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Training to Improve Pro-Agility Performance: A Systematic Review

by
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Effective directional change in sport is imperative to success in key game situations. Change of direction (COD) ability is underpinned by various athletic qualities which can be developed through specific and non-specific training methods. This review examined the effect of specific and non-specific training methods on pro-agility performance, by analysing the intervention type and resulting magnitude of training effects on pro-agility shuttle performance. A total of 20 studies were included for review. Data from 638 subjects and 29 intervention groups involving seven different training methods were extracted and analysed in relation to training method classification and primary outcome measures. Interventions involving sprint training, plyometric training, resistance training, and combined resistance, plyometric, and sprint training were found to produce statistically significant positive change on pro-agility performance per session ($p < 0.05$). Sprint training (0.108 ES), plyometric training (0.092 ES), resistance training (0.087 ES), and combined resistance, plyometric, and sprint training (0.078 ES) methods were found to have the highest per session training effect. While total time is the typical unit of measure for this test, different types of training may lead to preferential improvements in either acceleration, deceleration, or COD phases of the pro-agility shuttle. Specifically, resisted or inclined sprinting may develop the linear acceleration phases, unilateral resistance training may promote increased strength to overcome the imposed forces during the deceleration and COD phases, multiplanar plyometrics can help enhance stretch-shortening cycle capabilities across different force vectors, and a combination of two or more of these methods may enable simultaneous development of each of these qualities.

Key words: *change of direction, training, specificity, athletic performance.*

Introduction

The ability to change direction is critical for field and court sport athletes, as an improved capacity for this athletic task may provide a means to either evade an opponent or navigate a tactical scenario with greater efficiency (Baker & Newton, 2008; Spiteri et al., 2013). Consequently, there is an ever-growing body of research detailing the effectiveness of training methods for developing change of direction (COD) performance. Given this importance, the ability to assess and monitor this athletic quality would seem critical to develop an individual's sporting performance.

The measurement of COD performance provides indication of an athletes' ability to utilise reactive strength and anaerobic power in a multi-directional fashion (Reilly et al., 2000; Young et al., 2002). This is important as the capacity of athletic qualities involved with COD performance attributes to the success of a COD manoeuvre, which can be integral during key situations during a game. One test that is used to measure COD performance is the pro-agility shuttle; which is comprised of two 180° CODs over a total of 18.28 m and used in sports such as rugby (Speirs et al., 2016), American football (Leutzinger et al., 2018), and soccer (Kavaliauskas et al., 2017). The pro-agility shuttle contains high force-orientated CODs (180°), thereby, requiring athletes to accelerate, decelerate and arrest the body's momentum, come to a complete stop, change direction, and reaccelerate in the opposite

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direction. Therefore, to perform a successful COD in the pro-agility shuttle, it is imperative that athletes possess sufficient maximum, dynamic, and reactive strength which is contraction dependant (Spiteri et al., 2015).

A clear link has been identified between the implementation of specific and non-specific training methods for COD ability (Falch et al., 2019). Specificity of training is a fundamental principle in optimising transference of training to physiological performance (Campos-Vazquez et al., 2015; Reilly et al., 2009). Non-specific training methods tend to be gym-based, uniplanar (typically vertical), using high-loads and low-velocities. These high-force and low-velocity movements, whether implemented unilaterally or bilaterally, relate to the force-orientated nature of 180° performance (Bourgeois et al., 2017; Speirs et al., 2016). These types of movements and training methods do not resemble the biomechanics of movements performed during specific sporting tasks, thus the label non-specific. While non-specific training may allow for the development of physiological qualities related to pro-agility COD performance, it is speculated that specific COD training may provide better improvements in performance due to enhancements in technical and contraction-dependent capabilities related to the actual task being performed (DeWeese & Nimphius, 2018).

Whether specific training methods are better for improving COD performance provides the focus of this review. The findings of the review will provide practitioners important insight into exercise and training method selection for the development of pro-agility performance. Given the preceding information, the aim is to: 1) examine the training effects different non-specific and specific training methods have on pro-agility performance; and, 2) detail the limitations and future research directions in this content area.

Methods

Study Design

A systematic search of four electronic data bases (SPORTDiscus, PubMed, ScienceDirect, and OVID journals) was undertaken to identify original research articles published from the earliest available records up to November 2021. Keywords 'pro-agility', OR '20 yard shuttle', OR '5-10-5 shuttle' were used in conjunction with "training" OR "chronic" OR "longitudinal" using Boolean logic for query (Figure 1).

Screening Strategy and Study Inclusion

The articles needed to contain the following three criteria to be included in the review: 1) measurement of pro-agility shuttle performance before and after a training intervention; 2) a description of a training intervention, detailing the type of training, length of the intervention (minimum training length of four weeks), workload (volume per training session), and frequency of sessions per week; and, 3) the study needed to state the number of subjects and descriptive statistics pertaining to their characteristics. This literature search was not limited by sex or age, and had no restrictions regarding the subject's performance level or training status. Additionally, studies must have been written in English, otherwise they were excluded.

Data Extraction

Data were extracted by one author (J.F.) using a custom designed standardised excel database (version 16.0, Microsoft, Redmond, WA, USA). A secondary author (A.U.) ratified a cross-section of these ratings for quality control. Quality score cross-ratings were unanimously agreed on between authors (J.F., A.U.) for each article. General study data (i.e., author, year), subjects' characteristics (i.e., the number of subjects, age, body mass, body height, sports discipline, performance level), training intervention classification (e.g., resistance training, plyometric training, etc.), primary outcome measures (i.e., pre-test and post-test mean and standard deviation, percent change, statistical significance, and effect size (ES)) were extracted. Descriptive information related to training intervention classification information was used to categorise the data extracted from each of the studies. Where more than one intervention type was presented in an article, performance data and intervention effects were categorised in the appropriate intervention type for analysis.

Methodological Quality and Risk of Bias Assessment

To evaluate the methodological quality of the studies, a quality scale designed to evaluate research conducted in athletic-based environments was utilised (McMaster et al., 2013). This scale was modified using a combination of items from the Cochrane, Delphi, and PEDRO, as created by Brughelli et al. (2008) (Table 1). Each study's quality was independently rated against each of the 10 criteria on the list by two authors (J.F., A.U.). The included items for quality scoring are detailed in Table 1. The quality of each study could range between 0 to 20, each criterion score as 0 = clearly no; 1 = yes, not detailed; and 2 = yes, clearly detailed (see Table 1). Scoring was assigned depending on how well each criterion was met, assuming a maximum possible score of 20 (high quality, low risk of bias).

Statistical Analysis

Summary statistics were used to represent the percent change (%) and effect size (ES) of each study. After rating the quality of the articles, training programmes, un-equal workload, and differences related to performance or sex were categorised, to quantify the subjects' training improvement based on differences in the workload and physical background. Percent difference and ES were calculated to compare the effects of different training interventions on pro-agility performance. ES was quantified according to Cohen's *d* ($\frac{M2-M1}{S}$) (M2 = post-test mean, M1 = pre-test mean, *S* = pooled standard deviation). ES values of <0.2 were considered as "trivial", 0.2–0.5 "small", 0.5–0.8, "medium", and values of > 0.8 were considered as "large" ES., 1.2–2 as "very large", and values exceeding 2 "huge" (Cohen, 1988; Sawilowsky, 2009). Percent change and effect values were then normalised by dividing pre-post change (%) or ES by the total number of sessions (length in weeks*frequency of sessions) completed, to normalise the per session changes in pro-agility performance. A decrease in pro-agility time was quantified as a positive percent change and ES, representing improved pro-agility performance.

Results and Discussion

Literature Search Results

Studies that included the pro-agility assessment were initially included in the first screening phase (n = 156). An additional five eligible articles were included after reference checks (n = 161). To determine the number of eligible studies a three-stage screening process was implemented: 1) removal of duplicate studies (n = 47); 2) screening of the article title and abstract—studies that were deemed to be 'out of scope' (did not contain pro-agility data) were excluded (n = 26); and, 3) exclusion of studies that did not meet the inclusion criteria after screening the full text (n = 68). A total of 20 studies were included for analysis in this review.

Overview

There were 29 intervention groups, comprised of 638 subjects within the 20 studies. The length of interventions ranged from 4 to 18 weeks with 1 to 4 training sessions per week. Regarding the sporting season, two interventions were conducted at the pre-season, five at the in-season, two at the post-season, and in 11 studies, authors did not state the time of the season. Overall percent improvement in COD performance for all studies ranged from 0.00% (Johnson et al., 2012) to 12.41% (Schwarz et al., 2019), while a decrease in performance was observed in three studies, ranging from -1.09% to -1.42% (Johnson et al., 2012). Intervention ES ranged from trivial (ES = 0.00) (Faigenbaum et al., 2007) to very large (ES = 1.3) (Kavaliauskas et al., 2017). The reader needs to be cognisant that the number of studies and sample sizes that comprise this review are relatively small, and any interpretation of the reader should be made with this limitation in mind.

Quality Score

Included studies averaged a score of 17.73 (± 1.55) out of a maximum of 20. Some studies did not state inclusion criteria (n = 5) or did not include use of a control group (n = 7), while some studies 'maybe' (i.e., lacked detail or were not presented clearly) stated inclusion criteria (n = 9), assigned subjects appropriately (n = 4), defined dependant variables (n = 1), had adequate duration (n = 1), detailed appropriate statistics (n = 4), presented detailed results (n = 6), and insightful conclusions (n = 1). No researchers reported conflicts of interest and/or funding sources or were withdrawn due to quality which may have impacted the information included in the review. An overview of the quality scores associated with each reviewed study can be found in Table 2.

Resistance Training

Eleven resistance training interventions from six different studies were analysed (see Table 3), of which four interventions were found to produce statistically significant (p < 0.05) changes in pro-agility performance (Abt et al., 2016; Speirs et al., 2016). Resistance training intervention length ranged from 5 to 7 weeks (Abt et al., 2016; Speirs et al., 2016), an average change from 0.00% to 0.173%, and 0.00 to 0.087 ES per session (Abt et al., 2016; Johnson et al., 2012), was observed across the studies. As can be seen from the results, most of the interventions resulted in 0.02 to -0.11% and 0.008 to 0.017 ES, per session changes in COD performance. The greatest per session improvements (i.e., decreased pro-agility time), however, were noted in the study of Speirs et al. (15) where unilateral (0.173% and 0.087 ES) and bilateral (0.15% and 0.048 ES) strength (squat) training interventions over 10 sessions with sub-elite rugby athletes were completed.

Interestingly, the largest per session training effects (Speirs et al., 2016) were noted in the study involving unilateral squat training (Speirs et al., 2016), whereas bilateral exercises were performed in all other resistance training interventions (Abt et al., 2016; Johnson et al., 2012; Millar et al., 2020; Schilling et al., 2013; Weiss et al., 2010). The reasons for the larger effects could be attributed to: 1) the unilateral training emphasis and therefore greater specificity to COD performance; 2) the training history of the cohort, those who underwent unilateral squat training were sub-elite athletes, while most other subjects in other studies were novice athletes; 3) a shorter more intense training mesocycle (5 weeks), therefore less likelihood of training monotony and plateaus in adaptation; and, 4) related to the previous points is that the single and bilateral squat training utilised by Speirs et al. (2016) implemented high intensity loading schemes (4 sets x 3–6 reps, 75–92% 1RM), which was very different to the loading used with the novice athletes.

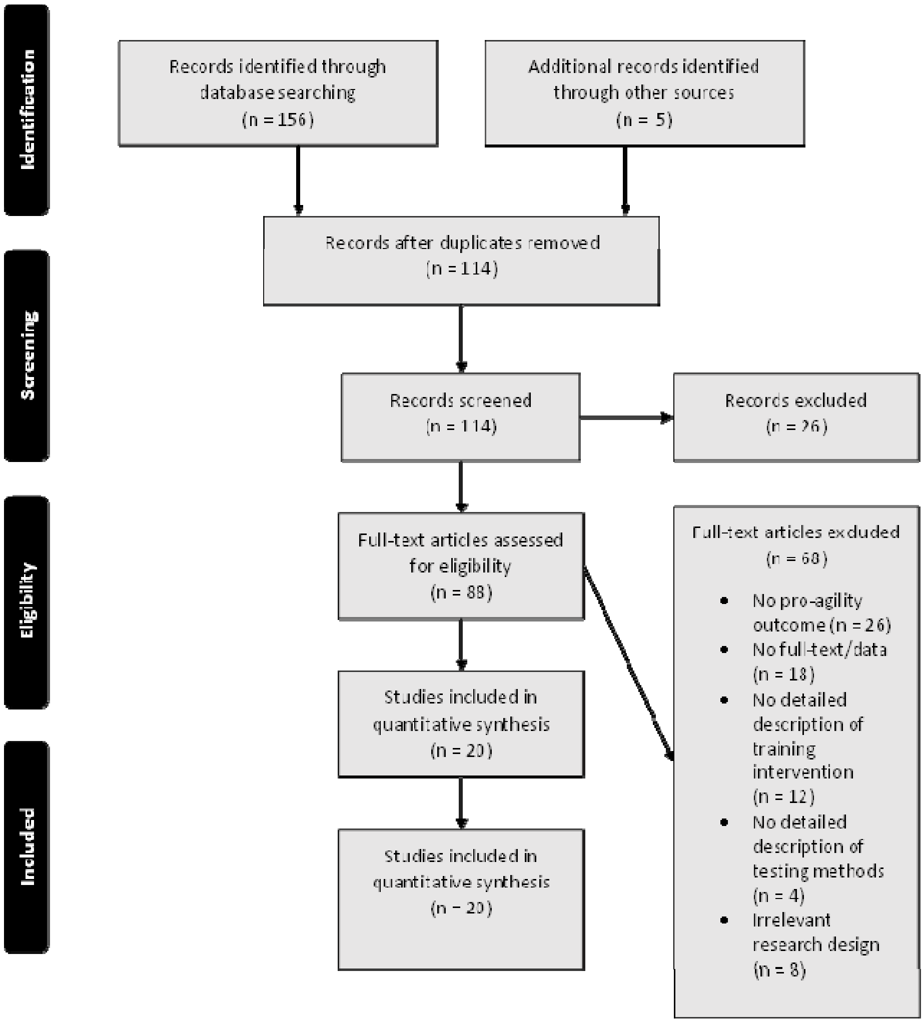

Figure 1. *Search Strategy.*

Table 1. *Study quality score (Brughelli et al., 2008).*

Number	Item	Score
1	Inclusion criteria stated	0–2
2	Subjects assigned appropriately	0–2
3	Intervention described	0–2
4	Control group	0–2
5	Dependant variable defined	0–2
6	Assessments practical	0–2
7	Duration	0–2
8	Statistics appropriate	0–2
9	Results detailed	0–2
10	Conclusions insightful	0–2

Table 2. *Quality score of included studies*.

Reference	Quality Score
Abt et al. (2016)	19
Bishop et al. (2017)	17
Chan et al. (2018)	19
Faigenbaum et al. (2007)	16
Ferley et al. (2020)	17
Johnson et al. (2012)	17
Jones et al. (2010)	15
Kavaliauskas et al. (2017)	19
Markovic et al. (2007)	19
Millar et al. (2020)	16
Moran et al. (2018)	19
Schilling et al. (2013)	16
Schwarz et al. (2019)	19
Šišková et al. (2021)	17
Speirs et al. (2016)	20
Thompson et al. (2017)	19
Toyomura et al. (2018)	17
Vescovi and VanHeest (2010)	20
Wagner et al. (2014)	15
Weiss et al. (2010)	18

Table 3a. *Overview of resistance training interventions*

Reference	Number (n) of subjects and mean age	Sport Training status	Control group	Experimental group	Improvement [normalised % change] Effect Size (ES) [normalised ES] p value (p)	Training intervention details Week/Sessions (total number of sessions) Loading Parameters
Abt et al. (2016)	EG, n = 46 Age = 29.4 ± 5.5 CG, n = 39 Age = 29.0 ± 6.0	Tactical Professional	Pre: R, 5.02 ± 0.26 L, 5.02 ± 0.27 Post: R, 5.00 ± 0.33 L, 4.98 ± 0.31	Pre: R, 5.10 ± 0.38 L, 5.09 ± 0.4 Post: R, 4.95 ± 0.34 L, 4.93 ± 0.32	R: 2.94% [0.06%] ES: 0.41 [0.009], $p < 0.001$ L: 3.14% [0.07], ES: 0.44 [0.009], $p < 0.001$	12/4 (48) Week 1–4: Upper and lower resistance training, 8–12 1RM. Week 5–8: Olympic lifts, 4–6 1RM. Week 9–12: High intensity strength and power training, 3–5 1RM.
Johnson et al. (2012)	N = 39 TRAD = 16 CIRC = 23 Age = TRAD, 16 ± 2; CIRC, 16 ± 1	American football Novice	Pre: Post:	Pre: CIRC, 4.61 ± 0.23 TRAD, 4.92 ± 0.45 Post: CIRC, 4.61 TRAD, 4.99	CIRC: 0.00% [> 0.00%], ES 0.25 [0.014], $p > 0.05$ TRAD: -1.42% [-0.08%], ES: -0.22 [-0.012], $p > 0.05$	6/3 (18) Day 1: hang clean, power jerk, bench press, dumbbell split squat, inverted rows. Day 2: dumbbell snatch, upright row, front squat, military press, lunges, pull-ups. Day 3: Hang clean, push press, back squat, incline bench, weighted step-ups.
Schilling et al. (2013)	STG: N = 5, Age = 20.0 ± 0.71; ETG: N = 5, Age = 22.0 ± 3.54	College students Novice	Pre: Post:	Pre: STG, 5.49 ± 0.34; ETG, 5.43 ± 0.34 Post: STG, 5.55 ± 0.33; ETG, 5.36 ± 0.33	STG: -1.09% [-0.091%], ES: -0.18 [-0.015], $p > 0.05$ ETG: 1.29% [0.107%], ES: 0.21 [0.017], $p > 0.05$	6/2 (12) STG: sit up, curl up, and trunk extension. 2–3 sets x 10–15 reps ETG: curl up, side plank, and bird dog 3 sets x 3–9 reps, 8–10 s hold

Key: EG: experimental group; CG: control group; R: right side; L: left side; TRAD: traditional training; CIRC: circuit training; STG: strength training group; ETG: endurance training group; UNI: unilateral group; BI: bilateral group; 1RM: 1 repetition maximum; HT: hip thrust group; SG: squat group.

Table 3b. *Overview of resistance training interventions*

Reference	Number (n) of subjects and mean age	Sport Training status	Control group	Experimental group	Improvement [normalised % change] Effect Size (ES) [normalised ES] p value (p)	Training intervention details Week/Sessions (total number of sessions) Loading Parameters
Speirs et al. (2016)	N = 18 Age = 18.1 ± 0.5	Rugby Sub-elite		Pre: UNI, 4.61 ± 0.11; BI, 4.71 ± 0.15 Post: UNI, 4.53 ± 0.07; BI, 4.64 ± 0.14	UNI: 1.74% [0.173%], ES: 0.87 [0.87], p < 0.05 BL: 1.49% [0.15%], ES: 0.48 [0.048], p < 0.05	5/2 (10) Bilateral or unilateral squat, 4 sets x 3–6 reps, 75–92% 1RM Tempo 2-0-1 (concentric-eccentric) 3 min rest intervals between sets
Weiss et al. (2010)	N = 38 Age = 18–32	Recreational athletes Novice	Pre: 5.49 ± 0.39 Post: 5.42 ± 0.29	Pre: 5.73 ± 0.33 Post: 5.65 ± 0.31	EG: 1.40% [0.066%], ES: 0.34 [0.016], p > 0.05 CG: 1.28%, ES: 0.20, p > 0.05	7/3 (21) CG: single and multi-joint machine and free-weight modalities EG: Multi-joint, multi-planar free weight and machine modalities
Millar et al. (2020)	N = 14 HT = 6, SG = 8 Age = HT, 15.7 ± 0.8; SG, 15.3 ± 0.7	Soccer Novice	Pre: Post:	Pre: HT, 5.267; SG, 5.285 Post: HT, 5.25 ± 0.19; SG, 5.27 ± 0.20	HT: 0.32% [0.027%], ES: 0.13 [0.011] SG: 0.28% [0.237%], ES: 0.09 [0.008]	6/2 (12) Day 1: hip thrust or squat, bench press, unilateral row, 30 s plank hold 2–6 sets x 3–8 reps Day 2: hip thrust or squat, overhead press, lat pulldown, 30 s plank hold 2–6 sets x 3–8 reps

Key: EG: experimental group; CG: control group; R: right side; L: left side; TRAD: traditional training; CIRC: circuit training; STG: strength training group; ETG: endurance training group; UNI: unilateral group; BI: bilateral group; 1RM: 1 repetition maximum; HT: hip thrust group; SG: squat group.

Table 4. *Overview of plyometric training interventions.*

Reference	Number (n) of subjects and mean age	Sport Training status	Control group	Experimental group	Improvement [normalised % change] Effect Size (ES) [normalised ES] p value (p)	Training intervention details Week/Sessions (total number of sessions) Loading Parameters
Faigenbaum et al. (2007)	N = 13 Age = 13.4 ± 0.90	Baseball and American football Novice	Pre: Post:	Pre: 5.60 ± 0.18 Post: 5.40 ± 0.18	3.57% [0.29%], ES: 1.11 [0.093}, p < 0.05	6/2 (12) Forward jump, backward jump, hurdle hops, lateral hops, 90° jump turn, unilateral hops, 180° jump turn, tuck jumps. 2 sets x 6–10 reps
Markovic et al. (2007)	N = 93 Age = 20.1 ± 1.1	Highschool students Novice	Pre: 5.02 ± 0.20 Post: 5.04 ± 0.18	Pre: PG, 5.05 ± 0.24 Post: PG, 4.98 ± 0.20	PG: 1.39% [0.046%], ES: 0.32 [0.011], p < 0.001	10/3 (30) PG: hurdle and drop jumps

Key: PG: Plyometric Group

Table 5a. *Overview of sprint training interventions*

Reference	Number (n) of subjects and mean age	Sport Training Status	Control group	Experimental group	Improvement [normalised % change] Effect Size (ES) [normalised ES] p value (p)	Training intervention details Week/Sessions (total number of sessions) Loading Parameters
Chan et al. (2018)	N = 16 Age = 29.8 ± 9.9 CG: n = 8 Age = 35.1 ± 11.5 EG: n = 8 Age = 23.7 ± 4.3	Soccer, basketball, and badminton Novice	Pre: 5.27 ± 0.17 Post: 5.29 ± 0.19	Pre: 5.22 ± 0.23 Post: 5.21 ± 0.11	CG: -0.3% [-0.025%], ES: -0.11 [-0.009], $p > 0.05$ EG: 0.19% [0.016%], ES: 0.006 [0.0005], $p > 0.05$	4/3 (12) 4 sets x 30 s sprints. Number of sprints increased by 1 per week.
Ferley et al. (2020)	INC: N = 17; male = 8; female = 9 Age = male, 16.4 ± 1.1; female, 15.1 ± 1.1 LEV: n = 14; male = 8; female = 6 Age = male, 15.4 ± 0.9; female, 14.8 ± 1.1 CG: n = 15; male = 8; female = 7 Age = male, 16.4 ± 1.5; female, 15.6 ± 0.5	Basketball, softball, baseball, and track Novice	Pre: 5.10 ± 0.40 Post: 5.09 ± 0.40	Pre: INC, 5.24 ± 0.30 LEV, 5.27 ± 0.30 Post: INC, 5.08 ± 0.30 LEV, 5.19 ± 0.30	INC: 3.05% [0.127%], ES: 0.53 [0.022], p = 0.53 LEV: 1.52% [0.063%], ES: 0.267 [0.011], p = 0.267 CG: 0.63% [0.026%], ES:0.025 [0.001], $p > 0.05$	8/2–3 (16–24) INC: 15–26 sets x 6–30 s sprints, 5–30% gradient. LEV: 10–14 sets x 4–30 s sprints, 1.5% gradient.
Kavaliauskas et al. (2017)	N = 14 Age = 22 ± 8	Soccer Novice	Pre: 6.012 ± 0.14 Post: 6.03 ± 0.14	Pre:5.96 ± 0.16 Post: 5.77 ± 0.23	CG: -0.1% [-0.008%], ES: -0.12 [-0.01], $p > 0.05$ EG: 3.19% [0.265%], ES: 1.3 [0.108], $p < 0.05$	6/2 (12) Uphill sprint training. 10 sets x 10 s sprints, 7% gradient.

Key: EG: Experimental group; CG: Control group; INC: Incline sprint group; LEV: Level ground sprint group; Pre-PHV: Pre-peak height velocity; Post-PHV: Post-peak height velocity; SG: Sprint group.

Table 5b. *Overview of sprint training interventions*

Reference	Number (n) of subjects and mean age	Sport Training Status	Control group	Experimental group	Improvement [normalised % change] Effect Size (ES) [normalised ES] Pvalue (p)	Training intervention details Week/Sessions (total number of sessions) Loading Parameters
Moran et al. (2018)	Pre-PHV - EG: N = 12, Age = 10.4 ± 0.8, CG: N = 13, Age = 10.0 ± 1.0; Post-PHV - EG: N = 7, Age = 13.6 ± 0.7, CG: N = 10, Age = 14.5 ± 1.0	Soccer Novice	Pre: Pre-PHV, 5.93 ± 0.22; Post-PHV, 5.29 ± 0.25 Post: Pre-PHV, 5.85 ± 0.34; Post-PHV, 5.04 ± 0.24	Pre: Pre-PHV, 5.77 ± 0.30; Post-PHV, 5.26 ± 0.31 Post: Pre-PHV, 5.55 ± 0.32; Post-PHV, 5.14 ± 0.26	Pre-PHV: 3.81% [0.476%], ES:0.69 [0.086] Post-PHV: 2.28% [0.285%], ES:0.43 [0.005]	8/1 (8) 16 sets x 20 metre sprints, 90 s rest intervals in between
Toyomura et al. (2018)	N = 18 Age = 22.8 ± 2.2	Recreational athletes Novice	Pre: Post:	Pre: Post: 10.97 ± 0.01	3.00% [0.2%], ES:0.67 [0.044], p = 0.007	5/3 (15) 20 min treadmill run, -10% gradient, 14.9 ± 0.6 $km \cdot h^{-1}$
Markovic et al. (2007)	N = 93 Age = 20.1 ± 1.1	Highschool students Novice	Pre: 5.02 ± 0.20 Post: 5.04 ± 0.18	Pre: SG, 5.10 ± 0.21 Post: SG, 4.88 ± 0.20	SG: 4.31% [0.144%], ES: 1.1 [0.036], $p < 0.001$	10/3 (30) 3–4 sets x 10–50 m sprints

Key: EG: Experimental group; CG: Control group; INC: Incline sprint group; LEV: Level ground sprint group; Pre-PHV: Pre-peak height velocity; Post-PHV: Post-peak height velocity; SG: Sprint group.

Table 6. *Overview of COD training interventions*

Reference	Number (n) of subjects and mean age	Sport Training status	Control group	Experimental group	Improvement [normalised % change] Effect Size (ES) [normalised ES] Pvalue (p)	Training intervention details Week/Sessions (total number of sessions) Loading Parameters
Šišková et al. (2021)	N = AT, 11; CG, 9 Age = AT, 10.0 ± 0.2; CG, 10.7 ± 0.1	Soccer Novice	Pre: 6.12 ± 0.15 Post: 5.17 ± 0.38	Pre: AT, 6.17 ± 0.3 Post: AT, 5.99 ± 0.23	AT: 2.92% [0.243%], ES:0.54 [0.045], p < 0.01	6/2 (12) AT: agility training x 5 sets (4 reps × 60° COD, 4 reps × 90°, 5 reps × 180°)
Wagner et al. (2014)	N = 15 (cube: 8, ladder: 7) Age = N/A	Recreational athletes Sub-elite		Pre: Cube, 5.37 ± 0.49; Ladder, 5.56 ± 0.52 Post: Cube, 5.23 ± 0.48; Ladder, 5.34 ± 0.53	Cube: 2.61% [0.163%], ES:0.29 [0.018], p < 0.025 Ladder: 3.96% [0.247%], ES:0.419 [0.026], p < 0.025	8/2 (16) Agility ladder or agility cube drills 45 min 3–5 sets per exercise

Key: AT: Agility training group; CG: Control group; Cube: Agility cube group; Ladder: Agility ladder group.

Table 7a. *Overview of combined training interventions*

Combined Resistance and Plyometric Training						
Reference	Number (n) of subjects and mean age	Sport Training status	Control group	Experimental group	Improvement % [normalised % change] Effect Size (ES) [normalised ES] p value (p)	Training intervention details Week/Sessions (total number of sessions) Loading Parameters
Bishop et al. (2017)	N = 14 Age = 26.2 ± 5.3	Cricket Elite	Pre: Post:	Pre: 4.75 ± 0.18 Post: 4.70 ± 0.21	1.05% [0.029%], ES:0.26 [0.007], p > 0.05	18/2 (36) Resistance training: Week 1–6: 3 sets x 10 reps, 70–80% 1RM. Week 9–16: ¾ sets x 4–6 reps, 80–90% 1RM. Week 17–23: Combined maximal strength and plyometric training. Cardio and sprint training.
Jones et al. (2010)	N = 46 Age = N/A	Soccer, field hockey, and softball Sub-elite	Pre: Post:	Pre: 5.39 ± 0.24 Post: 5.37 ± 0.25	EG: 0.37% [0.01%], ES:0.082 [0.0023], p > 0.05 Soccer: 2.22% [0.062%], ES:0.49 [0.014], p < 0.05	12/3 (36) 2 whole-body lifting sessions, 1 sprint and agility session.

Key: 1RM: 1 repetition maximum; APT: Agility and plyometric training group; EG: Experimental group; CG: Control group; FWS: Free-weight squat group; MS: Machine squat group

Table 7b. *Overview of combined training interventions*

Reference	Number (*n*) of subjects and mean age	Sport	Control group	Experimental group	Improvement % [normalised % change] Effect Size (ES) [normalised ES] Pvalue (*p*)	Training intervention details Week/Sessions (total number of sessions) Loading Parameters
Combined Speed and Plyometric Training						
Šišková et al. (2021)	*N* = APT, 10 Age = APT, 10.0 ± 0.1	Soccer Novice	Pre: 6.12 ± 0.15 Post: 5.17 ± 0.38	Pre: APT, 6.19 ± 0.35 Post: APT, 6.09 ± 0.3	APT: 1.62% [0.135%], ES:0.44 [0.036], *p* < 0.05	6/2 (12) APT: Plyometric jump 3–5 sets x 10–12 reps and agility training x 3–5 sets
Thompson et al. (2017)	*N* = EG, 16; CG, 9 Age = EG, 11.8 ± 0.9; CG, 12.1 ± 0.93	Team sport athletes Novice	Pre: 6.52 ± 1.04 Post: 6.25 ± 0.62	Pre: 5.63 ± 0.36 Post: 5.51 ± 0.34	EG: 2.13% [0.066%], ES:0.343 [0.011], *p* = 0.52	16/2 (32) Plyometric, sprint and agility training: Hurdle hops, depth jump, long jumps, sprints. Resistance training: Back/front squat, incline/bench press, row, push press, hang clean. 2 sets x 5 reps
Vescovi and VanHeest (2010)	*N* = 58 (EG: 31, CG: 27) Age = 13–18 years	Soccer Novice	Pre: 4.79 ± 0.15 Post: 4.95 ± 0.23	Pre: 4.79 ± 0.16 Post: 4.92 ± 0.22	-2.71% [-0.075%], ES:-0.676 [-0.0187], *p* = 0.106	12/3 (36) Plyometric and agility warm-up

Key: 1RM: 1 repetition maximum; APT: Agility and plyometric training group; EG: Experimental group; CG: Control group; FWS: Free-weight squat group; MS: Machine squat group

Table 7c. *Overview of combined training interventions*

Reference	Number (*n*) of subjects and mean age	Sport	Control group	Experimental group	Improvement % [normalised % change] Effect Size (ES) [normalised ES] P value (*p*)	Training intervention details Week/Sessions (total number of sessions) Loading Parameters
Combined Resistance, Speed and Plyometric Training						
Schwarz et al. (2019)	*N* = 27 Age = 22.7 ± 3.5	Recreational athletes Novice	Pre: 6.17 ± 0.60 Post: 5.91 ± 0.49	Pre: FWS, 6.76 ± 0.85; MS, 6.61 ± 1.04 Post: FWS, 6.18 ± 0.46, MS, 5.79 ± 0.66	FWS: 8.88% [0.715%], ES:0.849 [0.071], *p* < 0.01 MS, 12.41% [1.034%], ES:0.941 [0.078], *p* < 0.01	6/2 (12) Day 1: squat 3–6 sets x 3–12 reps, jump 2–3 sets x 5 reps, drop jump 3–4 sets x 5 reps Day 2: squat 3–6 sets x 3–12 reps, 2–4 sets x 30 metre sprints, 2–4 sets x pro-agility shuttle, 2–4 sets x zigzag run

Key: 1RM: 1 repetition maximum; APT: Agility and plyometric training group; EG: Experimental group; CG: Control group; FWS: Free-weight squat group; MS: Machine squat group

Table 8. *Ranking pro-agility improvement*

Per Session Effect Size	**Training Type**
0.108	Sprint
0.092	Plyometric
0.087	Resistance
0.078	Resistance, plyometric, and sprint
0.045	COD
0.036	Plyometric and sprint
0.014	Resistance and plyometric

It needs to be noted that the second largest training effect was found in the Speirs et al.'s (2016) study also, the bilateral squat intervention changes, whilst not practically (% change and ES) the same, were found to be statistically similar to the unilateral intervention. Whether unilateral or bilateral training is implemented, may be less important than the magnitude or intensity of the loading the subjects are exposed to. Nonetheless, intuitively it seems to make sense to train unilaterally given the nature of the pro-agility test.

Plyometric Training

Two plyometric training interventions from two studies were analysed (see Table 4), of which both interventions reported statistically significant ($p < 0.05$) changes in pro-agility performance (Faigenbaum et al., 2007; Markovic et al., 2007). Plyometric training intervention length ranged from 6 to 10 weeks with 2–3 training sessions per week, an average change of 0.046% to 0.297%, and 0.01 to 0.092 ES per session changes in COD performance were observed across the interventions (Faigenbaum et al., 2007; Markovic et al., 2007). The greatest improvements per session (0.297% and 0.092 ES) were noted in the study of Faigenbaum et al. (2007) where a plyometric training intervention over 12 sessions with novice American football and baseball athletes was completed.

The largest per session training effects (Faigenbaum et al., 2007) utilised a combination of bilateral and unilateral exercises in the horizontal, vertical, and lateral directions. Conversely, Markovic et al. (2007) performed only bilateral hurdle jumps in the horizontal direction and drop jumps in the vertical direction. It should be noted that both plyometric training interventions involved the use of fast stretch-shortening cycle (SSC) exercises, however, greater volume (72–120 vs. 50–100 repetitions) and the number of exercises (12 vs. 1), and in turn foot contacts, were performed in Faigenbaum et al. (2007), compared to those implemented by Markovic et al. (2007). Therefore, the discrepancies in intervention ES per session may be attributed to the relevancy and progression of exercises and the number of foot contacts performed. This highlights the importance of specificity and movement variability in exercise selection, and total workload per session in affecting the performance outcome (Reilly et al., 2009). Further, plyometric training showed greater improvement over the intervention compared to resistance training (0.00 to 0.173% and 0.046 to 0.297%, respectively), this may be attributed to the longer intervention length (5 to 7 weeks and 6 to 10 weeks, respectively) providing time for greater development to occur. These finding are comparable to Brughelli et al. (2008), who concluded that both unilateral and bilateral plyometric training should be performed and force application exerted in the horizontal, vertical, and lateral directions when aiming to develop COD ability.

Sprint Training

Seven sprint training intervention effects from five different studies were analysed (see Table 5), of which three interventions were found to have statistically significant ($p < 0.05$) changes in pro-agility performance (Kavaliauskas et al., 2017; Markovic et al., 2007; Toyomura et al., 2018). Sprint training intervention length ranged from 4 to 8 weeks (Chan et al., 2018; Ferley et al., 2020; Moran et al., 2018). An average change of 0.016% (Chan et al., 2018) to 0.476% (Moran et al., 2018) and 0.00 to 0.108 ES per session in COD performance was observed across these studies. The greatest per session improvements, in percentage, were noted in the study of Moran et al. (2018), where short repetitive sprint training (16 sets of 20 m sprints) in pre-PHV (0.476% and 0.086 ES) novice soccer athletes over 8 sessions was completed. However, the greatest per session effects were found to be in the study by Kavaliauskas et al. (2017), where training involved incline sprint training (10 sets of 10 s sprints at a 7% gradient) (0.265% and 0.108 ES) over 12 sessions in novice soccer athletes.

Interestingly, the largest per session training effects were noted in studies that included incline sprinting (Ferley et al., 2020; Kavaliauskas et al., 2017), while level ground sprints were completed in all other sprint training interventions (Chan et al., 2018; Ferley et al., 2020; Markovic et al., 2007; Moran et al., 2018; Toyomura et al., 2018). The reason for the larger effects may be attributed to: 1) the effect of greater hip flexion involved with incline sprinting, as well as a greater force demands, similar to that of resisted sprinting (Okudaira et al., 2021); 2) the younger age of athletes, where sprint training may be more effective in those pre-PHV (Bourgeois et al., 2017); and, 3) the sprint duration (i.e., 6–10 s) and/or distance (i.e., 20 m), may allow for higher intensity performance, utilization of stopping characteristics and greater relevance to that performed in the pro-agility.

Overall, the improvements were significant when performing incline sprinting at a 5%–30% gradients with 6–30 s duration (Ferley et al., 2020; Kavaliauskas et al., 2017). Although, in regard to sprinting over flat ground, the majority of researchers reported small to medium significant and non-significant effects on pro-agility performance, except for one study where a significant effect (0.144% and 0.036 ES, $p < 0.001$) was observed when performing 3–4, 10–50 m sprints, 3 times per week for 10 weeks (Markovic et al., 2007). These findings indicate that accelerated sprinting on an incline provides adaptations which transfer the most to pro-agility performance. This makes sense intuitively, considering that incline sprinting has biomechanical similarities with accelerating into and out of the COD in the pro-agility shuttle.

COD Training

Three COD training interventions from two different studies were included in analysis (see Table 6), of which all interventions were found to produce statistically significant ($p < 0.05$) improvements in pro-agility performance (Šišková et al., 2021; Wagner et al., 2014). COD training intervention length ranged from 6 to 8 weeks (Šišková et al., 2021; Wagner et al., 2014), where an average change of 0.162% to 0.247% and 0.018 to 0.045 ES per session was noted (Šišková et al., 2021; Wagner et al., 2014). The greatest per session effects were noted in the study by Šišková et al. (2021), where COD drill training (0.243% and 0.045 ES, $p < 0.01$) was implemented over 12 sessions in novice soccer players. Albeit, similar per session percent change was shown in Wagner et al. (2014), where agility ladder training over 16 sessions led to improvements in performance in sub-elite recreational athletes (0.247% and 0.026 ES, $p < 0.025$).

Interestingly, the largest per session training effects noted in the study by Šišková et al. (2021) involved COD drills performed as short sprints with 60°, 90°, and 180° directional changes, whereas the interventions in Wagner et al. (2014) involved exercises more focused around the use of agility ladder and agility cube equipment. The reasons for the larger effects in the Šišková et al. (2021) study could be attributed to: 1) the sprint COD drills by Šišková et al. (2021), providing greater exercise specificity to the pro-agility, compared to the small multi-dimensional (horizontal, vertical, and lateral orientation) movements performed in the ladder and cube intervention; 2) a more intense training mesocycle (6 weeks vs. 8 weeks) including higher volume (greater distance covered and repetitions performed) per session; and, 3) inclusion of 180° COD drills, leading to improved 180° efficiency and technical competency.

It is recommended that selection of 180° COD exercises be included when looking to improve performance in the pro-agility test. Furthermore, it should be acknowledged that the intervention by Šišková et al. (2021) was designed based on recommendations of previous researchers on the improvement of strength and speed variables in the soccer population (Beato et al., 2018; Miller et al., 2006). In contrast, Wagner et al. (2014) did not design and target the intervention towards any specific population. Nonetheless, participants of the included studies were either recreational or youth athletes, limiting the implications of these findings for competitive sport. This may provide reason as to the discrepancy between the findings of the two studies and further research is warranted.

Combined Training

Resistance and Plyometric Training

The effects of two combined resistance and plyometric training interventions from two different studies were analysed (see Table 7), of which one intervention was found to produce statistically significant ($p < 0.05$) changes in pro-agility performance (Jones et al., 2010). Combined resistance and plyometric training intervention length across the studies ranged from twelve to eighteen weeks (Bishop et al., 2017; Jones et al., 2010), resulting in an average change of 0.010% to 0.062%, and 0.002 to 0.014 ES per session (Bishop et al., 2017; Jones et al., 2010). The greatest per session improvements were noted in the study by Jones et al. (2010), where a whole-body free-weight exercises (i.e., not constrained to specific degrees of freedom) (0.062% and 0.014 ES) training intervention was implemented over 36 sessions in sub-elite soccer players. It should be noted in a combined population of sub-elite soccer, field hockey, and softball athletes (Jones et al., 2010), only soccer athletes showed a statistically significant ($p < 0.05$) improvement in pro-agility performance.

Interestingly, the largest per session

training effects (Jones et al., 2010) were noted in the study involving sub-elite soccer players. The reasons for the larger effects could be attributed to: 1) the small sample size (n = 14) used by Bishop et al. (2017), which may not have had ample statistical power to find statistical difference; 2) although the workloads were similar between all intervention groups across the studies, Bishop et al. (2017) integrated combined resistance and plyometric training within a smaller mesocycle as part of the larger intervention, however, only overall performance changes were reported for the intervention; and, 3) it was noted that soccer players possibly had a lower training age or conducted the intervention with greater effort than the other groups, as noted by Jones et al. (2010), but not measured. Overall, improvement in pro-agility performance was rather low. Considering the intervention lengths (12 to 18 weeks), it would be apparent the main cause of such low training effect may be attributed to the sub-elite level of the participants.

It needs to be noted that the second largest training effect was found in the Bishop et al. (2017) study, in elite cricket athletes over 36 sessions. However, readers should be aware that due to including combined resistance and plyometric training as a smaller mesocycle but only reporting performance results for the greater intervention, it is difficult to discern the resulting effects on pro-agility performance in cricket athletes.

Speed and Plyometric Training

The effects from three combined sprint and plyometric training interventions from three different studies (Šišková et al., 2021; Thompson et al., 2017; Vescovi & VanHeest, 2010) were analysed (see Table 7), of which one intervention was found to produce statistically significant ($p < 0.05$) changes in pro-agility performance (Šišková et al., 2021). Combined sprint and plyometric training intervention length across the studies ranged from 6 to 16 weeks (Šišková et al., 2021; Thompson et al., 2017; Vescovi & VanHeest, 2010), resulting in an average change of 0.066% to 0.135% and 0.011 to 0.036 ES per session. The greatest per session improvements were noted in the study of Šišková et al. (2021), where a combined sprint and plyometric training intervention over 12 sessions with novice soccer athletes was implemented (0.135% and 0.036 ES).

The largest per session training effects were observed in the study involving on field combined sprint and plyometric training (Šišková et al., 2021), meanwhile combined sprint and plyometric training involving 30 s of lateral hops, vertical hops, and horizontal hops, jumps, shuttle runs, and diagonal running exercises within a 15–20 min warm-up was noted to have an inverse effect, decreasing in pro-agility performance (-0.075% and -0.019 ES) (Vescovi & VanHeest, 2010).

The reasons for the disparity in training effects between studies by Šišková et al. (2021) and Thompson et al. (2017) vs. Vescovi and VanHeest (2010) could be attributed to: 1) training session duration of 25–45 min (Šišková et al., 2021; Thompson et al., 2017), as compared to 15–20 min (Vescovi and VanHeest, 2010), which provided a greater stimulus for adaptation; 2) both studies showing positive effects on pro-agility performance progressively overloaded intensity during exercises (Šišková et al., 2021; Thompson et al., 2017), whereas the warm-up intervention implemented by Vescovi and VanHeest (2010) emphasised lower intensity through the use of "soft landing" and large joint range of motion to ensure proper technique; 3) the intensity of the exercises could have been too low to elicit stimulus and/or the number of repetitions too high with insufficient recovery time between sets; and, 4) shorter more intense training mesocycle (6 weeks vs. 12 and 16 weeks), therefore less likelihood of training monotony and plateaus in adaptation.

Combined Resistance, Plyometric, and Speed Training

The effects of two resistance training interventions ($p < 0.05$) from a single study (Schwarz et al., 2019) were analysed (see Table 7). The intervention length was 6 weeks, with an average change of 0.715% to 1.034% and 0.071 to 0.078 ES per session (Schwarz et al., 2019). Both groups performed a combination of jumping, sprinting, and COD drills, with the only difference between groups being the utilisation of free-weight squats (FWS) (barbell back squat) or machine squat (MS) (machine hack squat) resistance exercise. The greatest per session improvements were noted in the MS training intervention (1.034% and 0.078 ES) over 12 sessions with novice recreational athletes.

While the largest per session training effects were noted in the MS group, as reported by Schwarz et al. (2019), there was no statistically significant difference in percent change and ES between either group. Furthermore, Schwarz et al.

(2019) acknowledged that combined sprint and plyometric training with FWS or MS resistance exercises did not provide additive effect as improvements in pro-agility performance may be a result of direct training (i.e., COD drills) and not maximal strength.

Inclusion of all three training modalities within a single intervention allowed for development of multiple components encompassing the pro-agility test. Namely, possessing adequate lower-body concentric, eccentric, and isometric strength and power for the propulsive, decelerative, and isometric phases due to high horizontal and lateral forces required during the COD portion of the pro-agility.

Limitations and Future Research

Several considerations should be acknowledged as to the limitations of the findings of this review. Firstly, between studies there were a number of variations in the cohorts used (i.e., gender, sport, skill level, training age). Similarly, the disparity in exercises selected in each of the interventions, coupled with intervention length, and total workload performed throughout the interventions were all factors that made comparisons and conclusions between studies problematic (i.e., the heterogeneity of the studies). Secondly, given the limited data available in the literature and consistency of methodologies for specific and non-specific training methods a meta-analysis could not be performed, therefore a comprehensive identification of the effects of the aforementioned training methods on pro-agility performance could not be established with certainty. Therefore, the conclusions made from only a few studies should be interpreted with caution. Further research is needed to determine the absolute effects of plyometric, sprint and COD training on pro-agility performance. Longitudinal examination of pro-agility performance (and pro-agility phases) is necessary to elucidate the effects of different training methods on phases of the pro-agility. This is vital to the understanding of how specific phases of the pro-agility can be developed in response to different training stimuli.

In terms of future research, it has been shown that the pro-agility is a widely utilised test of COD ability in various sports (Forster et al., 2022). However, all studies in this review utilised total-time as the measure for performance. Recent research by Forster et al. (2021) advanced the diagnostic value of the pro-agility test and established six distinct phases and six additional sub-tests incorporating acceleration, reacceleration, deacceleration, and COD components within the pro-agility test. Currently, while this review provides comprehensive evidence of the effect of different training methods on pro-agility performance, there are questions that need answering about how different training methods (e.g., specific and non-specific training) can improve performance in different phases of the pro-agility shuttle. From this standpoint, with the available literature, the phases and sub-tests measures can be conceivably affiliated to specific athletic capability (e.g., SSC for reacceleration or eccentric strength for deceleration), which can be developed through specific training methods.

Conclusion/Practical Implications

This review is unique in respect to previous reviews regarding training methods to improve COD performance because it focuses narrowly on the effectiveness of training methods that enhance pro-agility performance specifically. This would seem important given that the pro-agility test forms part of many testing batteries such as the NFL combine, which is used for scouting purposes. Assuming no technique issues, then taking an evidence-based approach to understanding and implementing training methods that produce the greatest pro-agility improvements, could make the difference in securing lucrative contracts.

Cognizant of the limitations cited previously, some conclusions are made based on the summary of averaged increases in effect sizes as shown in Table 8. Sprinting, plyometric, resistance training, and a combination of those three were found to have greater per session effects (ES > 0.078) on pro-agility scores compared to COD, and a combination of plyometrics and sprinting or plyometrics and resistance training. Sprint training, specifically inclined sprint training, was found to have the largest per session training effect. This could be attributed to the fact that inclined or resisted sprint training methods have been found to be particularly effective for enhancing accelerative capability (Cahill et al., 2019; Okudaira et al., 2021). Given the large linear sprinting component and the limited number of changes of direction associated with the pro-agility shuttle, this makes sense since athletes are required to accelerate between each COD (Brughelli et al., 2008). Plyometric training was found to be the second most effective method, which underlies the importance of the SSC and leg power in COD given the accelerative and decelerative nature of this motor task. Implementing plyometric exercises that involve multi-planar motion i.e., horizontal and lateral as well as vertical jumping tasks, was found to be particularly beneficial for enhancing pro-agility shuttle performance. Resisted strength training, particularly unilateral strength training, is another training method that appears to transfer well to pro-agility performance. This makes sense in terms of specificity given the high force demands associated with 180˚ COD (Bourgeois et al., 2017) and that sprinting and changing direction are unilateral in nature. Finally, combing resistance, plyometric, and sprint training can produce beneficial neuromuscular adaptations which lead to improved pro-agility shuttle performance. This could be attributed to the simultaneous utilisation of the aforementioned training methods to allow for development of multiple neuromuscular qualities related to performance in the pro-agility shuttle. However, training all three training types concurrently, with the same emphasis, may not provide ample stimulus compared to focusing on developing one neuromuscular quality to a greater extent compared to another. For example, coaches are likely to include jumping, sprinting, and lifting throughout an annual cycle, but programming a resistance training cycle focusing on maximum strength prior to a plyometric or sprinting-focused cycle may help improve contractile tissues capabilities which will then enable greater elastic tissue development, thereby SSC performance, in subsequent cycles.

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