

# Neurodevelopmental readiness of children for participation in sports

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**Abstract:** Many children participate in organized sports each year as a means of socialization, and physical skill building. Sports participation is dependent on physical growth, and neurodevelopmental readiness of the child. It is important to be aware of a child's level across the various streams of development and engage in specific strategies to optimize their ability at each age group. This article first outlines developmental skills across various age groups in childhood, and makes suggestions for such strategies.

**Keywords:** Neurodevelopment; sports readiness; developmental domains; social comparison

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## Introduction

Organized sports is enjoyed by approximately 30 to 40 million children and adolescents in the United States each year (1). Sports participation is an important means of socialization, physical skill building, and learning prosocial behaviors (2-4). A fundamental knowledge of normal child/adolescent development is necessary to advise caregivers and children on developmentally appropriate sports activities.

Neurodevelopment is often described in terms of specific domains or streams (*Table 1*) which progress concurrently and interdependently. The sequence of progress generally is similar, but acquisition of specific milestones varies from one child to another. Motor milestones are mostly influenced by genetic factors driving maturation of the neurologic system, and environmental factors (such as opportunity, expectations, and social context) play a significant role in social and adaptive skill acquisition (5). Sports participation decisions rely not only on neurodevelopmental maturation and milestone acquisition, but also on qualitative progress of specific skills (ability and fluency) that is enhanced by sports-specific skills training (2,6,7,8-21). Essential factors to consider for sports participation are physical growth, and neurodevelopmental readiness, where a child acquires necessary motor, physical, cognitive, social and adaptive abilities

to meet the demands of a given sport (1,10,14,22-26). This is largely influenced by biologic, physiologic, psychosocial, and environmental factors (10,12,24,26,27-29). Apart from motor skills such as agility, strength and endurance, cognitive skills such as processing speed and cognitive flexibility enable the child/adolescent to coordinate actions necessary for sports participation. While the prevailing wisdom had been that "critical periods" determine when sports skills are ideally acquired (1,11,14), not all children acquire the skills in the same period due to the impact of environmental factors and varying rates of growth and developmental progression. An example is only 60% of children were able to perform the expected tasks in one study (8,9). This is what makes identifying talent and predicting future success in children fraught with uncertainty. (12,14,24,25,28,30,31). Certain motor and cognitive abilities are needed when considering a child's readiness to participate in sports (*Tables 2,3*) (10,15,32-35).

## Sports readiness by age

### *The infant and toddler*

In the first year of life, the primary motor reflexes gradually integrate into more complex and coordinated

**Table 1** Child neurodevelopment

Domains	Streams
Physical or somatic	Gross motor
Neurologic	Fine motor
Sensory-perceptual	Visual-motor problem solving
Cognitive	Expressive language
Psychosocial	Receptive language
Emotional	Social skills
	Adaptive skills

**Table 2** Cognitive milestones relevant to sports-readiness

Milestone	Typical age of attainment (years)
Compare one's own abilities to those of other children	6
Cognitive maturity to understand the competitive nature of sport	9
Ability to comprehend complex sport specific tasks	12

**Table 3** Key infant and toddler motor developmental milestones

Typical age range of attainment (months)	Milestones
9–16	Stand without support
10–20	Walk sideways
18–30	Jump from the last stair to the floor
23–30	Walk upstairs, alternating a forward foot. Run, jump in place, and throw a large ball overhead
24–36	Full arm swing, run well, hop up to three times, throw a ball with forearm extension, catch a ball with fixed outstretched arm

responses (36,37) with a predictable acquisition of milestones though there is wide individual variation. Attempting earlier acquisition through early training is generally not successful (13,38).

In the 2<sup>nd</sup> year of life, the toddler engages in more coordinated and efficient walking, running, climbing, carrying skills due to improved posture and locomotion

skills, and emergent unipedal stand, stair navigation and ball skills set the stage for more advanced skills in preschool years (39). Simultaneously, acquisition of cognitive, language, and social skills such as following commands, attending for brief periods of time, imitation and parallel play are all necessary for later sports participation (37,40).

### *The pre-school and early school years*

During the preschool years (3 to 5 years of age), physical growth slows down compared to earlier stages; however, motor skills proceed at a rapid pace including balance, coordination, body strength, and endurance (37,40). Preschoolers master riding a tricycle, then a bicycle (with and without training wheels), and learn ball skills (catching, throwing) (13,21,28,41).

By 4 years of age, children can stand on one foot for up to 5 seconds, broad jump about 1 foot, hop up to 6 times, skip on one foot, climb a jungle gym, catch a ball (direct and bounced), throw overhand, kick a ball forward, and agilely move backward and forward (13,28,40,42).

By 5, children can run well, do a one-foot skip, hop on one foot up to 9 times, catch a ball with both hands, swing, and somersault (43).

By 6, most children can run and hit a target with a small ball, ride a bicycle, jump up to 1 foot and broad jump up to 3 feet (40).

Further refinement depends on practice of learned skills and training (especially during initial adaptation), and are associated with age-specific changes in the motor, cardiopulmonary and metabolic systems (13,14,28,40,41,44,45).

During preschool years, children can remember and recall basic information, answer some “wh” questions, name four colors, count ten or more objects, understand simple similarities and differences and analogies (36,37,40). Increase in expressive vocabulary is impressive with words at age 5 being 2,500 doubling to 5,000 by age 6 with increasing intelligibility and increasing sentence length, use of future tense, though some difficulties with homonyms (40). Despite improvement in auditory comprehension, environmental auditory and social distractions may cause children to have difficulty following directions. This improves with age and maturity, which is important for success in team sports, where the expectation is to attend to and comprehend instructions and to be alert to events in the sports environment.

Children at these ages focus on their own performance,

and have difficulty understanding the perspective of another. They can play games with simple rules but do not always understand the competitive purpose of sports (24,28) and may become upset when they lose (36). Cooperative play improves during this time, though some examples of lack of coordinated team efforts can be seen in preschool “swarming” around a soccer ball rather than passing. Children learn autonomy and trust through their successes or failures (46). Being egocentric, they may not understand why one child gets more “play” time and have trouble deferring instant gratification. They may have a hard time generalizing skills learned in one sport to another, and with changing their performance from “practice” to competitive game due to their concrete way of thinking (18,24).

Children younger than 6 or 7 are often naturally farsighted, and this may lead to limited ability in tracking objects and judging speed of moving objects (29,47). They can orient their bodies in space and in relation to others and objects, and distinguish laterality (14,36). However, they may not have mastered all complex motor planning necessary, for example, controlling velocity and trajectory of the ball in softball or timing base running as these require temporal sequencing, body awareness, eye-hand coordination, and visual-spatial skills (20,21).

### *Middle childhood*

From 6 to 11 years of age, the synergy of physiologic, neurologic, and musculoskeletal systems allows children to adopt mature motor patterns for optimal stability, effort, symmetry and physiologic cost (30,48), however aerobic and anaerobic capacities are still limited compared to adolescents. Refinement of skills occurs with practice, and may be influenced by training, and motivation. During this period, while there may be no gender differences in growth velocity, gender differences are noted in certain motor tasks (6,8,9,11,18,19,28,47); boys, for example, do better in jumping, running with speed and throwing for distance but girls have better balance and but learn to hop, skip, and catch a little earlier (8,9). Children at this age show interest in team sports, and have mastered fundamental motor skills to be successful in this.

By age 7, children are learning to pitch and bat, and pedal a bicycle well (37,49,50). By age 8, children begin to learn soccer or baseball and by age 9, they can catch a fly ball, and have unipedal stand for at least 15 seconds (50). By age 10 or 11, they can hit a baseball, shoot a basketball, throw over-arm and strike overhead (as in tennis) (24,51).

Children at this age have concrete thinking, with less ability to process future consequences. They can apply factual knowledge to familiar situations, but may not be able to extrapolate that knowledge to novel situations (5,34). Their concrete thinking may incorrectly lead them to assume that being able to hit a ball is an “all or nothing” skill, not something that is graded along a scale. Children in early middle stages (upto 6 years) engage in magical thinking and cannot process the consequences of their actions; like imitating mimicking wrestling moves from TV programs. (9,31,34) Although they have longer attention spans, they may still be easily distracted. They can plan and execute simple motor sequences and have more rapid decision-making (34,47,50). They can understand and follow directions, and have enhanced ability to use critical thinking and problem-solving skills (5,40,46). They are beginning to understand the purpose of the rules and can recognize differences between their own performance and that of others (1,14,33). They are still developing their sense of self in terms of confidence, esteem, and consciousness (46). They have the ability to give complex directions to others and to understand a broader range of words and their symbolic use (40,50), including synonyms, homonyms and antonyms.

At this stage, children understand well the difference between right and wrong and want to play by the rules, often becoming upset with others who do not (46). They enjoy playing organized games and enjoy comparisons of athletic prowess, but generally refrain from humiliating peers of other players. They are now better able to control their anger or hurt feelings when they cannot get their own way. They are able to distinguish between children who are popular and those who are not, and become aware of their body image (52). Those children with more advanced skills may not yet understand that their skills may not be permanent, and some become less motivated to practice to refine those skills (1,10,14,33).

Auditory discrimination and visual acuity are well developed, and children can more clearly separate the directions and comments of coaches and parents from other auditory distractions (28,40). They have the ability to integrate a variety of proprioceptive, visual, and vestibular cues and with improved manual dexterity, analytical thinking, problem solving skills, and motor-planning skills are able to engage optimally for most sports (14,24,28,36,40,50). Children can link sensory and motor output to engage in complex activities (like timing accuracy in tennis which requires estimation of the arrival

of a moving object based on velocity, acceleration, and deceleration) and practice accelerates this skill in various sports (51,53,54).

### Strategies to optimize sports participation

Based on the awareness of the developmental status of a child, it is possible for adults, both coaches and training personnel, as well as parents, to engage in strategies to optimize a child's participation in sports. Below, we have outlined strategies for each age group.

#### *Infants and toddlers*

While there are some instances of infants and toddlers being initiated into sports programs such as swimming and gymnastics, early participation does not increase skill and the American Academy of Pediatrics indicates that children are not developmentally ready for swimming lessons until after 4 years of age (55,56).

#### *Preschool and early school years*

Repeated practice in a variety of activities that allow children to explore their environmental space and enhance their mastery of skills is key in this age group. They learn better using visual aids, and from redirection and repetition, as they tend to have short attention spans (5–15 minutes). Encouraging participation in activities that focus on cooperation and socialization abilities allow preschool-aged children to practice, refine skills, and have fun (30,41).

Goals are to enhance horizontal and vertical mobility skills, and mastery of postural control and balance. Altering the surface, orientation and activity makes experiences challenging, yet fun (like incorporating turning, spinning, rolling, tumbling), in various directions and different temporal sequences (speed, tempo, rhythm) (41). Exploring the tactile, visual, kinesthetic properties of objects and learning magnitude of force, speed, weight, repeatedly allows experiences to integrate over time and provides children with foundational skills to be successful in various sports and develop confidence in their ability for most sport participation (24,28,41).

Adults should consider giving instructions using simple sentences combined with visual cues (including the use of videos or pictures), combined with modeling slow, exaggerated movements to allow the child time to process and coordinate visuomotor and gross motor skills.

Teaching children to use their expressive language skills to communicate frustration or excitement in a manner appropriate to their environment, while enhancing interpersonal skills with peers is also key at this age.

#### *Middle childhood*

Children during these middle years need opportunities to practice their fundamental skills in a variety of settings as they engage in more complex sport activities. The focus should be on practice, with remediation of weakness, overall skill development and optimal attempts (not performance). This gives children a broader set of criteria on which they can base their self-esteem or self-belief in their own abilities. They should be involved in more than one sport, engaging at least in one non-competitive one, as well as other activities that allow them to develop a sense of being well-rounded. In the early middle years, as children are just beginning to compare their performance with those of their peers, involvement in competitive sports should be minimal (1,14,24,33). It is more important to work on the perceptual motor skills, decision-making skills, and problem-solving skills necessary for participation in a number of different sports rather than prematurely specializing in one or two sports (14,30,57).

Special attention from coaches and parents to the less gifted or skilled child may facilitate positive social adaptation of these children, build their confidence and avoid them withdrawing from, or losing interest in activities. Apart from skill development, socioemotional skills such as problem solving, anger management and cooperative play helps children develop appropriate skills for competitive play that is both fun and instructive. Adults should avoid severe criticism, or extremely animated verbal, nonverbal or physical communication (yelling, screaming) to provide feedback. This might lead to confusion since some children will internalize the negative connotations of the feedback due to the emotion of the message. Intertwining demonstrations with practice sessions to enhance skills is recommended (24).

### Conclusions

Neurodevelopmental readiness of children for participation in sports depends on a complex interplay of multiple factors. These include individual factors (level of development, past experiences) and the environmental factors (opportunities, peer and adult attitudes). A child's level of participation in

sports should be guided by individual physical, neuromotor, cognitive, perceptual-motor, and psychological maturation. Understanding the child's neurodevelopmental level helps adults in their environment provide the optimal guidance for the child to have successful experiences in sports participation.

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### Footnote

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