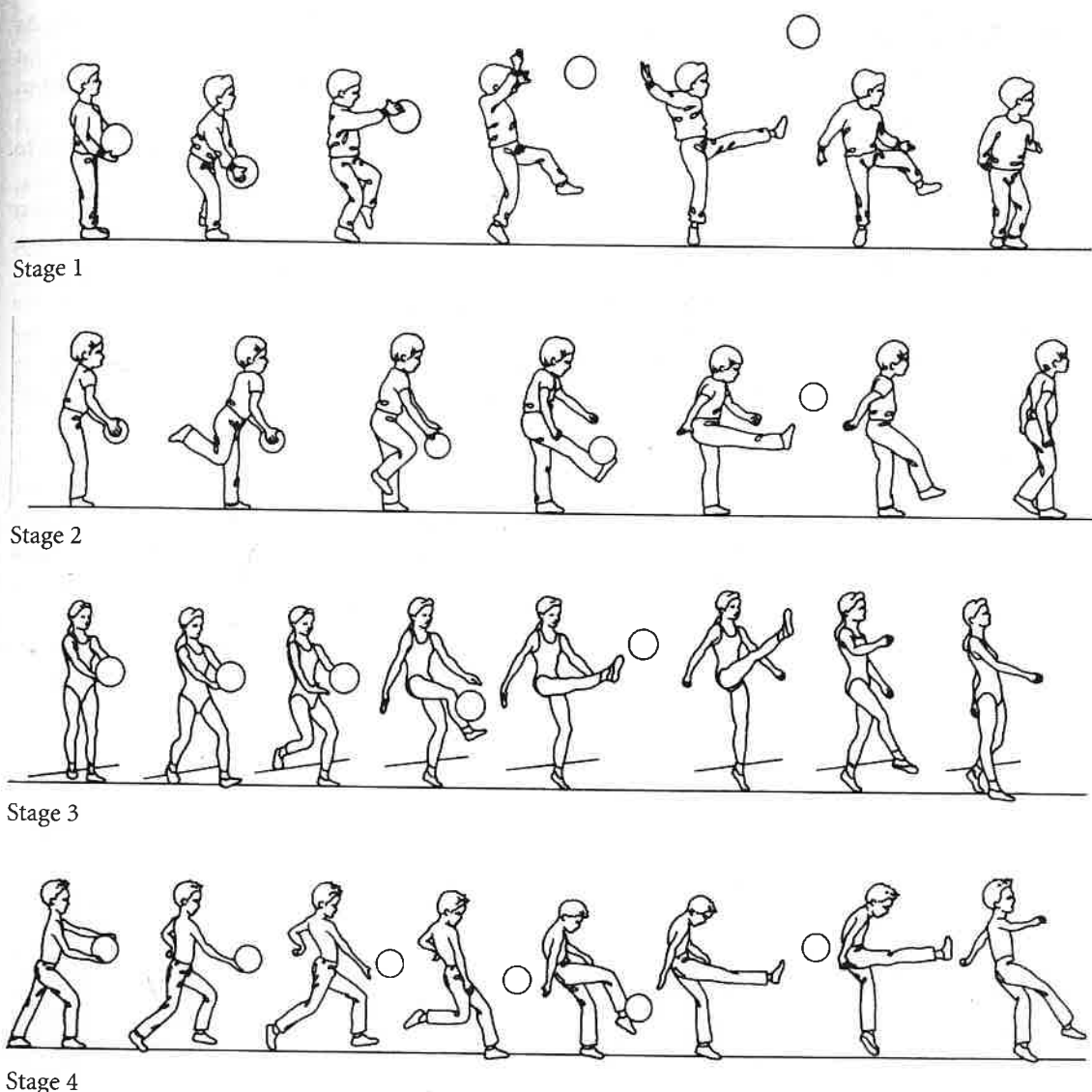
The only study found on punting examined the influence of two instructional approaches (teacher versus learner rotated format) on the punting

skills of fifth-grade children. Both approaches were valuable to teach punting to low-ability children; however, the learner rotated format was most profitable (Goldberger and 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. 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-aged physical education curriculum. There are several forms of striking such as sidearm,

**Figure 11.7**

Developmental Sequences of Punting

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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 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

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 one time per week 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 educator 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?

How would you respond to Jose and Yolanda's mother?

(sidearm strike) and a volleyball serve (overarm strike). Striking is an essential skill in many life-time 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.

There are several factors that are important to being able to strike an object. Eye-hand 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 (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. 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-aged child swing a bat at a stationary ball on a tee, and watch her 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 has to comprehend the distal end of the bat, and then struggles in the precise task of making the end of the bat contact the ball. In this situation, the child needs to use a shorter bat, "choke up" on the bat, or use his hand in order to reduce the demands of the task. 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. 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 curved ball 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 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 over-arm 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 strikers, the timing of the child’s swing can be out of synch with the flight of the object.

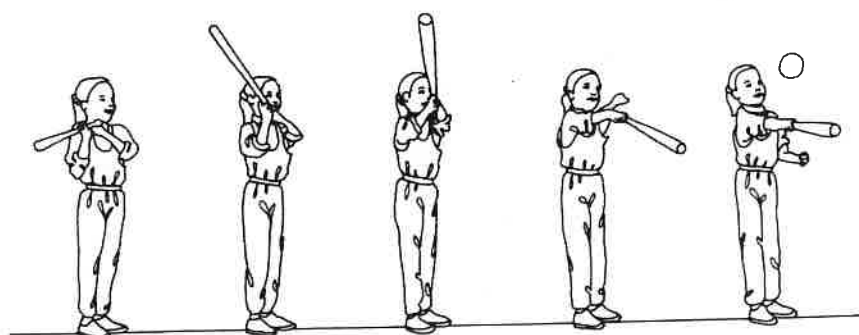
Development of Two-Handed Striking (Batting)

Only one group of researchers has identified developmental sequences for striking with a bat (Seefeldt & Haubenstricker, 1982). Table 11.1 and Figure 11.8 show the four-stage sequence of striking with a bat. Figure 11.4 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.

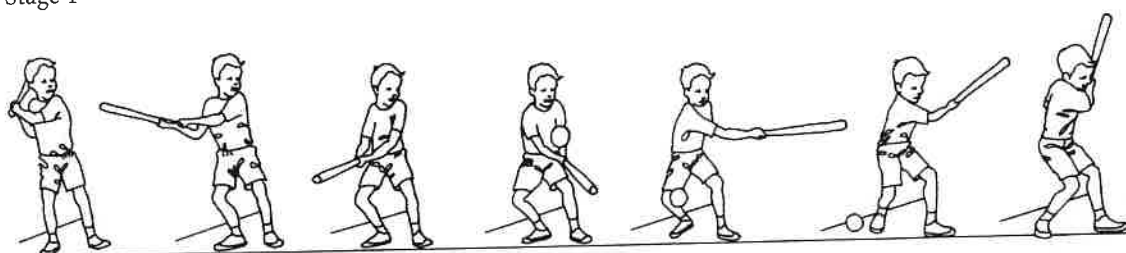
These data in Figure 11.4 are supported by other data in the literature on striking. Espenschade and Eckert (1980) suggest that sidearm striking becomes apparent by approximately 36 months. Harper and Struna (1973) studied longitudinal changes in one-handed striking of two children across a year. This work showed that as children developed in their striking skills, they developed more of a sidearm swing, contralateral

TABLE 11.10 Characteristics of a Proficient Striker

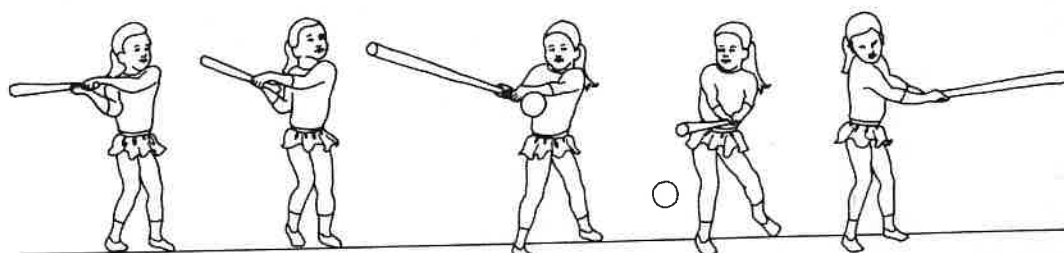
Sidearm Striking	Batting
Preparatory Action • Swinging bat back in a horizontal plane • Body oriented sideways	Preparatory Action • Body oriented sideways with weight on back leg • Step and weight shifts forward as hands go back
Force Production Action • Long contralateral step into hit • Swinging through a full range of motion • Differentiated trunk and hip 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	Force Production Action • Contralateral step into hit • Swinging through a full range of motion • Differentiated rotation to contribute rotary 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 • Arm comes across body • Body moves across base leg	Follow-Through Action • Wrists roll • Bat swings across body • Weight shifts to front foot



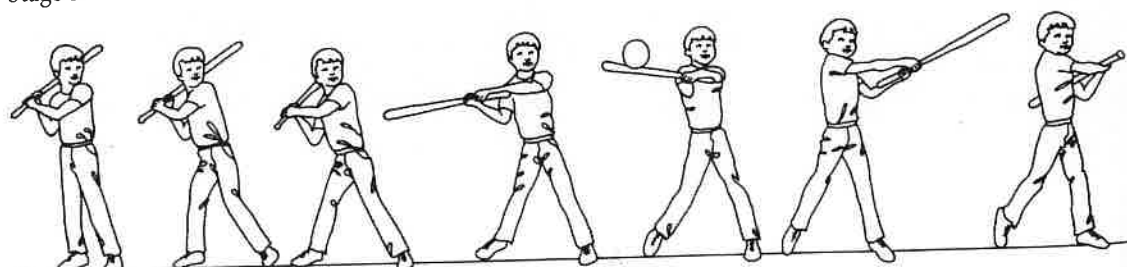
Stage 1



Stage 2



Stage 3



Stage 4

Figure 11.8

Developmental Sequences of Striking

step, and spinal and pelvic rotation. Wickstrom's (1968) study of 33 preschool children aged 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 aged 4–14 years. Development of mature striking was associated with sex; boys performed better at all grades except in 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 aged 6–7 or 9–10 years on 6 trials of striking the ball for distance, the MASI found a significant correlation between process measures (MASI) and product measures (distance of ball). 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.

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 grade 4. 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.

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. Robertson 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.

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 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 it 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.

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?

CRITICAL READINGS

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WEB RESOURCES

National Association of Sport and Physical Education

<http://www.aahperd.org/naspe/>

Website provides links to national standards in physical education and a host of resources for practitioners in promoting motor skills. Physical education website—PE Central

<http://www.pecentral.org/>

Website provides lesson plans, assessment instruments, and other professional resources for physical education and health teachers.

Head Start Body Start

<http://www.aahperd.org/headstartbodystart/>

Website provides ideas to promote physical activity and motor skills in preschool-aged children.

University of Michigan Your Child Development and Behavior Resources

<http://www.med.umich.edu/yourchild/topics/devmile.htm>

Website provides resources on developmental milestones of infants and children.