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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 integrate agility exercises within the training programs of youths at different stages of maturation, in a safe, logical and effective manner.

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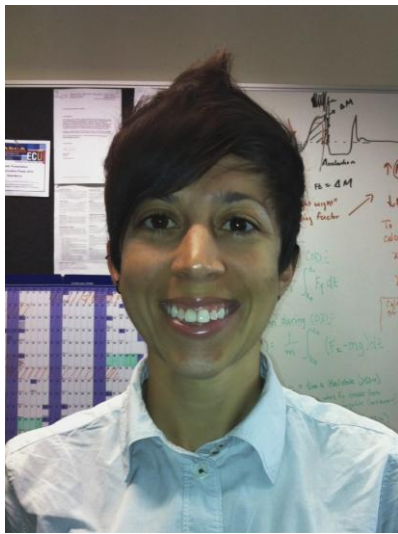


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1 MANUSCRIPT TITLE: Considerations for the development of agility during
2 childhood and adolescence

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6 LEAD SUMMARY

7 Despite being recognized as an essential component of sports performance, agility
8 development in youths is largely under-researched. This article reviews the evidence
9 examining the effects of growth, maturation and training on both change of direction
10 speed and cognitive processing in children and adolescents, and how combined, these
11 factors may influence agility. Training guidelines are provided to help strength and
12 conditioning coaches integrate agility exercises within the training programs of youths
13 at different stages of maturation, in a safe, logical and effective manner.

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1 INTRODUCTION

2 It has been suggested that agility is a key requirement for optimal performance in
3 sport (19). Research has highlighted the importance of agility for success in lacrosse
4 (11), basketball (9) and soccer (38), all of which are intermittent and multi-directional
5 sports in nature, requiring rapid changes of direction in response to a variety of
6 stimuli. Additionally, it has been established that agility is a fitness quality that can
7 distinguish between levels of playing ability in a range of different sports (37,14,17).
8 Despite the significance of agility for sports performance, it was not prominent in
9 early long-term athlete development models, and has recently been highlighted as one
10 of the most under-researched fitness components within the paediatric literature (24).
11 However, with the recent evolution of the Youth Physical Development (YPD) model
12 (24), the need for a structured and logical approach to developing agility throughout
13 childhood and adolescence has been highlighted.

14
15 DEFINING AGILITY, AND METHODS OF ASSESSMENT IN YOUTH

16 Agility can be defined as the ability of a fast, whole-body movement involving the
17 changing of direction or speed in response to a given stimulus (36). Sheppard and
18 Young (36) expand on this definition and highlight change of direction speed (CODS)
19 and perceptual and decision-making processes as key sub-components of agility
20 performance. Within the scope of CODS; technique, straight-line running speed,
21 lower limb strength and power, and anthropometry are highlighted as contributing
22 variables; whilst perceptual and decision-making processes are comprised of visual
23 scanning, knowledge of situations, pattern recognition and anticipation. The
24 acknowledgement and appreciation of this definition is crucial, as most existing
25 paediatric literature has measured agility using test protocols that are pre-planned in

1 their movements, and do not require reaction to a given stimulus. Such tests have
2 included an 8-figure test (42), quadrant jump test (10), Harre circuit (7), 5x10m sprint
3 test (32,43), 10 x 5 m test (15), line drill and T-test (41), and the 505 agility test (39).
4 Consequently, the majority of previous paediatric literature has more closely
5 examined change of direction speed (CODS) in children and adolescents which is
6 closed and pre-planned in nature, as opposed to reactive agility, which incorporates
7 open and unplanned changes of direction in response to a stimulus. Accordingly, the
8 current manuscript will discuss how growth, maturation and training affect both the
9 development of CODS and cognitive functioning independently across childhood.

10

11 NATURAL DEVELOPMENT AND TRAINABILITY OF AGILITY DURING
12 CHILDHOOD AND ADOLESCENCE

13 Change of direction speed (C O D S)

14 Existing longitudinal and cross-sectional data indirectly suggest that CODS improves
15 naturally throughout childhood and adolescence, albeit in a non-linear fashion
16 (7,10,42). This trend is underlined in recent evidence, which indicates that CODS is
17 significantly greater in 14-year old boys in comparison to 12-year olds (18). During
18 the prepubescent years, males and females appear to demonstrate similar capacities
19 for agility-related tasks (10). However, around the onset of the pubertal spurt, it is
20 evident that sex-associated differences begin to appear, with reports indicating that
21 peak rate of development in CODS performance occurs at approximately 13-14 years
22 of age in male youths, which is commensurate with the timing of peak height velocity
23 (42). Research also indicates that following this key maturational reference point; sex-
24 associated differences in CODS continue to emerge due to continued physical

1 performance enhancement in males, and performance plateaus or decrements in
2 females (10).

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4 Underpinning mechanisms to explain such developmental trends in CODS
5 performance would suggest that prepubertal adaptations are likely to result from
6 nervous system development, governed by improvements in intramuscular and
7 intermuscular coordination, and general motor control improvement (23,34,44).

8 Circumpubertal and postpubertal adaptations are likely to be mediated by increases in
9 sex androgen concentrations such as testosterone, growth hormone and insulin-like
10 growth factor (26). Such hormonal changes will lead to increased force producing
11 capabilities emanating from continued neural development, and increased muscle
12 cross-sectional area, muscle pennation angle and continued fibre type differentiation
13 (40).

14
15 Literature examining the trainability of CODS during childhood is sparse, however,
16 research does suggest that strength training (20), plyometrics (28,39), and a
17 combination of strength training and plyometrics (13) are all effective in promoting
18 gains in CODS performance in youths. Relationships have already been identified
19 between CODS and relative strength (30) and reactive strength (45), and therefore
20 effective force producing capabilities would appear important for effective CODS
21 movements. Results indicate that both children (3) and adolescents (13) can make
22 significant gains in strength, and therefore in order to improve CODS, it would seem
23 prudent for youth training programmes to focus on a combination of technical
24 (fundamental movement skills), physical qualities throughout childhood and
25 adolescence.

1

2 Perceptual and decision-making processes

3 Minimal literature appears to exist examining the impact of growth and maturation on
4 the perceptual and decision-making processes related to agility performance as
5 identified by Sheppard and Young (36). However, whilst not directly related to sport,
6 research does suggest that for children and adolescents, repeated exposure to a given
7 stimulus will result in faster response times and enhanced overall cognitive capacity,
8 owing to strengthening of existing synaptic pathways (6) and synaptic pruning (5).
9 This notion is supported by research that suggests a breadth and depth of experiences
10 in different sporting activities is likely to aid in the development of expert decision-
11 making processes in young athletes (2). Importantly, for the health and wellbeing of
12 young athletes, Baker and colleagues (2) suggest that exposure to various activities
13 where generic pattern recognition, hand-eye coordination, and decision-making skills
14 can be tested and developed, may reduce the need for early specialization in a single
15 sport. This has important implications for youths as early specialization has
16 previously been linked to increased injury risk in young athletes (29). Further research
17 suggested that a cumulative exposure to a breadth of sporting experiences may indeed
18 result in selective transfer of pattern recall skills and facilitation of expert
19 performance (1). Recent research, albeit, in a group of mature youths (under-20 years
20 of age), has suggested that the perceptual and decision-making processes associated
21 with agility performance are indeed trainable (35). However, while this research
22 suggests that the cognitive element of agility performance can be enhanced through
23 appropriate training; it fails to provide an insight into how the training response
24 changes throughout different stages of maturation.

25

1 TRAINING FOCUS FOR AGILITY DEVELOPMENT THROUGHOUT
2 CHILDHOOD AND ADOLESCENCE

3 In an attempt to determine how agility training should differ according to maturational
4 status of the child, *figure 1* presents an overview for the breakdown of time devoted to
5 training different components of agility. The three components included within the
6 model are fundamental movement skills (FMS), CODS and reactive agility training
7 (RAT). *Figure 1* proposes that both children and adolescents should be exposed to all
8 three components at all times; however, the percentage of time dedicated to each
9 component within a given training session will vary according to maturational stage.
10 Rationales for the approaches to agility development at each level of maturation are
11 provided below, and maturity-related example training sessions for junior tennis
12 players are provided in *tables 1-3*. The example sessions provided are for a 1-hour
13 duration, however, it is possible that strength and conditioning coaches may be
14 required to tailor the contents of the session dependent on time availability (for
15 example, agility development training may be integrated into the start of a generic
16 skills based session). Tennis was selected owing to the frequent changes of direction
17 experienced within a typical match (22). Example drills are illustrated in *figures 3-5*.
18 As a caveat, it should be highlighted that this manuscript will only discuss direct
19 agility training methods; and that a well-rounded youth-based training program will
20 include training methods devoted to enhancing strength, power, speed and other key
21 fitness components as suggested by the recently published YPD model (24).

22
23 ***Insert figure 1 near here***

24
25 Prepubertal Training Focus

1 The primary training focus during prepubescence is FMS development. The
2 development of FMS during childhood has previously been deemed essential for
3 long-term athletic development (24), and increased levels of physical activity in later
4 life (25). Specific to the concept of agility training, it has been proposed that FMS
5 development is vital during the early years to ensure that the correct movement
6 patterns are mastered in a safe and fun environment, before these movements are
7 tested in more complex, open-skilled, sport-specific situations (31). This notion is
8 emphasized in the example of the agility cutting movement as displayed in *figure 2*.
9 Research has indicated that ligament loading at the knee joint increases during
10 unanticipated cutting manoeuvres when compared to straight line running due to an
11 increased knee valgus moment, which predisposes the anterior cruciate ligament
12 (ACL) to greater risk of injury (4). Female adolescents typically demonstrate a greater
13 valgus knee position than their male counterparts during unanticipated cutting actions,
14 and therefore possess an increased risk of ACL rupture (16). Due to the increased
15 injury risk associated with unanticipated cutting movements, the development of FMS
16 (specifically targeting knee, hip and ankle stability in addition to core bracing) is
17 viewed as an essential starting point for long-term agility development.

18

19 ***Insert figure 2 near here***

20

21 Owing to the neural plasticity associated with the prepubertal years (6,33), it would
22 appear appropriate to develop sound movement mechanics during the early years, that
23 can subsequently be exposed to greater external loadings during more dynamic, sport-
24 specific movements. Nevertheless, it is suggested that exposure to sport-specific
25 movement inclusive of both CODS and RAT is also necessary during prepubescence,

1 since Elliott et al. (12) reported that movement and muscle activity patterns in young
2 soccer players were evident by 11 years of age.

3

4 Circumpubertal Training Focus

5 For circumpubertal children, *figure 1* suggests that following a dedicated period of
6 time on FMS mastery during the prepubertal phase, a greater emphasis can then be
7 placed on CODS development. Such an approach enables the child to develop the
8 ability to combine key FMS, and in doing so learn to rapidly accelerate, decelerate,
9 and then reaccelerate, but in a controlled and pre-planned environment, with prior
10 knowledge of the direction and magnitude of change(s) of direction. Whilst *figure 1*
11 proposes that circumpubertal children should dedicate most time to CODS
12 development (40%), there is also significant time devoted to continued FMS
13 development (30%) and RAT (30%). This underlines the need to expose
14 circumpubertal children to FMS and RAT training as they approach puberty to
15 reinforce previously learnt movement patterns, and to develop sport-specific, reactive
16 agility techniques during a timeframe where the sensorimotor cortex is susceptible to
17 rapid gains in development (5,33).

18

19 It should be noted that as children approach and experience puberty, they will
20 experience rapid changes in limb length as a result of the adolescent growth spurt.
21 This physiological process is referred to as peak height velocity (PHV), and such
22 changes in stature can lead to temporary decrements in motor control performance, a
23 concept that has been termed 'adolescent awkwardness' (32). Whilst adolescent
24 awkwardness will not affect all children, coaches should be aware of the potential

1 need to re-train certain movement patterns that may have been negatively affected as
2 children become accustomed to movement with longer limbs.

3 4 5 6 7 4 Postpubertal Training Focus

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10 5 As proposed by Lloyd and Oliver (24), the range of movement skills developed
11 6 throughout the prepubertal phase, and refined and retained throughout puberty, will
12 7 continue to improve during late adolescence and into early adulthood. This is
13 8 expected to arise as youths are exposed to an increasing volume of learning
14 9 experiences within various sporting situations. Due to cognitive ability naturally fine-
15 10 tuning throughout childhood and adolescence (5) it is proposed that agility training
16 11 prescription will need to become more challenging as adolescents approach
17 12 adulthood. This notion is reflected in *figure 1* where a much greater training focus is
18 13 devoted to RAT (60%). Therefore, whilst the majority of exercises within a training
19 14 session for a postpubertal adolescent would incorporate RAT drills, it is
20 15 recommended that FMS and CODS movements should also form part of the session
21 16 to reinforce correct movement mechanics. This could be introduced as part of the
22 17 warm-up to the training session before the athlete is introduced to any RAT exercises.
23 18 Such an approach has been supported by previous research that reinforces proper
24 19 mechanics at the beginning of training sessions to reduce the risk of fatiguing effects
25 20 on lower extremity mechanics during unanticipated running tasks and cutting
26 21 manoeuvres (8). A similar strategy of prioritising mechanics as part of the warm-up
27 22 prior to more dynamic movements, has proven to successfully reduce the total number
28 23 of injuries in young male and female soccer players, during both training and
29 24 competition (21,27)

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1 ***Insert tables 1-3 near here***

2 ***Insert figures 3-5 near here***

3

4 SUMMARY

5 The current manuscript has highlighted the lack of literature examining agility
6 development throughout childhood and adolescence, and has emphasized the current
7 lack of understanding surrounding the effects of maturation on its performance.

8 Despite the lack of research, a model has been provided that promotes a different
9 training focus for each stage of maturation, based on FMS, CODS and RAT exercises.

10 It is suggested a prepubertal focus is based on FMS development to ensure correct
11 movement patterns are established at an early age. As children progress through
12 adolescence, it is then recommended that a greater focus be placed on RAT, which
13 develops the cognitive ability to respond to various stimuli. As is the case with
14 holistic athletic development models, there must be an appreciation for a flexible
15 approach given the varied rates of maturation of children, and therefore at all times,
16 individual-specific training approaches should be adopted.

17

18

19 FIGURE CAPTIONS

20 Figure 1: Primary agility training focus for prepubertal, circumpubertal and
21 postpubertal children

22 Figure 2: Example of a circumpubertal athlete performing a cutting movement. Note
23 the red circle above the outer knee, which during such movements is at an increased
24 risk of injury due to excessive ligamentous loading.

25 Figure 3: Single leg balance with reaches

1 Figure 4: Half-court races with slide (on clay court)

2 Figure 5: Ball exchange competition

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Figure 2

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Figure 3
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Table 1. Example 60 minute agility development training session for a prepubertal tennis squad

Phase of Training Session	Focus of Training Phase	Exercise	Volume (sets x reps)	Intensity	Rest (seconds)	Approximate Total Time for Phase (minutes)
Warm-up	FMS (60%)	Lower limb foam roller complex	2 x 10	Low	30-60	36
		Hip mobility complex	2 x 10 each drill			
		Mini-band clam shells	2 x 8 each leg			
		Mini-band glute bridge	2 x 8 each leg			
		Single leg box squat	2 x 8 each leg			
		6-point lunge pattern	3 x 6 each leg			
		Single leg balance with reaches	2 x 30 seconds each leg			
		Single-leg partner mirroring	2 x 30 seconds each leg			
		Jump to low box	3 x 6			
		CMJ and stick	2 x 4			
		Lateral SJ Jump and stick	2 x 4 each leg			
		Main 1	CODS (25%)			
Pre-planned 6-point grid court drill (2m x 2m)	4 x 10 seconds					
Multidirectional pre-planned relays (5m)	4 x 10 seconds					
Main 2	RAT (15%)	Randomized multidirectional ball throws with hold	4 x 6	High	60	9
		Service box “piggy in the middle”	4 x 20 seconds			

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

Phase of Training Session	Focus of Training Phase	Exercise	Volume (sets x reps)	Intensity	Rest (seconds)	Approximate Total Time for Phase (minutes)
Warm-up	FMS (30%)	Mini-band clam shells	2 x 8 each leg	Low	30-60	18
		Hip mobility complex	2 x 10 each drill			
		Single leg box squat	3 x 8 each leg			
		SL partner mirroring	2 x 45 seconds each leg			
		Jump to medium box	2 x 4			
		CMJ and stick	2 x 4			
		SL lateral jump and stick	2 x 4 each leg			
		Main 1	CODS (40%)			
Pre-planned 6-point grid court run	8 x 10 seconds					
Pre-planned ball pick ups (3-5m grid)	6 x 10 seconds					
Pre-planned lateral ball catches	4 x 6					
Main 2	RAT (30%)	Randomized multidirectional ball throws	5 x 6	High	90 90	18
		Lateral shuffle + react to catch ball	5 x 6			
		Team tag in service boxes	6 x 10 seconds			

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

Phase of Training Session	Focus of Training Phase	Exercise	Volume (sets x reps)	Intensity	Rest (seconds)	Approximate Total Time for Phase (minutes)
Warm-up	FMS (20%)	Hip mobility complex	2 x 10 each drill	Low	30-60	12
		Mini-band monster walks	2 x 8 each leg			
		Single leg box squat	3 x 8 each leg			
		Lateral SL bounds	4 x 4			
		Low level multidirectional DJ and stick	4 x 4			
Main 1	CODS (20%)	Pre-planned ball catches	6 x 10 seconds	Moderate	60	12
		Pre-planned multidirectional ball pick ups	6 x 10 seconds		60	
Main 2	RAT (60%)	Randomized multidirectional ball throws	6 x 8	High	90	36
		Lateral cone shuffle + react to catch ball	6 x 8		90	
		Half-court team tag	6 x 15 seconds		90	
		Ball exchange competition	First to 7 points		90	

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