Considerations for the Development of Agility During Childhood and Adolescence

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ABSTRACT

DESPITE BEING RECOGNIZED AS AN ESSENTIAL COMPONENT OF SPORTS PERFORMANCE, AGILITY DEVELOPMENT IN YOUTHS IS LARGELY UNDER-RESEARCHED. THIS ARTICLE REVIEWS THE EVIDENCE EXAMINING THE EFFECTS OF GROWTH, MATURATION AND TRAINING ON BOTH CHANGE OF DIRECTION SPEED AND COGNITIVE PROCESSING IN CHILDREN AND ADOLESCENTS, AND HOW COMBINED, THESE FACTORS MAY INFLUENCE AGILITY. TRAINING GUIDELINES ARE PROVIDED TO HELP STRENGTH AND CONDITIONING COACHES PRESCRIBE AGILITY TRAINING FOR YOUTHS AT DIFFERENT STAGES OF MATURATION, IN A SAFE AND EFFECTIVE MANNER.

INTRODUCTION

It has been suggested that agility is a key requirement for optimal performance in sport (19). Research has highlighted the importance of agility for success in lacrosse (12), basketball (9), and soccer (38), all of which are intermittent and multidirectional sports in nature, requiring rapid changes of direction in response to a variety of stimuli.

Additionally, it has been established that agility is a fitness quality that can distinguish between levels of playing ability in a range of different sports (14,17,37). Despite the significance of agility for sports performance, it was not prominent in early long-term athlete development models and has recently been highlighted as one of the most underresearched fitness components within the pediatric literature (24). However, with the recent evolution of the Youth Physical Development (YPD) model (24), the need for a structured and logical approach to developing agility throughout childhood and adolescence has been highlighted.

DEFINING AGILITY AND METHODS OF ASSESSMENT IN YOUTH

Agility can be defined as the ability of a fast whole-body movement involving the changing of direction or speed in response to a given stimulus (36). Sheppard and Young (36) expand on this definition and highlight change of direction speed (CODS) and perceptual and decision-making processes as key subcomponents of agility performance. Within the scope of CODS, technique, straight-line running speed, lower limb strength and power, and anthropometry are highlighted as contributing variables, while perceptual and decision-making processes comprise visual scanning, knowledge of situations, pattern recognition, and anticipation.

The acknowledgment and appreciation of this definition is crucial, because most existing pediatric literature has measured agility using test protocols that are preplanned in their movements and do not require reaction to a given stimulus. Such tests have included an 8-figure test (42), quadrant jump test (10), Harre's circuit (7), 5 × 10 m sprint test (32,43), 10 × 5 m test (15), line drill and T-test (41), and the 505 agility test (39). Consequently, the majority of previous pediatric literature has more closely examined CODS in children and adolescents, which is closed and preplanned in nature, as opposed to reactive agility, which incorporates open and unplanned changes of direction in response to a stimulus. Accordingly, the current article will discuss how growth, maturation, and training affect both the

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development of CODS and cognitive functioning independently across childhood.

NATURAL DEVELOPMENT AND TRAINABILITY OF AGILITY DURING CHILDHOOD AND ADOLESCENCE

CHANGE OF DIRECTION SPEED

Existing longitudinal and cross-sectional data indirectly suggest that CODS improves naturally throughout childhood and adolescence, albeit in a nonlinear fashion (7,10,42). This trend is underlined in recent evidence, which indicates that CODS is significantly greater in 14-year-old boys in comparison to 12-year-olds (18). During the prepubescent years, males and females appear to demonstrate similar capacities for agility-related tasks (10). However, around the onset of the pubertal spurt, it is evident that sex-associated differences begin to appear, with reports indicating that peak rate of development in CODS performance occurs at approximately 13–14 years of age in male youths, which is commensurate with the timing of peak height velocity (PHV) (42). Research also indicates that following this key maturational reference point, sex-associated differences in CODS continue to emerge because of continued physical performance enhancement in males and performance plateaus or decrements in females (10).

Underpinning mechanisms to explain such developmental trends in CODS performance would suggest that prepubertal adaptations are likely to result from nervous system development, governed by improvements in intramuscular and intermuscular coordination and general motor control improvement (23,34,44). Circumpubertal and postpubertal adaptations are likely to be mediated by increases in sex androgen concentrations such as testosterone, growth hormone, and insulin-like growth factor (26). Such hormonal changes will lead to increased force-producing capabilities emanating from continued neural development and increased muscle cross-sectional area, muscle pennation angle, and continued fiber-type differentiation (40).

Literature examining the trainability of CODS during childhood is sparse; however, research does suggest that strength training (20), plyometrics (28,39), and a combination of strength training and plyometrics (13) are all effective in promoting gains in CODS performance in youths. Relationships have already been identified between CODS and relative strength (30) and reactive strength (45), and therefore, effective force-producing capabilities would appear important for effective CODS movements. Results indicate that both children (3) and adolescents (13) can make significant gains in strength, and therefore, to improve CODS, it would seem prudent for youth training programs to focus on a combination of technical (fundamental movement skills [FMS]) and physical qualities throughout childhood and adolescence.

PERCEPTUAL AND DECISION-MAKING PROCESSES

Minimal literature appears to exist examining the impact of growth and maturation on the perceptual and decision-making processes related to agility performance as identified by Sheppard and Young (36). However, although not directly related to sport, research does suggest that for children and adolescents, repeated exposure to a given stimulus will result in faster response times and enhanced overall cognitive capacity, owing to strengthening of existing synaptic pathways (5) and synaptic pruning (6). This notion is supported by research that suggests a breadth and depth of experiences in different sporting activities is likely to aid in the development of expert decision-making processes in young athletes (2).

Importantly, for the health and well-being of young athletes, Baker et al. (2) suggest that exposure to various activities, where generic pattern recognition, hand-eye coordination, and decision-making skills can be tested and developed, may reduce the need for early specialization in a single sport. This has important implications for youths as early specialization has previously been linked to increased injury risk in young athletes (29). Further research suggested that a cumulative exposure to a breadth of sporting experiences may indeed result in selective transfer of pattern recall skills and facilitation of expert performance (1).

Recent research, albeit, in a group of mature youths (younger than 20 years), has suggested that the perceptual and decision-making processes associated with agility performance are indeed trainable (35). However, although this research suggests that the cognitive element of agility performance can be enhanced through appropriate training, it fails to provide an insight into how the training response changes throughout different stages of maturation.

TRAINING FOCUS FOR AGILITY DEVELOPMENT THROUGHOUT CHILDHOOD AND ADOLESCENCE

In an attempt to determine how agility training should differ according to maturational status of the child, Figure 1 presents an overview for the breakdown of time devoted to training different components of agility. The 3 components included within the model are FMS, CODS, and reactive agility training (RAT). Figure 1 proposes that both children and adolescents should be exposed to all 3 components at all times; however, the percentage of time dedicated to each component within a given training session will vary according to maturational stage. Rationales for the approaches to agility development at each level of maturation are provided below, and maturity-related example training sessions for junior tennis players are provided in Tables 1–3.

The example sessions provided are for a 1-hour duration; however, it is possible that strength and conditioning coaches may be required to tailor the contents of the session depending on time availability (e.g., agility development training may be integrated into the start of a generic skill–based session). Tennis was selected owing to

Figure 1. Primary agility training focus for prepubertal, circumpubertal, and postpubertal children.

the frequent changes of direction experienced within a typical match (22). Examples of drills are illustrated in Figures 3–5. As a caveat, it should be highlighted that this article will only discuss direct agility training methods and that a well-rounded youth-based training program will include training methods devoted to enhancing strength, power, speed and other key fitness components as suggested by the recently published YPD model (24).

PREPUBERTAL TRAINING FOCUS

The primary training focus during prepubescence is FMS development. The development of FMS during childhood has previously been deemed essential for long-term athletic development (24) and increased levels of physical activity in later life (25). Specific to the concept of agility training, it has been proposed that FMS development is vital during the early years to ensure that the correct movement patterns are mastered in a safe and fun environment, before these movements are tested in more complex, open-skilled, sport-specific situations (31). This notion is emphasized in the example of the agility cutting movement as displayed in Figure 2.

Research has indicated that ligament loading at the knee joint increases during unanticipated cutting maneuvers when compared with straight-line running because of an increased knee valgus moment, which predisposes the anterior cruciate ligament (ACL) to greater risk of injury (4). Female adolescents typically demonstrate a greater valgus knee position than their male counterparts during unanticipated cutting actions and therefore possess an increased risk of ACL rupture (16). Because of the increased injury risk associated with unanticipated cutting movements, the development of FMS (specifically targeting knee, hip and ankle stability in addition to core bracing) is viewed as an essential starting point for long-term agility development.

Owing to the neural plasticity associated with the prepubertal years (5,33), it would appear appropriate to develop sound movement mechanics during the early years that can subsequently be exposed to greater external loadings during more dynamic sport-specific movements. Nevertheless, it is suggested that exposure to sport-specific movement inclusive of both CODS and RAT is also necessary during prepubescence, because Elliott et al. (11) reported that movement and muscle activity patterns in young soccer players were evident by 11 years of age.

CIRCUMPUBERTAL TRAINING FOCUS

For circumpubertal children, Figure 1 suggests that after a dedicated period on FMS mastery during the prepubertal phase, a greater emphasis can then be placed on CODS development. Such an approach enables the child to develop the ability to combine key FMS and, in doing so, learn to rapidly accelerate, decelerate, and then reaccelerate but in a controlled and preplanned environment, with prior knowledge of the direction and magnitude of change of direction. Although Figure 1 proposes that circumpubertal children should dedicate most time to CODS development (40%), there is also significant time devoted to continued

Table 1
Example of 60-minute agility development training session for a prepubertal tennis squad

Phase of training session	Focus of training phase	Exercise	Volume (sets × reps)	Intensity	Rest, s	Approximate total time for phase, min
Warm-up	FMS (60%)	Lower limb foam roller complex	2 × 10	Low	30–60	36
		Hip mobility complex	2 × 10 each drill			
		Mini-band clam shells	2 × 8 each leg			
		Mini-band glute bridge	2 × 8 each leg			
		Single-leg box squat	2 × 8 each leg			
		6-point lunge pattern	3 × 6 each leg			
		Single-leg balance with reaches	2 × 30 seconds each leg			
		Single-leg partner mirroring	2 × 30 seconds each leg			
		Jump to low box	3 × 6			
		CMJ and stick	2 × 4			
		Lateral SJ and stick	2 × 4 each leg			
Main 1	CODS (25%)	Preplanned step patterns (drop, jab, and pivot)	6 × each pattern	Moderate	30	15
		Preplanned 6-point grid court drill (2 × 2m)	4 × 10 s		60	
		Multidirectional preplanned relays (5 m)	4 × 10 s			
Main 2	RAT (15%)	Randomized multidirectional ball throws with hold	4 × 6 s	High	60	9
		Service box "piggy in the middle"	4 × 20 s			

CMJ = countermovement jump; CODS = change of direction speed; FMS = fundamental movement skills; RAT = reactive agility training; SJ = squat jump.

Table 2
Example of 60-minute agility development training session for a circumpubertal tennis squad

Phase of training session	Focus of training phase	Exercise	Volume (sets × reps)	Intensity	Rest, s	Approximate total time for phase, min
Warm-up	FMS (30%)	Mini-band clam shells	2 × 8 each leg	Low	30–60	18
		Hip mobility complex	2 × 10 each drill			
		Single-leg box squat	3 × 8 each leg			
		SL partner mirroring	2 × 45 s each leg			
		Jump to medium box	2 × 4			
		CMJ and stick	2 × 4			
		SL lateral jump and stick	2 × 4 each leg			
Main 1	CODS (40%)	Half-court lateral races (drop, jab, and pivot)	4 × 4	Moderate	30	24
		Preplanned 6-point grid court run	8 × 10 s			
		Preplanned ball pickups (3–5 m grid)	6 × 10 s		90	
		Preplanned lateral ball catches	4 × 6			
Main 2	RAT (30%)	Randomized multidirectional ball throws	5 × 6	High	90	18
		Lateral shuffle + react to catch ball	5 × 6		90	
		Team tag in service boxes	6 × 10 s			

CMJ = countermovement jump; CODS = change of direction speed; FMS = fundamental movement skills; RAT = reactive agility training; SL = single leg.

Table 3
Example of 60-minute agility development training session for a postpubertal tennis squad

Phase of training session	Focus of training phase	Exercise	Volume (sets × reps)	Intensity	Rest, s	Approximate total time for phase, min
Warm-up	FMS (20%)	Hip mobility complex	2 × 10 each drill	Low	30–60	12
		Mini-band monster walks	2 × 8 each leg			
		Single-leg box squat	3 × 8 each leg			
		Lateral SL bounds	4 × 4			
		Low-level multidirectional DJ and stick	4 × 4			
Main 1	CODS (20%)	Preplanned ball catches	6 × 10 s	Moderate	60	12
		Preplanned multidirectional ball pickups	6 × 10 s		60	
Main 2	RAT (60%)	Randomized multidirectional ball throws	6 × 8	High	90	36
		Lateral cone shuffle + react to catch ball	6 × 8		90	
		Half-court team tag	6 × 15 s		90	
		Ball exchange competition	First to 7 points			

CODS = change of direction speed; DJ = drop jump; FMS = fundamental movement skills; RAT = reactive agility training; SL = single leg.

FMS development (30%) and RAT (30%). This underlines the need to expose circumpubertal children to FMS and RAT training as they approach puberty to reinforce previously learned movement patterns and to develop sport-specific reactive agility techniques during a timeframe where the sensorimotor cortex is susceptible to rapid gains in development (6,33).

It should be noted that as children approach and experience puberty, they will experience rapid changes in limb length as a result of the adolescent growth spurt. This physiological process is referred to as PHV, and such changes in stature can lead to temporary decrements in motor control performance, a concept that has been termed "adolescent awkwardness" (32). Although adolescent awkwardness will not affect all children, coaches should be aware of the potential need to retrain certain movement patterns that may have been negatively affected as children become accustomed to movement with longer limbs.

POSTPUBERTAL TRAINING FOCUS

As proposed by Lloyd and Oliver (24), the range of movement skills developed throughout the prepubertal phase, and refined and retained throughout puberty, will continue to improve during late adolescence and into early adulthood. This is expected to arise as youths are exposed to an increasing volume of learning experiences within various sporting situations. Because of cognitive ability naturally fine-tuning throughout childhood and adolescence (6), it is proposed that agility training prescription will need to become more challenging as adolescents approach adulthood. This notion is reflected in Figure 1 where a much greater training focus is devoted to RAT (60%). Therefore, although the majority of exercises within a training session for a postpubertal adolescent would incorporate RAT drills, it is recommended that FMS and CODS movements should also form part of the session to reinforce correct movement mechanics. This could be introduced

Figure 2. Single leg balance with reaches.

as part of the warm-up to the training session before the athlete is introduced to any RAT exercises. Such an approach has been supported by previous research that reinforces proper mechanics at the beginning of training sessions to reduce the risk of fatiguing effects on lower extremity mechanics during unanticipated running tasks and cutting maneuvers (8). A similar strategy of prioritizing mechanics, as part of the warm-up before more dynamic movements, has proven to successfully reduce the total number of injuries in young male and female soccer

Figure 3. Half-court races with slide (on clay court).

Figure 4. Ball exchange competition.

players, during both training and competition (21,27).

SUMMARY

The current article has highlighted the lack of literature examining agility development throughout childhood and adolescence and has emphasized the current lack of understanding surrounding the effects of maturation on its performance. Despite the lack of research, a model has been provided that promotes a different training focus for each stage of maturation, based on FMS, CODS, and RAT exercises. It is suggested that a prepubertal focus is based on FMS development to ensure correct movement patterns are established at an early age. As children progress through adolescence, it is then recommended that a greater focus be placed on RAT, which develops the cognitive ability to respond to various stimuli. As is the case with holistic athletic development models, there must be an appreciation for a flexible approach given the varied rates of maturation of children, and therefore, at all times, individual-specific training approaches should be adopted.

Figure 5. Example of a circumpubertal athlete performing a cutting movement. Note the red circle above the outer knee, which during such movements is at an increased risk of injury because of excessive ligamentous loading.

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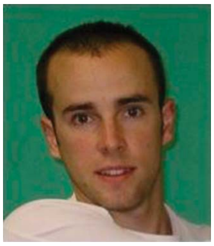

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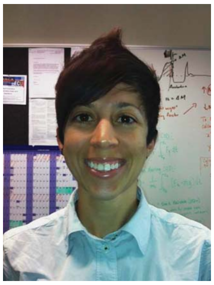

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