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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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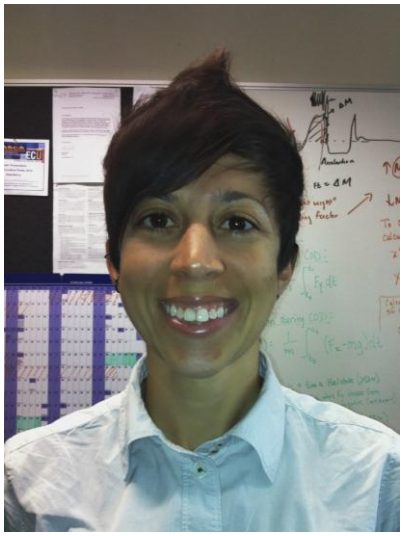

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LEAD SUMMARY

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.

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 (11), basketball (9) and soccer (38), all of which are intermittent and multi-directional 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 (37,14,17). 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 under-researched fitness components within the paediatric 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 sub-components 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; whilst perceptual and decision-making processes are comprised of visual scanning, knowledge of situations, pattern recognition and anticipation. The acknowledgement and appreciation of this definition is crucial, as most existing paediatric literature has measured agility using test protocols that are pre-planned 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 circuit (7), 5x10m sprint test (32,43), 10 x 5 m test (15), line drill and T-test (41), and the 505 agility test (39). Consequently, the majority of previous paediatric literature has more closely examined change of direction speed (CODS) in children and adolescents which is closed and pre-planned in nature, as opposed to reactive agility, which incorporates open and unplanned changes of direction in response to a stimulus. Accordingly, the current manuscript will discuss how growth, maturation and training affect both the development of CODS and cognitive functioning independently across childhood.

NATURAL DEVELOPMENT AND TRAINABILITY OF AGILITY DURING CHILDHOOD AND ADOLESCENCE

Change of direction speed (CODS)

Existing longitudinal and cross-sectional data indirectly suggest that CODS improves naturally throughout childhood and adolescence, albeit in a non-linear 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 (42). Research also indicates that following this key maturational reference point; sex-associated differences in CODS continue to emerge due to 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 fibre 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 in order to improve CODS, it would seem prudent for youth training programmes to focus on a combination of technical (fundamental movement skills), 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, whilst 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 (6) and synaptic pruning (5). 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 wellbeing of young athletes, Baker and colleagues (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 (under-20 years of age), has suggested that the perceptual and decision-making processes associated with agility performance are indeed trainable (35). However, while 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 three components included within the model are fundamental movement skills (FMS), CODS and reactive agility training (RAT). *Figure 1* proposes that both children and adolescents should be exposed to all three 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 dependent on time availability (for example, agility development training may be integrated into the start of a generic skills based session). Tennis was selected owing to the frequent changes of direction experienced within a typical match (22). Example drills are illustrated in *figures 3-5*. As a caveat, it should be highlighted that this manuscript 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).

Insert figure 1 near here

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 manoeuvres when compared to straight line running due to 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). Due to 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.

Insert figure 2 near here

Owing to the neural plasticity associated with the prepubertal years (6,33), 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 prepubscence,

since Elliott et al. (12) 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 following a dedicated period of time 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 pre-planned environment, with prior knowledge of the direction and magnitude of change(s) of direction. Whilst *figure 1* proposes that circumpubertal children should dedicate most time to CODS development (40%), there is also significant time devoted to continued 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 learnt movement patterns, and to develop sport-specific, reactive agility techniques during a timeframe where the sensorimotor cortex is susceptible to rapid gains in development (5,33).

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 peak height velocity (PHV), and such changes in stature can lead to temporary decrements in motor control performance, a concept that has been termed ‘adolescent awkwardness’ (32). Whilst adolescent awkwardness will not affect all children, coaches should be aware of the potential

need to re-train 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. Due to cognitive ability naturally fine-tuning throughout childhood and adolescence (5) 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, whilst 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 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 manoeuvres (8). A similar strategy of prioritising mechanics as part of the warm-up prior to more dynamic movements, has proven to successfully reduce the total number of injuries in young male and female soccer players, during both training and competition (21,27)

Insert tables 1-3 near here

Insert figures 3-5 near here

SUMMARY

The current manuscript 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 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 CAPTIONS

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

Figure 2: 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 due to excessive ligamentous loading.

Figure 3: Single leg balance with reaches

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

Figure 5: Ball exchange competition

REFERENCES

1. Abernethy B, Baker J and Côté J. Transfer of pattern recall skills may contribute to the development of sport expertise. Appl Cognit Psychol 19: 705-718, 2005.
2. Baker J, Côté J and Abernethy B. Sport-specific practice and the development of expert decision-making in team ball sports. J Appl Psychol 15: 12-25, 2003.
3. Behringer M, vom Heede A, Matthews M and Mester J. Effects of strength training on motor performance skills in children and adolescents: A meta-analysis. Pediatr Exerc Sci 23: 186–206, 2011.
4. Besier TF, Lloyd DG, Cochrane JL and Ackland TR. External loading of the knee joint during running and cutting manoeuvres. Med Sci Sports Exerc 33: 1168-1175, 2001.
5. Casey BJ, Tottenham N, Liston C and Durston S. Imaging the developing brain: what have we learned about cognitive development? Trends Cogn Sci 9: 104-110, 2005.
6. Casey BJ, Giedd JN and Thomas KM. Structural and functional brain development and its relation to cognitive development. Biol Psychol 54: 241–257, 2000.
7. Chiodera P, Volta E, Gobbi G, Milioli MA, Mirandola P, Bonetti A, Delsignore R, Bernasconi S, Anedda A and Vitale M. Specifically designed physical exercise programs improve children's motor abilities. Scand J Med Sci Sports 18: 179-187, 2008.

8. Cortes N, Quammen D, Lucci S, Greska E and Onate J. A functional agility short-term fatigue protocol changes lower extremity mechanics. J Sports Sci 30: 797-805, 2012.

9. Delextrat A and Cohen D. Physiological testing of basketball players: toward a standard evaluation of anaerobic fitness. J Strength Cond Res 22: 1066-1072, 2008.

10. Eisenmann JC and Malina RM. Age and sex-associated variation in neuromuscular capacities of adolescent distance runners. J Sports Sci 21: 551-557. 2003.

11. Enemark-Miller EA, Seegmiller JG, and Rana SR. Physiological profile of women's lacrosse players. J Strength Cond Res 23: 39-43, 2009.

12. Elliott BC, Bloomfield J, and Davies CM. Development of the punt kick: a cinematographical analysis. J Hum Move Stud 6: 142-150, 1980.

13. Faigenbaum AD, McFarland JE, Keiper FB, Tevlin W, Ratamess NA, Kang J and Hoffman JR. Effects of a short-term plyometric and resistance training program on fitness in boys age 12 to 15 years. J Sports Sci Med 6:519-525, 2007.

14. Farrow D, Young W and Bruce L. The development of a test of reactive agility for netball: a new methodology. J Sci Med Sport 8: 52–60, 2005.

15. Figueiredo AJ, Gonçalves CE, Coelho E Silva MJ and Malina RM. Youth soccer players, 11-14 years: maturity, size, function, skill and goal orientation. Ann Hum Biol 36: 60-73, 2009.

16. Ford KR, Myer GD, Toms HE and Hewett TE. Gender differences in the kinematics of unanticipated cutting in young athletes. Med Sci Sports Exerc 37: 124-129, 2005.

17. Gabbett TJ. Physiological characteristics of junior and senior rugby league players. Br J Sports Med 36:334–339, 2002.

18. Jakovljevic ST, Karalejic MS, Pajic ZB, Macura MM and Erculj FF. Speed and agility of 12 and 14 years old elite male basketball player. J Strength Cond Res, in press

19. Jeffreys I. Motor learning—Applications for agility, part 1. Strength Cond J 28: 72–76, 2006.

20. Julien H, Bisch C, Largouët, Manouvrier C, Carling C and Amiard V. Does a short period of lower limb strength training improve performance in field-based tests of running and agility in young professional soccer players. J Strength Cond Res 22: 404-411, 2008.

21. Junge A, Lamprecht M, Stamm H, Hasler H, Bizzini M, Tschopp M, Reuter H, Wyss H, Chilvers C and Dvorak J. Countrywide campaign to prevent soccer injuries in Swiss amateur players. Am J Sports Med 39: 57-63, 2011.

22. Kovacs MS. Movement for tennis: the importance of lateral training. Strength Cond J 31: 77-85, 2009.

23. Kraemer WJ, Fry AC, Frykman PN, Conroy B and Hoffman J. Resistance training and youth. Pediatr Exerc Sci, 1: 336-350. 1989.

24. Lloyd RS and Oliver JL. The Youth Physical Development Model: A new approach to long-term athletic development. Strength Cond J, 34: 61-72, 2012.

25. Lubans DR, Morgan PJ, Cliff DP, Barnett LM and Okely AD. Fundamental movement skills in children and adolescents. Sports Med 40: 1019-1035, 2010

26. Malina RM, Bouchard C and Bar-Or O. Growth, maturation, and physical activity. Human Kinetics, Champaign: IL, 41-77, 2004.

27. Mandelbaum BR, Silvers HJ, Watanabe DS, Knarr JF, Thomas SD, Griffin LY, Kirkendall DT and Garrett W. Effectiveness of a neuromuscular and proprioceptive training program in preventing the incidence of anterior cruciate ligament injuries in female athletes. Am J Sports Med 33: 1-8, 2005.

28. Meylan C and Malatesta D. Effects of in-season plyometric training within soccer practice on explosive actions of young players. J Strength Cond Res 23: 2605-2613, 2009.

29. National Association for Sport and Physical Education. Position Statement: guidelines for participation in youth sport programs: specialization versus multiple-sport participation. American Alliance for Health, Physical Education, Recreation and Dance, 2010.

30. Nimphius S, McGuigan MR and Newton RU. Relationship between strength, speed, and change of direction performance of female softball players. J Strength Cond Res 24: 885-895, 2010.

31. Oliver JL, Lloyd RS and Meyers RW. Training elite child athletes: Welfare and well-being. Strength Cond J 33: 73–79, 2011.

32. Philippaerts RM, Vaeyens R, Janssens M, Van Renterghem B, Matthys D, Craen R, Bourgois J, Vrijens J, Beunen GP and Malina, RM. The relationship between peak height velocity and physical performance in youth soccer players. J Sports Sci 24:221-230, 2006.

33. Rabinowickz T. The differentiated maturation of the cerebral cortex. In: Human Growth: A Comprehensive Treatise, Postnatal Growth: Neurobiology. Falkner F and Tanner J, eds. Vol. 2. New York, NY: Plenum, 1986.

34. Ramsay JA, Blimkie CJR, Smith K, Garner S, MacDougall JD and Sale DG. Strength training effects in prepubescent boys. Med Sci Sports Exerc 22: 605-614, 1990.

35. Serpell BG, Young WB and Ford M. Are the perceptual and decision-making components of agility trainable? A preliminary investigation. J Strength Cond Res 25: 1240-1248, 2011.

36. Sheppard JM and Young WB. Agility literature review: classifications, training and testing. J Sports Sci 24: 919-932, 2006.

37. Sheppard JM, Young WB, Doyle TA, Sheppard TA and Newton RU. An evaluation of a new test of reactive agility, and its relationship to sprint speed and change of direction speed. J Sci Med Sport 9:342–349, 2006.

38. Stolen T, Chamari K, Castagna C and Wisloff U. Physiology of soccer: an update. Sports Med 35: 501-536, 2005.

39. Thomas K, French D and Hayes PR. The effect of plyometric training techniques on muscular power and agility in youth soccer players. J Strength Cond Res, 23:332-335, 2009.

40. Tonson A, Ratel S, Le Fur Y, Cozzone P and Bendahan D. Effect of maturation on the relationship between muscle size and force production. Med Sci Sports Exerc 40: 918-925, 2008.

41. Vanderford ML, Meyers MC, Skelly WA, Stewart CC and Hamilton KL. Physiological and sport-specific skill response of Olympic youth soccer athletes. J Strength Cond Res 18: 334-342, 2004.

42. Vänttinen T, Blomqvist M, Nyman K and Häkkinen K. Changes in body composition, hormonal status, and physical fitness in 11-, 13-, and 15-year-old

Finnish regional youth soccer players during a two-year follow up. J Strength Cond Res 25: 3342-3351, 2011.

43. Verschuren O, Bloemen M, Kruitwagen C and Takken T. Reference values for anaerobic performance and agility in ambulatory children and adolescents with cerebral palsy. Dev Med Child Neurol 52: 222-228, 2010.

44. Viru A, Loko J, Harro M, Volver A, Laaneaots L and Viru M. Critical periods in the development of performance capacity during childhood and adolescence. Eur J Phys Educ 4: 75-119, 1999.

45. Young WB, James R and Montgomery I. Is muscle power related to running speed with changes of direction? J Sports Med Phys Fitness 42: 282-288, 2002.

Figure 1
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Figure 2
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Figure 3
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Figure 5
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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 step patterns (drop, jab and pivot)	6 x each pattern	Moderate	30	15
		Pre-planned 6-point grid court drill (2m x 2m)	4 x 10 seconds		60	
		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%)	Half-court lateral races (drop, jab and pivot)	4 x 4	Moderate	30	24
		Pre-planned 6-point grid court run	8 x 10 seconds		90	
		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	18
		Lateral shuffle + react to catch ball	5 x 6		90	
		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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