CHAPTER 4

Selected Factors Related to Motor Development

KEY TERMS

- Developmental direction
- Growth rate
- Reciprocal interweaving
- Readiness
- Sensitive periods
- Phylogenetic skills
- Ontogenetic skills
- Bonding
- Premature
- Very low birth weight (VLBW)
- Low birth weight (LBW)
- Young-for-date
- Anorexia nervosa
- Bulimia nervosa
- Obesity
- Binge-eating disorder
- Physical fitness
- Force
- Law of acceleration
- Law of inertia
- Law of action and reaction

CHAPTER COMPETENCIES

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

- Identify genetic and environmental factors influencing growth and biological maturation.
- Derive principles of motor development and apply these principles to teaching/learning situations at various points in the life span.
- Describe “catch-up” growth and the factors affecting this phenomenon.
- Analyze relationships among growth, biological maturation, and physiological changes in motor skill development.
- Discuss the effects of environmental deprivation on life span motor development.
- Discuss the effects of enrichment, special practice, and teaching on life span motor development.
- Define and discuss the concepts of critical and sensitive periods, phylogenetic and ontogenetic skills, and co-twin control.
- Identify and order from simple to complex the environmental variables that may influence developmental levels.
- Explain the similarities and differences between bonding and imprinting.
- Hypothesize about the impact of temperament on the interactive process of development.
- Describe differences and similarities implied by the terms “low birth weight” and “young-for-date.”
The development and refinement of movement patterns and movement skills are influenced in complex ways. Both the process and products of movement are rooted in one’s unique heredity and background of experiences, coupled with the specific demands of the movement task. Any study of motor development would be incomplete without a discussion of several of these influencing factors. This chapter focuses on factors within the individual, the environment, and the tasks that influence the process of development throughout the life cycle.

**Factors Within the Individual**

The unique genetic inheritance that accounts for our individuality can also account for our similarity in many ways. One similarity is the trend for human development to proceed in an orderly, predictable fashion. A number of biological factors affecting motor development seem to emerge from this predictable pattern.

**Developmental Direction**

The concept of developmental direction, namely that change is cumulative and directional, was first formulated by Gesell (1954) as a means of explaining increased coordination and motor control as a function of the maturing nervous system. Through observations, Gesell noted that an orderly, predictable sequence of physical development proceeds from the head to the feet (cephalocaudal) and from the center of the body to its periphery (proximodistal).

The concept of developmental direction has encountered recent criticism and should not be viewed as operational at all levels of development or in all individuals. It may be that the observation of tendencies toward distinct developmental directions is not exclusively a function of the maturing nervous system, as originally hypothesized by Gesell, but is due, in part, to the demands of the specific task and the experiences of the child. For example, the task demands of independent walking are considerably greater than those for crawling or creeping. There is less margin for error in independent walking than there is in creeping and, in turn, crawling. In other words, it is mechanically easier to crawl than it is to creep, and easier to crawl than it is to walk. Therefore, the apparent cephalocaudal progression in development may be due not only to maturation of the nervous system, but also to the performance demands of the task. Care, therefore, should be taken when interpreting the concept of developmental direction, particularly during the period of infancy.

**Concept 4.1**

Neuromotor maturation may be used to account for, in part, both the sequence and rate of motor development throughout the life cycle.

The cephalocaudal aspect of developmental direction refers specifically to the gradual progression of increased control over the musculature, moving from the head to the feet. It may be witnessed in the prenatal stages of fetal development as well as in later postnatal development. In the developing fetus, for example, the head forms first, and the arms form prior to the legs. From a cephalocaudal standpoint, the newborn infant first gains control of her head, then her shoulders and trunk. At the point the infant has control over his hips and core, she will be able to sit independently, and ultimately once she has some control over her lower limbs and feet, she will be able to walk. Young children are often clumsy and exhibit poor motor control over their lower extremities. This may be due to incomplete cephalocaudal development and to the complexity of the task demands of independent walking.

The second aspect of developmental direction, known as proximodistal development, refers specifically to the child’s progression in control of the musculature from the center of the body to its most distant parts. As with cephalocaudal development, the proximodistal concept applies to both growth processes and the acquisition of movement skills. For example, with regard to growth, the trunk and shoulder girdle grow prior to arms and legs, which grow prior to the fingers and toes. Another example of the proximodistal law of developmental direction includes the sequences in learning how to catch, where children first catch the ball in the midline, and it is not until later they can catch more distal to their body. In skill acquisition, the young child is able to control the muscles of the trunk and shoulder girdle prior to the muscles of the wrist, hand, and fingers. This principle of
development is frequently used in the primary grades when children are taught the less refined elements of manuscript writing before they learn the more complex and refined movements of cursive writing.

The cephalocaudal and proximodistal process is operational throughout life and has a tendency to reverse itself as one ages. Actions of the lower body and extremities are the first to regress. For example, many older adults shift to a more primitive walking pattern with a short stride and step height (cephalocaudal) and struggle with fine motor manipulation (proximodistal) like picking up pennies. Certainly, however, older individuals can forestall and reduce such regression by staying active throughout life. (See Chapter 19 for more details on older adults).

Rate of Growth

An individual’s growth rate follows a characteristic pattern universal for all and is resistant to external influences. A minor interruption of the normal pace of growth is compensated for by a still-unexplained process of self-regulatory fluctuation (Gesell, 1954) that enables a child to catch up to his or her age-mates. This developmental plasticity occurs, for example, when a severe illness limits a child’s normal gains in height, weight, and movement ability, but upon recovery, the child tends to catch up. The same phenomenon is seen with low-birth-weight (LBW) infants. Despite low weights at birth, most of these babies catch up to the characteristic growth rates of their age-mates in a few years. Conditions surrounding the causes of LBW, such as inadequate nutrition, must not persist. Appropriate intervention must occur early on for this developmental plasticity process to fully manifest in the growing infant. Measures of height, weight, and motor development taken prior to age 2 are generally meaningless for predicting later growth and development.

The self-regulatory process of growth will compensate for relatively minor deviations in the growth pattern, but it is frequently unable to make up for major deviations, especially during infancy and childhood. For example, LBW infants under 3 pounds and children experiencing severe and prolonged nutritional deficiencies frequently suffer permanent deficits in height and weight, as well as in their cognitive and motor development.

Severe and prolonged restricted opportunities for movement and deprivation of experience have been shown repeatedly to interfere with children’s abilities to perform movement tasks characteristic of their age levels. The effects of sensory and motor experience deprivation can sometimes be overcome when near-optimal conditions are established for a child. The extent to which the child will be able to catch up to his or her peers, however, depends on the duration and severity of deprivation, the age of the child, and the child’s genetic growth potential.

Reciprocal Interweaving

The coordinated and progressive intricate interweaving of neural mechanisms of opposing muscle systems into an increasingly mature relationship, termed reciprocal interweaving by Gesell (1954), is characteristic of the developing child’s motor behavior. Developmental change is therefore seen as generally qualitatively differentiated and sequential in nature. Two different but related processes are associated with this increase of functional complexity: differentiation and integration.

Neuromotor maturation is evidenced through increased ability to differentiate and integrate motor and sensory mechanisms.

Differentiation is associated with the gradual progression from the gross globular (overall) movement patterns of infants to the more refined and functional movements of children and adolescents. For example, the manipulative behaviors of the newborn for
reaching, grasping, and releasing objects are poor; there is little control of movement. But as the child develops, the control improves. The child is able to differentiate among various muscle groups and begins to establish control. Control continues to improve with practice until we see the precise movements of block building, cutting with scissors, cursive writing, and violin playing.

Integration refers to bringing various opposing muscle and sensory systems into coordinated interaction with one another. For example, the young child gradually progresses from ill-defined corolling movements when attempting to grasp an object to more mature and visually guided reaching and grasping behaviors. The differentiation of movements of the arms, hands, and fingers, followed by the integration of the use of the eyes with the movements of the hand to perform hand-eye coordination tasks, is crucial to normal development.

Differentiation and integration tend to be reversible with aging. As one ages and movement abilities begin to regress, the coordinated interaction of sensory and motor mechanisms frequently becomes inhibited. The extent to which one’s coordinated movement abilities regress is not merely a function of age, but is influenced greatly by lifestyle factors such as disease, physical activity levels, mental capacities, and attitude.

There is little doubt that the processes of differentiation and integration operate simultaneously. The complex abilities of the adult cannot be explained merely as a process of integration of simpler responses. What occurs, instead, is a constant interlacing of both processes.

Readiness

E. L. Thorndike (1913), the "grandfather" of learning theory, first proposed the concept of readiness primarily in reference to emotional responses to actions or expected actions. According to his concept, readiness depended on the biological maturation model, which was popular at the turn of the century. Today’s concept of readiness, however, is much broader and refers to readiness for learning.

Readiness may be defined as convergence of the requirements of the task, the biology of the individual, and the conditions of the environment that make mastery of a particular skill appropriate. The concept of readiness, as used today, extends beyond biological maturation and includes consideration of factors that can be modified or manipulated to encourage or promote learning. Several related factors combine to promote readiness. Physical and mental maturation, interacting with motivation, prerequisite learning, and an enriching environment all influence readiness. At this juncture, we do not know how to pinpoint exactly when someone is ready to learn a new movement skill. However, research suggests that early experience in a movement activity before the individual is ready is likely to have minimal benefits.

CONCEPT 4.4

Readiness for learning depends on convergence of biological, environmental, and physical factors.

In recent years, a great deal of attention has been focused on developing reading readiness through appropriate types of preschool and primary grade experiences. Entire educational programs have been built around the notion that children must achieve a certain level of development before they are ready to pursue intellectual tasks such as reading and writing (Bergen et al., 2001; Bredenkamp & Rosengrant, 1995), and mathematics (Kamii & Houman, 2000), as well as movement tasks involving locomotion, manipulation, and stability (Gallahue & Cleland-Donnelly, 2003; California Department of Education, 2010). Readiness training is a part of most preschool and primary grade educational programs. An integral part of these readiness programs has been the use of movement as a means of enhancing
basic perceptual-motor qualities. Although it has not been conclusively documented that perceptual-motor experiences have a direct effect on the attainment of specific cognitive readiness skills, it is safe to assume that they have at least an indirect influence because they encourage a child’s self-esteem and a positive “Yes, I can” approach to learning.

The concept of readiness, whether for the learning of cognitive skills or motor skills, is probably best summed up in Bruner’s (1965) statement that “the foundation of any subject may be taught to anybody at any age in some form” (p. 12). In other words, the burden of being “ready” is as much the instructor’s responsibility in recognizing it as it is the student’s. Readiness, a combination of maturational “ripeness,” environmental openness, and caregiver sensitivity, has numerous implications for lifelong learning opportunities.

### Critical and Sensitive Learning Periods

The concept of critical and sensitive learning periods is closely aligned to readiness and revolves around the observation that an individual is more sensitive to certain kinds of stimulation at certain times. Normal development in later periods may be hindered if a child fails to receive the proper stimulation during a critical period. For example, inadequate nutrition, prolonged stress, inconsistent nurturing, or a lack of appropriate learning experiences may have a more negative impact on development if they occur early in life rather than at a later age. The concept of critical periods also has a positive side. It suggests that appropriate intervention during a specific period tends to facilitate more positive forms of development at later stages than if the same intervention occurs at another time.

One should recognize that the tendency of a child to follow a critical period pattern is closely linked to the theory of developmental tasks and, to a lesser degree, linked to the milestone and phase-stage views. Robert Havighurst’s theoretical framework of development is a critical period hypothesis, applied from the perspective of education. This framework is reviewed in Chapter 2.

The notion of critical periods of development has been so pervasive in education that an entire federally funded educational program was established on this premise. Operation Head Start, begun in the 1960s and continued today throughout the United States, viewed the age period of 3 to 5 years as critical to children’s intellectual development. It was hypothesized that if given a “head start” through a carefully structured environment designed to develop school-oriented skills, deprived children would be able to begin school on nearly the same level as their non-deprived counterparts. The results of Head Start programs did not entirely bear out the critical period hypothesis (Congress of the U.S., 2003). This was probably due to the existence of more than one critical period for intellectual development. In addition, the age period of 3 to 5 years may not be as pivotal as originally assumed. Current views of the critical period hypothesis reject the notion that one must develop movement skills within highly specific time frames.

![Image](https://via.placeholder.com/150)

CONCEPT 4.5

There are broadly defined sensitive periods during which individuals can learn new tasks most efficiently and effectively.

It is safe to assume, however, that there are sensitive periods, or broad time frames, for development. Critical or sensitive periods should not be too narrowly defined. Failure to account for individual differences and for special environmental circumstances will lead one to conclude that a sensitive period is a universal point in time. Instead, a notion of sensitive periods as broad, general guidelines susceptible to modification should be adopted. Learning is a phenomenon that continues throughout life. As scientists learn more about the aging brain and the aging motor system, they continually demonstrate this important concept (Hinton, 1992; Heise et al., 2013; Selkoe, 1992; Ward & Frackowiak, 2003). Learning can be a lifelong process, and the effects of aging can be slowed and reduced through continual use of the brain and motor system.
Individual Differences

Change is variable between children. The tendency to exhibit individual differences is crucial. Each person is unique with his or her timetable for development. This timetable is a combination of an individual's heredity and environmental influences. Although the sequence of appearance of developmental characteristics is predictable, the rate of appearance may be highly variable. Furthermore there is some value in using chronological classification of development by age, we need to exert caution in applying these criteria strictly recognizing that children's “normal” motor development is highly variable.

CONCEPT 4.6

Inter-individual and intra-individual variation are the key concepts upon which developmental education is based.

The “average” ages for the acquisition of all sorts of developmental tasks, ranging from learning how to walk (the major developmental task of infancy) to gaining bowel and bladder control (often the first restrictions of a civilized society on the child) have been banded about in the professional literature and the daily conversation of parents and teachers for years. It must be remembered that these average ages are just that and nothing more than mere approximations that serve as convenient indicators of developmentally appropriate behaviors. It is common to see deviations from the mean of as much as 6 months to one year in the appearance of numerous movement skills. For example, some children walk as early as 9 months while others, often with disabilities, may not walk independently until they are 2 years or more. The tendency to exhibit individual differences is closely linked to the concept of readiness and helps to explain why some individuals are ready to learn new skills when others are not.

Phylogeny and Ontogeny

Many of the rudimentary abilities of the infant and the fundamental movement skills of the young child, when viewed from the maturation perspective proposed by Gesell (1954), are considered to be phylogenetic; that is, they tend to appear automatically and in a predictable sequence within the maturing child. Phylogenetic skills (skills of the species) are resistant to external environmental influences. Movement skills such as the rudimentary manipulative tasks of reaching, grasping, and releasing objects; the stability tasks of gaining control of the gross musculature of the body; and the fundamental locomotor abilities of walking, jumping, and running are examples of what may be viewed as phylogenetic skills. Ontogenetic skills (skills that are more environmentally determined), on the other hand, depend primarily on learning and environmental opportunities. Such skills as swimming, bicycling, batting, and ice skating are considered ontogenetic because they do not appear automatically within individuals but require a period of practice and experience and are influenced by one's culture. The entire concept of phylogeny and ontogeny needs to be reevaluated in that many skills heretofore considered phylogenetic can be influenced by environmental interaction.

CONCEPT 4.7

Several types of movement patterns may have their basis in phylogeny (biology), but ontogenetic (environmental) conditions shape the rate and extent to which the patterns are acquired.

Although there may be a biological tendency for the development of certain abilities due to phylogenetic processes, it is simplistic to assume that maturation alone will account for motor development. The extent or level to which any voluntary movement skill is mastered depends, in part, on ontogeny, or the environment. In other words, opportunities for practice, encouragement, and instruction, and the ecology, or conditions, of the environment contribute significantly to movement skill development throughout life. Little solid support exists for Gesell’s notion that “ontogeny recapitulates phylogeny,” although some phylogenetic behaviors may be present in humankind.
**Factors in the Environment**

Over the past several years considerable speculation and research have focused on the effects of parenting behaviors during infancy and early childhood as they influence the subsequent functioning of children. Because of the extreme dependence of human infants on their caregivers and because of the length of this period of dependence, a variety of parental care factors influence later development. Among the most crucial are the effects of environmental stimulation and deprivation, and the bonding that occurs between parent and child during the early months following birth.

**Bonding**

The study of parent-to-infant attachment, or bonding, has its roots in the early imprinting (i.e., attachment) studies conducted by Lorenz (1966), Hess (1959), and others on birds, ducks, and other animals. These experiments with animals revealed that the degree to which the newborn imprinted on its mother was directly related to their contact time. Human infants do not imprint in the narrow sense of the word as animals do, but it is commonly believed by many that there is a broad “sensitive” period in which parent-to-infant attachment occurs during the early months of postnatal life. Popular culture has speculated that if this sensitive period is missed, the parent and child may fail to bond. Compelling evidence places the validity of this belief in jeopardy (Eyer, 1994; Lewis, 1998; Myers, 1984; Thompson, 1991). Experiences such as the death of a family member, divorce, accidents, and severe and prolonged disease are far more important to the long-term development of children and youth than the early maternal bond.

**CONCEPT 4.8**

The reciprocal interaction between parent and child influences both the rate and extent of development.

Bonding is a strong emotional attachment that endures over time, distance, hardship, and desirability. This emotional bond begins developing at birth and may be incompletely established with early separation. The leading factors contributing to initial separation are prematurity and LBW, which result in the incubation of the newborn and mild or severe neonatal problems at birth.

**CONCEPT 4.9**

Bonding plays a yet undetermined role in the process of human development.

**Infant Bonding: Is the Critical Period Hypothesis Valid?**

For many years, it has been suggested that early attachment between parent and child is critical to parent-child bonding and may influence some aspects of development. This historical view has been influenced by the imprinting studies of animals such as ducklings. However, it is fair to question whether bonding in the first few weeks of life is essential to the welfare of the child. As a child adopted by my parents around 3 months of age (Jackie Goodway), I missed out on these early weeks of bonding but still believe the emotional bond with my parents was no different than those of my friends who were held by their parents from the first moments of life. Generations of adopted children will attest to the success of their development even though bonding with “mother” was delayed by weeks, months, or even years. The reciprocal interaction between parent and child creates a mutually satisfying and rewarding relationship, the importance of which cannot be minimized. Care must be taken, however, not to define the concept of bonding too narrowly or to overemphasize its importance. What is your view of this developmental dilemma?

**Stimulation and Deprivation**

A great deal of study has been done over the years to determine the relative effects of stimulation and deprivation on the learning of a variety of skills. There has been considerable controversy among hereditarians (individuals who believe that genetics is most important) and environmentalists (individuals who believe the context or environment is most important) over the issue during the past 100 years. Numerous textbooks have recorded the nature-versus-nurture debates, but little has been settled in the attempt to categorize the effects of each on development. The classic study of Jimmy and Johnny (McGraw, 1935) explores the impact on development over the first two years of life of identical twins, one of whom received environmental stimulation and the other who did not. The current trend has been to respect the individual importance of both nature and nurture and
Students of motor development have recognized the futility of debating the separate merits of maturation and experience and have instead concentrated their research on three major questions. The first of these questions deals with the approximate ages at which various skills can be learned most effectively. The second question deals with the effects of special training on the learning of motor skills. A number of co-twin control studies have been conducted to ascertain the influence of special practice on early learning. The use of identical twins enables the researcher to ensure identical hereditary backgrounds and characteristics of the research participants. One twin is given advanced opportunities for practice while the other is restricted from practicing the same skills over a prescribed time. The famous studies of Gesell and Thompson (1929), Hilgard (1932), and McGraw (1935, 1939) demonstrated the inability of early training to hasten development to an appreciable degree. However, follow-up studies of the co-twin control experiments of both Gesell and McGraw showed that the trained participants exhibited greater confidence and assurance in the activities in which they had received special training. In other words, special attention and training may not influence the quantitative aspects of the movement skills learned as much as the qualitative aspects. Again, we see the complex interrelationship between maturation and experience.

With the advent of neonatal and infant intensive care units in the 1970s, the survival rate for preterm and LBW infants has risen dramatically. Parents, physicians, and researchers have wondered about the effects of infant stimulation programs on the subsequent development of these high-risk infants. Ulrich (1984), in her comprehensive review of the research, concluded: “Despite difficulties in comparing studies due to the variability of subjects used, and type, intensity, and duration of treatment, the overwhelming
evidence indicates beneficial effects” (p. 68). Such a conclusion is encouraging and leads one to consider the timing and duration of special training or stimulation. Is there a “sensitive period” beyond which the benefits of stimulation are minimally beneficial? Pepino and Mezzacappa (2015) found that tactile/kinesthetic stimulation was a promising tool to promote weight gain in preterm infants, but it was hard to make conclusions, as many of the studies did not describe the nature of their program in sufficient detail.

From the 1980s until the present, there has been a tremendous surge of interest in stimulation programs for infants, toddlers, and preschoolers. Structured swim-and-gym programs have sprung up all across North America and beyond. There have been considerable claims and counterclaims about the supposed benefits of these programs. To date, there has not been a widespread evaluation of such commercial programs.

The third question concerns the effect of limited or restricted opportunities for practice on the acquisition of motor skills. Studies of this nature have centered generally on experimentally induced environmental deprivation in animals. Only a few studies have been reported in which children have been observed in environments where unusual restrictions of movement or experience have existed.

An investigation conducted by Dennis (1960) examined infants reared at three separate institutions in Iran. The infants in two of the institutions were found to be severely retarded in their motor development. In the third, there was little motor retardation. The discrepancy led Dennis to investigate the lifestyles of the children in each institution. The results of his investigation led to the conclusion that lack of handling, blandness of surroundings, and general absence of movement opportunity or experience were causes of motor retardation in the first two institutions. Another investigation, by Dennis and Najarian (1957), revealed similar findings in a smaller number of creche infants reared in Beirut, Lebanon. Both investigations lend support to the hypothesis that behavioral development cannot be fully attributed to the maturation hypothesis.

Due to cultural mores, the humanitarian virtues of most investigators, and concerned parents, there are few experiments in which the environmental circumstances of infants or young children have been intentionally altered to determine whether serious malfunctioning or atypical behavior will result. However, a movie, Three Identical Strangers, tracks the lives of identical triplets who were deliberately separated at birth and placed in different kinds of families to examine how their development might be similar and different. This movie is a fascinating, but disturbing, look at the role of heredity and environment on children's developmental trajectories. Overall, the general consensus of the research that does exist is that severe restrictions and lack of experience can delay normal development.

To understand the influence of experience on development, we need only to look as far as the school playground and observe many girls jumping rope expertly and many boys throwing and catching balls with great skill. When asked to reverse the activities, however, each group tends to revert to less mature patterns of movement. Factors within our culture, unfortunately, often predetermine the types of movement experiences in which boys and girls engage (Barnett et al., 2013; Gallahue et al., 1994). Barnett and colleagues (Barnett et al., 2013) in their study of child, family, and environmental correlates of children's motor skill proficiency found that correlates differed according to skill category (e.g., locomotor skills or manipulation skills) and that child level correlates appeared to be more important. Additionally, the gross motor development of blind children, as well as children confined in their early weeks and months of postnatal life to the neonatal intensive care unit, have repeatedly been shown to be behind their age-mates on standardized measures of gross motor behavior as well as classroom behavior (Hack et al., 1994; Houwen et al., 2007). Furthermore, very LBW babies (<1500 g), as well as blind children, have been shown to acquire some rudimentary movement skills out of the normally expected sequence.

**CONCEPT 4.11**

Extreme conditions of environmental deprivation may disrupt both the sequence and rate of movement skill acquisition.

In summary, both maturation and learning play important roles in the acquisition of movement skills. Although experience seems to have little influence on the sequence of their emergence, it does affect the time of appearance of certain movements and the extent of their development. One of the greatest needs of children is to practice skills at a time when they are developmentally ready to benefit the most from such skills. Chapter 14 provides an overview of motor skill programs to promote motor development for children.

Special practice prior to maturational readiness is of dubious benefit. The key is to be able to accurately judge the time at which each individual is “ripe” for
learning and then to provide a series of educationally sound and effective movement experiences. However, all indications are that young children are generally capable of more than we have suspected, and many of the traditional readiness signposts that we have used may be incorrect.

**CONCEPT 4.12**
The extent to which environmental stimulation may affect development is as yet unknown.

### Physical Task Factors

A number of additional factors affect motor development. The influence of ethnicity and social class (Barnett et al., 2013; Malina, Bouchard, & Bar-Or, 2004), gender (Branta, Painter, & Kiger, 1987; Goodway, Robinson & Crowe, 2010), and ethnic and cultural background (Bril, 1985; Gallahue et al., 1996; Malina, Bouchard, & Bar-Or, 2004) all have an impact on growth and motor development. Motor development is not a static process. It is not only the product of biological factors but also is influenced by environmental conditions and physical laws. The interaction of both environmental and biological factors modifies the course of motor development during infancy, childhood, adolescence, and adulthood. Prematurity, eating disorders, fitness levels, and biomechanical factors, as well as the physiological changes associated with aging and lifestyle choice, all influence the lifelong process of motor development in important ways. It is not possible within this chapter to provide a comprehensive overview of these topics, rather the intent is to provide a brief summary of the potential influence of these factors on motor development.

### Prematurity

The typical average birth weight of an infant is about 3,300 g (about 7 pounds). Formerly, any infant weighing under 2,500 g (about 5.5 pounds) was classified as premature. Today, however, 1,500–2,500 g (about 3.35 pounds to 5.56 pounds) is used as the standard, as weighing under 2,500 g (about 5.5 pounds) was classified as LBW, and this number has trended upward since 2014 (Hamilton et al., 2017; Martin et al., 2010). Two standard deviations below the mean for a given gestational age is the generally accepted criterion for LBW. Therefore, an LBW infant may be one born at term (40 weeks) or preterm (37 weeks or under). LBW infants have experienced "intrauterine growth retardation" and are generally called "small-for-date." A variety of prenatal maternal factors have been implicated, including diet, drugs, smoking, infections, and disease (Kopp & Kaler, 1989; Malina, Bouchard, & Bar-Or, 2004). Other factors such as social class, multiple births, and geographic locale have been shown to influence birth weight (Mason, 1991). The long-term effects of LBW are directly related to the degree of reasons. First, it is often difficult to accurately determine the gestational age of the infant, and second, the highest mortality and morbidity rates are present for infants of the very lowest birth weights. As a result, the terms low birth weight and young-for-date have emerged as more accurate indicators of prematurity in the true sense of the word. Prematurity is of major concern because it is closely associated with physical and mental retardation, hyperactivity, and infant death. Prevention is considered to be the most important factor in improving infant health and survival rates.

**CONCEPT 4.13**
Prematurity puts the newborn at risk and frequently undermines the process of motor development.

### Low Birth Weight

Low-birth-weight (LBW) infants weigh less than expected for their gestational age. In the United States, approximately 8.2% of live births are considered to be LBW, and this number has trended upward since 2014 (Hamilton et al., 2017; Martin et al., 2010). Two standard deviations below the mean for a given gestational age is the generally accepted criterion for LBW. Therefore, an LBW infant may be one born at term (40 weeks) or preterm (37 weeks or under). LBW infants have experienced "intrauterine growth retardation" and are generally called "small-for-date." A variety of prenatal maternal factors have been implicated, including diet, drugs, smoking, infections, and disease (Kopp & Kaler, 1989; Malina, Bouchard, & Bar-Or, 2004). Other factors such as social class, multiple births, and geographic locale have been shown to influence birth weight (Mason, 1991). The long-term effects of LBW are directly related to the degree of...
Preterm Infants

Children born at the expected birth weight (less than two standard deviations below the mean) for their gestational age but before full term (37 weeks or less) are called preterm infants. In 2016, approximately 9.85% of live births in the United States were considered to be preterm (Hamilton et al., 2017). There is little agreement on the exact causes of preterm birth, but a number of factors have been shown to contribute, including drug use, smoking, maternal age, excessive weight gain, and adverse social and economic conditions: Until recent years, the prognosis for preterm infants who were either small-for-date or normal-weight-for-date was bleak. Their morbidity and mortality rates were abnormally high when compared with normal-term infants. Bennett (1997) reported that the lower the gestational age, the higher the incidence of major disability. More recent data show that the developmental outcomes for preterm infants compared to full term infants is still of concern (Yaari et al., 2018). Additionally, it shows that male infants and infants of mothers with low maternal education had particularly poor outcomes (Yaari et al., 2018). Overall, the preterm infant is still likely to have more learning difficulties, language and social interaction disadvantages, and motor coordination problems than his or her full-term counterpart.

Long-Term Effects of Prematurity

The data are clear that VLBW babies are more likely to die in the first few weeks following birth than are normal-weight babies. There are racial disparities in infant mortality and morbidity across different gestational ages (how preterm an infant was) and these persist even when the research accounted for potential confounding variables like poverty (Anderson et al., 2018). Preterm LBW ranks second behind birth defects as the leading cause of infant death in the United States. In the United States infant mortality is approximately 5.97 per 1,000 live births, making the United States number 38 in the number of infant deaths among developed countries. Luxembourg (1.58) and Singapore (1.77) rank among the lowest infant mortality rates in the world (data from the United Nations population division).

The long-term effects of premature birth are not as clear as are the short-term consequences. In recent years, neonatal intensive care units have been implicated in long-term developmental problems of some premature babies. The effects of noise, light, and the absence of pleasurable touch on the developing neurologic system have been studied. More recently, neonatal units caring for preterm infants have recognized the importance of engaging the family and holding the infant in developmental outcomes (Yu et al., 2017). The encouraging news is that the majority of premature infants survive with little or no disability. But as the age of viability (i.e., the lowest gestational age possible for survival) continues to decrease with medical advances, and the survival rate of VLBW babies increases, there has been a greater incidence of both minor and major developmental disabilities (Fontana et al., 2016; Lemons et al., 2001; Tommiska et al., 2001).

Eating Disorders

North Americans live in a world far different from that of their ancestors. Vigorous physical exertion is not a necessary part of the daily life pattern of most people. Today, most exercise, if it occurs, is planned and is not an integral part of one's existence. In addition, many, for the present, have an abundance of food. It is possible for an individual to consume a large amount of food and use up little of the energy contained in that food. The maintenance of body weight mostly requires maintaining a balance between caloric intake and caloric expenditure. There are a variety of identified eating disorders. Eating disorders such as anorexia nervosa (limiting calories and starving themselves) and bulimia nervosa (binge eating followed by purging) during childhood and particularly the adolescent growth spurt can impact the overall growth potential of adolescents.

Obesity and Overweight

Obesity is defined as a body mass index (BMI) greater than 30 and overweight as a BMI between 25–29.9. There are many good BMI calculators to estimate an individual’s BMI (see website section at the end of the
BMI is calculated using the equation “kg/m^2” where kg is a person’s weight in kilograms and m^2 is their height in meters squared.

The Organization for Economic Cooperation and Development (OECD) ranks the United States as the twelfth most obese country in the world, with the Centers for Disease Control and Prevention (CDC) stating that 39.8% of adults in America are obese. Obesity is related to higher rates of conditions such as heart disease, stroke, type 2 diabetes and certain types of cancer, and obesity is one of the leading causes of preventable, premature death. The estimated annual medical cost of obesity in the United States was $147 billion in 2008. The difference in the medical cost of treating someone who is obese compared to someone who is not is $1,429.

There are significant disparities in obesity with Hispanics (47.0%) and non-Hispanic blacks (46.8%) having the highest age-adjusted prevalence of obesity, followed by non-Hispanic whites (37.9%) and non-Hispanic Asians (12.7%) (CDC, 2018a). Younger adults aged 20 to 39 years (35.7%) were less obese (42.8–41.0%) than adults 40 years or older. Overall, people in lower SES groups are more obese than those with higher incomes, but these data are complex and vary by sex, race, and ethnicity. The CDC website (https://www.cdc.gov/obesity/index.html) provides comprehensive data and maps on obesity demonstrating the increases in prevalence of obesity by state.

Perhaps what is of most concern is that over the past few decades, childhood obesity has escalated to be one of the most critical public health problems in the United States and globally. In the United States, childhood obesity is defined as a BMI at or above the 95th percentile on CDC sex-specific growth charts describing BMI for age (CDC, 2017). BMI calculators for children include the child’s age and gender in order to compare him/her to same-aged peers (CDC, 2019).

In 2016, the World Health Organization estimated the number of overweight children under the age of 5 years to be 41 million. In the United States, one in three children is considered to be overweight or obese. The prevalence of obesity in the United States (Hales et al., 2017) was 18.5% and affected 13.7 million children and adolescents. Like adults, there were racial and ethnic disparities in the rates of obesity with Hispanics (25.8%), non-Hispanic blacks (22.0%) having higher obesity prevalence than non-Hispanic whites (14.1%). Non-Hispanic Asians (11.0%) had lower obesity prevalence than other groups. There were also income-related patterns in obesity levels (CDC, 2018b).

Obesity rates in children aged 2-19 years decreased as the education level of the head of the household was higher. Additionally, obesity rates are disproportionately higher in children from low-income families, specifically those families who are racially or ethnically diverse.

As obesity and overweight data have increased, so have the onset of “adult-like” diseases such as type 2 diabetes mellitus, high lipid profiles, and hypertension in children (Kumar & Kelly, 2017). A growing body of evidence has implicated obesity as a major contributing factor in a wide variety of negative health outcomes, several of which are depicted in Table 4.1. In addition, obese children and adults frequently suffer ridicule from their peers, poor academic performance, poor self-image, and persistent concern with dieting.

Dietary modifications and increased physical activity within the context of the family are considered the best strategies to address childhood obesity (Kumar & Kelly, 2017). The treatment of childhood obesity is beginning to shift from a medical deficit model to more of a “capacity-oriented” approach involving the family and community in finding support and solutions to the issue (Foster et al., 2018). The CDC has many recommendations for obesity prevention strategies and guidelines for a wide range of sectors within the United States (CDC, 2018c). Among these many strategies are promoting breastfeeding, developing policies and environments for our children and schools to decrease obesogenic behaviors, impacting the built environment to promote physical activity, and increasing the consumption of fruits and vegetables.

The primary environmental causes of obesity in individuals with normal hormonal balances are excessive eating and lack of exercise, or a combination of both. Poor eating and exercise habits are formed in childhood and carried on into adult life. The child urged to clean the plate at every meal but not encouraged to exercise regularly has the potential for a serious weight problem.

An area of interest to many who study obesity is the activity levels of obese children (Treuth et al., 2004). There are clear differences in the physical activity levels of children who are obese and healthy weight, especially with regard to moderate to vigorous physical activity (Elmesmari et al., 2018). However, both obese and non-obese groups were below the recommended levels of physical activity (Elmesmari et al., 2018). High levels of screen time are associated with obesity, with males having more screen time than females (Wachira et al., 2018). Interestingly, screen time was not associated with BMI (Wachira et al., 2018). Bar-Or and Baranowski (1994) noted in a review paper of physical activity
and obesity among adolescents studies several studies that clearly indicate that the intensity of physical activity is significantly lower in obese children and adolescents. Although increased levels of physical activity coupled with moderation in caloric intake may be the keys to reducing the trend toward increased fatness, Bar-Or and Baranowski concluded that of the many keys to reducing the trend toward increased fatness, coupled with moderation in caloric intake may be the best and most healthful solution (USDHHS, 2001; Dettz, 2004).

### TABLE 4.1 Overweight and Obesity Increase the Risk of Several Diseases and Are Associated with Numerous Negative Health Conditions

<table>
<thead>
<tr>
<th>Overweight and Obesity Are Known Risk Factors for:</th>
<th>Overweight and Obesity Are Associated with:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 2 diabetes</td>
<td>Elevated cholesterol</td>
</tr>
<tr>
<td>Heart disease</td>
<td>Complications during pregnancy</td>
</tr>
<tr>
<td>Stroke</td>
<td>Menstrual irregularities</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Excessive body and facial hair</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>Birth defects (neural tube defects)</td>
</tr>
<tr>
<td>Osteoarthritis (especially of the knees, hips, back, and hands)</td>
<td>Carpal tunnel syndrome</td>
</tr>
<tr>
<td>Sleep apnea</td>
<td>Daytime sleepiness</td>
</tr>
<tr>
<td>Some forms of cancer (breast, uterine, colorectal, kidney, and gallbladder)</td>
<td>Gout</td>
</tr>
<tr>
<td>Gallbladder disease</td>
<td>Impaired immune response</td>
</tr>
<tr>
<td>Heat disorders</td>
<td>Impaired respiratory function</td>
</tr>
</tbody>
</table>


...and obesity among adolescents studies several studies that clearly indicate that the intensity of physical activity is significantly lower in obese children and adolescents. Although increased levels of physical activity coupled with moderation in caloric intake may be the keys to reducing the trend toward increased fatness, Bar-Or and Baranowski concluded that of the many physical intervention programs studied, there was only a small (1–3% body fat) reduction in adiposity among adolescents. Dieting does not appear to be the complete, or the best, solution to behaviorally based obesity in children. Their food intake may be normal, so dieting may cause serious deficiencies in the nutrients required for proper growth and health. A major cause of obesity in children is lack of activity, therefore long-term increases in this area may be the best and most healthful solution (USDHHS, 2001; Dettz, 2004).

### INTERNATIONAL PERSPECTIVES

#### We Are Not Alone

Over the past 20 years, the United States has witnessed a secular trend (generational shift) in the percentage of Americans who are considered to be overweight or obese. Today, over two-thirds of all adults and one-third of all children are either overweight or obese. The statistics are startling because of the negative health consequences associated with obesity. But we are not alone. The obesity epidemic is now a worldwide phenomenon. Worldwide obesity has more than tripled since 1975, and in 2016 more than 1.9 million adults were overweight (39%) with 650 million being obese (13%). Most of the world’s population lives in countries where overweight and obesity kills more than underweight. Children across the world mirror adults, with 41 million children under the age of 5 and 340 million children and adolescents overweight or obese. Yes, the United States has the dubious honor of being number one in the percentage of overweight and obesity among its citizens, but our nearest followers, Mexico and New Zealand, are not far behind. Neither are Hungary, Australia, the United Kingdom, Canada, and Chile (OECD, 2017). Additionally, a large number of countries are reporting still relatively small, but heretofore unheard of, increases in their nations’ obesity rates, including China and Indonesia—countries where much of their populations is shifting from rural areas to the cities (OECD, 2017; Stettler, 2004).

It appears that a fundamental shift has occurred in the lifestyles of not only those living in North America, but in much of the rest of the world also. Welcome to the global community. What should we do to address this issue?
The etiology of obesity in most children is unknown, but genetic as well as environmental factors appear to be involved. Obesity appears to have a familial influence with either a hereditary or environmental basis or a combination of both. Genes provide a role in instructing the body to respond to changes in the environment and certainly influence obesity. More recent research has compared similarities and differences in obesity among family members, twins, and also among adopted children and suggest that a fairly large variation in weight among adults is due to genetic factors. Other studies have compared differences in genes between obese and non-obese people and suggest that genes could influence behaviors such as the desire to overeat and be sedentary or impact metabolism. However, there is no simple explanation and we cannot point to a single gene as the culprit for obesity. Most obesity is the product of complex interactions among multiple genes and a variety of environmental factors. We still have much to learn in this area. Although both hereditary and environmental factors play a role, regular, vigorous physical activity may be the most important variable in preventing obesity.

One possible explanation for the obesity epidemic is the “thrifty genotype” hypothesis that suggests there is a mismatch between today’s food rich environment and “old genes” that held onto food and helped our ancestors survive occasional famines. Other hypotheses have been to look to our gut microbiome and the role it might play in obesity along with the potential for epigenetic changes associated with early life exposures.

**Binge-Eating Disorder**

**Binge-eating disorder** is probably the most common eating disorder, occurring in about 3% of the adult population in the United States. It is more common in women than men and in obese individuals than those who are not obese (NIDDK, 2008). Although the causes are yet unknown, binge-eating disorder includes up to 50% with a history of depression. Negative emotions such as anger, anxiety, sadness, and boredom may trigger episodes of binge eating. Individuals with a binge-eating disorder consume large amounts of food in binges but do not engage in the purging or fasting behaviors typical of individuals with bulimia or anorexia. An individual with binge-eating disorder is characterized as having reoccurring episodes of binge eating (without purging) within any 2-hour period, at least 2 days per week for a period of at least 6 months. Furthermore, binge eaters typically eat much more rapidly than usual; eat until feeling uncomfortably full; eat large quantities of food when not feeling hungry; eat alone because of embarrassment about how much they eat; and feel guilty, depressed, or disgusted with themselves after overeating (NIDDK, 2008; Spitzer et al., 1993).

**Anorexia Nervosa/Bulimia Nervosa**

A problem as perplexing and potentially as dangerous as obesity is anorexia nervosa, characterized by an aversion to the consumption of food and an obsession with being “too fat,” even when the person is clearly underweight. These self-starvers can lose 25–50% of their normal body weights in the pursuit of thinness. They start dieting and, although emaciated, continue to refuse food because they see themselves as fat. Bulimia nervosa, another severe eating disorder, is similar to anorexia in terms of results. Persons with bulimia have the same “need” for thinness but use a binge–purge process (e.g., vomiting, laxatives, extreme exercising, etc.). It is estimated that anorexia and bulimia occur in 3–4% of the female population, with 90% of all cases being female (Hudson et al., 2007). Both disorders have major long-term health consequences and are related to amenorrhea (loss of the menstrual cycle) during the childbearing years and osteoporosis (bone loss) during the postmenopausal years.

**CONCEPT 4.16**

Anorexia nervosa and bulimia nervosa are disorders that culminate in an aversion to food and self-starvation that results in developmental delays and even death.
Society is partly to blame for the increase in eating disorders in North America. The lean, slender form is glorified by society, which propagates the idea that being thin symbolizes beauty, desirability, and self-control and is a magic key to a happier life. Educators may be among the first to recognize eating disorders. They should be able to recognize the early stages of either illness while it is still relatively easy to reverse and refer the child for professional evaluation and support.

**Fitness Levels**

A wide variety of factors from all three domains of human behavior (cognitive, affective, and psychomotor) influence development, as well as factors within the individual, the environment, and the task. Task factors within the psychomotor domain are termed **physical** and **mechanical** factors. These factors have a profound impact on the acquisition, maintenance, and diminution of our movement abilities throughout life. Our level of **physical fitness** coupled with the mechanical requirements of a task greatly influence our ability to move with control, skill, and confidence. **Figure 4.1** illustrates this important concept.

The interaction among physical activity, genetics, and nutrition suggests the upper and lower limits of physical fitness that can be reasonably expected of an individual. Nutritional status can greatly inhibit or enhance one’s level of physical functioning (Meredith & Dwyer, 1991; Rickard et al., 1996), and genetic structure determines the ultimate level of fitness that can be attained (Malina, Bouchard, & Bar-Or, 2004). Therefore, for the purposes of this text, physical fitness is defined as a set of attributes that one possesses related to the ability to perform physical activity, coupled with one’s genetic makeup, and the maintenance of nutritional adequacy. Physical fitness may be subdivided into health-related and performance-related components.

**Health-Related Fitness**

Muscular strength, muscular endurance, aerobic endurance, joint flexibility, and body composition are usually considered the components of health-related fitness. The extent to which each of these factors is possessed will influence an individual’s performance capabilities in movement. For example, how far a person can run or ride a bicycle is related to his or her level of muscular strength, muscular endurance, and aerobic endurance.

**TABLE 4.2 Early Warning Signs of Eating Disorders**

<table>
<thead>
<tr>
<th>Binge-Eating Disorder</th>
<th>Anorexia Nervosa</th>
<th>Bulimia Nervosa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Eating binges without purging</td>
<td>1. Overidentification with a doctor-prescribed weight-control program</td>
<td>1. Eating binges followed by purging</td>
</tr>
<tr>
<td>2. Irregular weight loss</td>
<td>2. Obsession with dieting and talk of food</td>
<td>2. Irregular weight loss</td>
</tr>
<tr>
<td>3. Frequent obesity</td>
<td>3. Social isolation accompanying slimness (loner)</td>
<td>3. Long periods in the bathroom after meals</td>
</tr>
<tr>
<td>4. Difficulty losing weight and keeping it off</td>
<td>4. No participation in the courting behavior of classmates</td>
<td>4. Variable performance</td>
</tr>
<tr>
<td>5. Obsessed with food</td>
<td>5. Sudden increased involvement in athletics, usually of a solitary nature</td>
<td>5. Loss of tooth enamel</td>
</tr>
<tr>
<td>6. Frequent among people on a medically supervised weight-control program</td>
<td>6. Exaggerated concern with achieving high academic grades</td>
<td>6. Fear of gaining weight</td>
</tr>
<tr>
<td>7. Disgusted with self after a binging episode</td>
<td>7. Overconcern with weight</td>
<td>7. Prolonged/extreme exercise</td>
</tr>
<tr>
<td>8. Frequent history of depression</td>
<td>8. Failure to consume food</td>
<td>8. Emotional instability and impulsivity</td>
</tr>
<tr>
<td></td>
<td>10. Obsession with exercise</td>
<td>10. Throat, esophagus, stomach, or colon problems</td>
</tr>
</tbody>
</table>

**CONCEPT 4.17**

One’s personal level of health-related and performance-related fitness influences motor development in many ways.
Performance-Related Fitness

Performance-related fitness, also widely known as motor fitness, is the performance aspect of physical fitness. *Motor fitness* is generally thought of as one’s current performance level as influenced by factors such as movement, speed, agility, balance, coordination, and power. One’s motor fitness has a definite effect on the performance of any movement activity that requires quick reactions, speed of movement, agility and coordination of movement, explosive power, and balance.

Biomechanics

Before embarking on a detailed discussion of motor development, it will be useful to review some mechanical principles of movement as they relate to stability, locomotion, and manipulation. The human body is capable of moving in numerous ways. Learning all of the skills involved in the performance of children’s game, sport, and dance activities may appear to be an impossible task. Closer inspection of the total spectrum of movement will reveal, however, that fundamental mechanical laws affect all human movement. Selected mechanical principles are considered here to serve as basic preparation for more advanced information.

**FIGURE 4.1** Physical and mechanical factors affect the development of movement potential at all phases of motor development.

**Performance-Related Fitness**

All movement is governed by fundamental mechanical laws.

**Balance**

All masses within the gravitational pull of the earth are subjected to the force of gravity. The three primary factors of concern in the study of balance principles are (1) center of gravity, (2) line of gravity, and (3) base of support.

A *center of gravity* exists within all objects. In geometric shapes, it is located in the exact center of the object. In asymmetrical objects (e.g., human bodies), it is constantly changing during movement. The center of gravity of our bodies always shifts in the direction of the movement or the additional weight (FIGURE 4.2). The center of gravity of a child standing in an erect position is approximately at the top of the hips between the front and the back of the trunk. Activities in which the center of gravity remains in a stable position, such as standing on one foot or performing a headstand, are known as static balance activities. If the center of gravity is constantly shifting, as in jumping rope, walking, or doing a forward roll, the activities are dynamic balance movements.

The *line of gravity* is an imaginary line that extends vertically through the center of gravity to the center of the earth. The interrelationship of the center of gravity and the line of gravity to the base of support determines the degree of stability of the body (FIGURE 4.3).

The *base of support* is the part of the body that comes into contact with the supporting surface. If the line of gravity falls within the base of support, the body will be in balance. If it falls outside the base, it is out of balance. The wider the base of support, the greater the stability, as can be seen when one balances on two feet rather than on one foot. The nearer the base of support
to the center of gravity, the greater the stability. Someone standing erect may be pushed off balance more easily than someone in a lineman’s stance with the feet spread and the body slightly forward. The nearer the center of gravity to the center of the base of support, the greater the stability. A foot position that allows for a larger base of support in the direction of the movement gives additional stability. This principle is illustrated by the foot position of a runner attempting to stop or of a catcher trying to receive and control a heavy object.

**Giving Force**

*Force* is one of the basic concepts of movement and body mechanics. Force is the instigator of all movement and may be defined as the effort that one mass exerts on another. The result may be (1) movement, (2) cessation of movement, or (3) resistance of one body against another. There may be force without motion, as is seen in isometric activities, but motion is impossible without the application of some form of force. Three forces relative to the human body are of concern to us: (1) force produced by muscles, (2) force produced by the gravitational pull of the earth, and (3) momentum. The entire science of force is based on Newton’s three laws of motion, namely, the law of inertia, the law of acceleration, and the law of action and reaction.

The *law of inertia* states that a body at rest will remain at rest and a body in motion will remain in motion at the same speed in a straight line unless acted upon by an outside force. For movement to occur, a
force must act upon a body sufficiently to overcome that object's inertia. If the applied force is less than the resistance offered by the object, motion will not occur. Large muscles can produce more force than small muscles. Once an object is in motion, it takes less force to maintain its speed and direction (i.e., momentum) than it does to stop it. This may be readily observed in snow skiing, the glide in swimming, or rolling a ball. The heavier the object and the faster its speed, the more force is required to overcome its moving inertia or to absorb its momentum. It is harder to catch a heavy object than it is to catch a light object.

The law of acceleration states that the change in the velocity of an object is directly proportional to the force producing the velocity and inversely proportional to the object's mass. The heavier an object, the more force is needed to accelerate or decelerate it. This may be observed when a heavy object (shot put) and a light object (softball) are thrown a given distance. An increase in speed is proportional to the amount of force that is applied. The greater the amount of force imparted to an object, the higher the speed at which the object will travel. If the same amount of force is exerted on two bodies with a different mass, greater acceleration will be produced on the lighter or less massive object. The heavier object, however, will have greater momentum once inertia is overcome and will exert a greater force than the lighter object on something that it contacts.

The law of action and reaction states that for every action there is an equal and opposite reaction. This principle of counterforce is the basis for all locomotion and is evident when one leaves footprints in the sand. This principle applies to both linear and angular motion. Its application requires that adjustments be made by an individual to sustain the primary forces in any movement. For example, the use of opposition in the running pattern counters the action of one part of the body with that of another.

Receiving Force

To stop ourselves or a moving object, we absorb force over the greatest distance possible and with the largest surface area possible. The greater the distance over which the force is absorbed, the less the impact on whatever receives the force. This may be demonstrated by catching a ball with the arms straight out in front of the body and then catching again with the arms bent. The same thing may be observed when landing from a jump with the legs bent as opposed to landing with the legs straight. Forces should be absorbed over as large a surface area as possible. The impact is reduced in proportion to the size of the surface area, and the likelihood of injury is diminished. For example, trying to absorb the shock of a fall with the hands and arms extended will probably result in injury because the small surface area of the hand must receive the entire impact. It is far better to let as much of the body as possible absorb the impact.

The final direction of a moving object depends on the magnitude and the direction of all of the forces that have been applied. Therefore, whenever we kick, strike, or throw an object, its accuracy and the distance the object travels depend on the forces acting on it. If we are performing a vertical jump, we must work for a summation of forces in a vertical direction, whereas a good performance in the long jump requires a summation of horizontal and vertical forces so that the takeoff is at the appropriate angle.

Separate discussion of the principles of balance, giving force, and receiving forces should not be taken to mean that one is used in the absence of the others. Most of our movements combine all three. An element of balance is involved in almost all of our movements, and we give and receive force whenever we perform any locomotor or manipulative movement. A gymnast, for example, must maintain his or her equilibrium when performing a tumbling trick, such as a front flip, and also must absorb force from the body (on the landing). A tennis player must move to a position of readiness (giving force to and receiving force from the body), contact the ball (giving force to an object), and maintain balance. Although each of the movement patterns and skills discussed in the chapters that follow involve a specific sequence of movements, all incorporate the basic mechanics discussed here because these mechanical principles are common to all movement situations.

Summary

Motor development represents one aspect of the total developmental process. It is intricately interrelated with the cognitive and affective domains of human behavior and is influenced by a variety of factors. The importance of optimal motor development must not be minimized or regarded as secondary in relation to other developmental areas. Common factors affecting motor development emerge. These factors illustrate the gradual progression from relatively simple levels of functioning to more complex levels. Biological,
experiential, and physical factors influence the process and the products of motor development. Each individual is unique in his or her development and will progress at a rate determined by environmental and biological circumstances in conjunction with the specific requirements of the movement task.

Questions for Reflection

1. Neuromotor maturation seems to account for developmental progression in infants and children. What about the opposite: neuromotor regression frequently seen in individuals with cognitive impairments brought about by disease or old age?

2. The problem of obesity has reached “epidemic” proportions in the United States and several other countries. From an ecological perspective, what, in your view, are the primary proximal causes?

3. In your own life, how do you manage the issue of excess weight and what are your long-term personal strategies for combating overweight and obesity, and other eating disorders?

4. What are the primary causes and consequences of LBW and VLBW, and what are the best practices for combating this major health problem?

5. Why is a working knowledge of biomechanics important to physical education and sport educators as well as physical therapists and orthopedists?

Critical Readings


References


References


U.S. Department of Health and Human Services (USDHHS). (2001). The Surgeon General's call to action to prevent and


