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# Does Specialisation Impact Sprint and Change of Direction Performance in Youth Football Players?

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## ABSTRACT

**Purpose:** Specialisation in youth football is common, often with the goal of heightened sporting success later in life. The purpose of this study was to investigate if sprint and change of direction (COD) performance differs between specialised and diversified youth football players.
**Methods:** Twenty male football players (age: 15.9 ±1.1 years), grouped as specialised (*n*=11) or diversified (*n*=9), were compared in 30m sprint and 5-0-5 COD tasks. In the sprint, 10m and 30m completion time and force-velocity profiles were examined. COD performance was assessed using total time, COD deficit, and 2-dimensional video to determine if participants used backward trunk inclination and heel strike during their penultimate foot contact. Linear mixed models and Chi-square analyses were used to compare groups with significance set at $p \leq 0.05$.
**Results:** Sprint and COD performance did not differ between groups ($p > 0.05$). Significantly greater COD asymmetries were seen in the specialised group (9%) compared to the diversified group (4%). While not significantly different, effect sizes suggest potential differences in task completion strategy were observed based on force-velocity profiles during sprints.
**Conclusions:** These results suggest a specialised pathway does not lead to improved performance in sprint or COD in youth football players, but it may lead to differences in the strategy used to perform these tasks.

**Keywords:** soccer, adolescent, sport specialisation, sport sampling, youth development

## INTRODUCTION

Football is one of the most popular youth sports across the world. Youth football pathways into elite teams can be considered as either specialised (focused, intentional, year-round involvement in a single sport[1]), or diversified (exposure to a variety of seasonal sports[2]). A recent study indicated up to 48% of youth football players in NZ were classified as highly specialised[3]. A single sport focus potentially limits exposure to, and development of, a broad variety of movement patterns and motor skills. Players often start on a specialised pathway, when joining football academies, before or during adolescence[4]. Training load and intensity increase in these environments, and participation in other sports are often restricted. While involvement in an academy is associated with an increased chance of selection for major professional teams[5], there is little evidence to suggest that specialising earlier (i.e. at a younger age) leads to enhanced performance or future success[6]. Conversely, studies investigating specialisation across multiple sports have shown an increased risk of negative outcomes including impacts on movement competency[4], injury, burnout and dropout[7].

Football performance can be split into three domains: career-specific (e.g., level of achievement), task-specific (e.g., sprint speed, agility), and sport-specific (e.g., technical and tactical skills, shooting accuracy, and pattern recognition). Specialisation has been shown to benefit career-specific performance in adulthood, with male professionals reporting more organised football exposure in adulthood than amateurs[8]. However, current evidence supports a diversified approach through childhood and early adolescence to improve the chances of achieving a higher level of play in sports such as football, where peak performance occurs after physical maturation[4,6]. Adult football players who achieve elite-level career-specific performance also tend to specialise at a later age than those who did not achieve the same level of competition[8]. This suggests a diversified pathway throughout childhood and adolescence may be more beneficial for football career development; however, there is little evidence as to the mechanisms underlying this benefit.

Task-specific performance in football includes relevant athletic/physical competencies including cardiovascular fitness, jump landing technique, power, sprint speed and change of direction (COD) ability. It has been suggested that a diversified pathway promotes exposure to a broader range of movement patterns, and thus enhances movement competency[9]. Therefore, it would be expected that specialised players display inferior task-specific physical performance compared to diversified players, when matched for the level of competition. This has been observed previously where boys who followed a diversified pathway were superior, in assessments of cardiovascular fitness, muscular endurance[10], and jump distance[10] compared to boys who specialised in a single sport (across a range of sports)[10]. An additional confounding factor which may influence task-specific performance is the increased risk of injury[7], in particular gradual onset injuries[3]. These injuries occur frequently in specialised youth footballers and may influence their performance and underpinning movement strategy. Furthermore, injuries can influence the development of athletic performance variables due to decreased training availability[11].

Sprint and COD performance are key physical determinants of success in football[5]. Exposure to different sports has been associated with alterations in movement strategy in these tasks[10]. Within sprint tasks, athletes may display differences in mechanical efficiency in producing horizontal force and velocity[12]. Similarly, strategies used in a COD task may differ based on a player's ability to absorb braking forces and create accelerating forces[13]. However, there is limited data to examine if sprint and COD performance and task completion strategy differ in youth players based on their level of specialisation[6].

Cumulatively, the effects of sport specialisation on task-specific physical determinants of football performance are not well established. Thus, the aim of this study was to investigate if differences in sprint and COD performance exist between youth football players on development pathways classified as either specialised or diversified. Given the exposure to a wider range of athletic tasks, it was hypothesised that diversified players would perform better in sprint and COD tests and may display different movement strategies in both tasks.

## METHODS

### *Participants*

Twenty male youth outfield football players (age: 15.9 ±1.1 years; height: 174.7 ±7.1 cm; body mass: 66.0 ±8.3 kg; maturation offset: 1.5 ±0.8 years) competing at a regional level in Auckland, NZ, were recruited for this study. All players were required to be free from lower limb injury at the time of testing, and at least 6-months post-peak height velocity (PHV) to minimise the effect of maturation on performance outcomes.

### *Design*

A cross-sectional study design was used to investigate the differences between specialised and diversified youth football players in sprint and COD performance, and task completion strategies. Institutional review board approval was granted by the University's Ethics Committee (AUTEC# 19/113), informed parental consent and participant assent were obtained prior to data collection. Participants took part in a single data collection session during their normal training time.

### *Methodology*

#### *Participation Pathway*

Prior to the performance tests, participants completed a 10-question survey[7], modified to be football-specific, to categorise their football pathway as either specialised or diversified (Supplementary File A). Questions focussed on sport participation history at each chronological age and sport specialisation. Researchers were blinded to participant group categorisation (specialised or diversified) during data collection and processing.

Participation pathway was categorised based on the player's current level of specialisation, using the responses to the questions: 'do you consider football more important than any other sport?', 'do you train more than 8 months of the year in football?', 'have you quit other sports to focus on football?', and 'have you only ever played football?'. Any participants who answered 'yes' to three of these questions were placed in the specialised group[14] (*n* = 11; mean time specialised 3.6 ±1.7 years). All other players were allocated to the diversified group (*n* = 9) and were currently participating in an average of 2.0 ±0.5 sports including cricket (*n*=4), futsal (*n*=2), basketball (*n*=1), swimming (*n*=1), touch rugby (n=1), volleyball (*n*=1), handball (*n*=1), and Australian football (*n*=1).

*Estimate of Biological Maturation*

Participants' sitting and standing height and body mass were measured using a stadiometer and electronic scales (SECA 216, Germany). Seated height was taken on a 35cm box, and leg length was also measured to calculate maturation offset[15]. With the participants standing with their weight evenly distributed, leg length was measured as the distance from the anterior superior iliac spine to the medial malleolus using a tape measure[16]. The length of both legs was measured, and the mean length was used to calculate maturation.

*Sprint Performance*

Three 30m maximal sprints were performed with one-minute recovery between efforts. Dual-beam infrared timing gates (Swift Performance, Lismore, Australia) were positioned at 0, 10, 20, and 30m, with the start line 0.5m behind the first set of gates. A radar gun (Stalker ATS 5.0, Texas, USA) was also used, positioned 2m behind the start line, at a height of 1m. The radar was used to enable the calculation of force-velocity variables for a more in-depth analysis of sprint mechanics. Participants started when ready, to remove any reaction time effect, and were instructed to sprint maximally until passing through the final gate. Ten and 30m times were recorded.

*Change of Direction Task*

Change of direction speed was assessed using a 5-0-5 test (Figure 1). Participants sprinted maximally to a line of cones positioned 15m from the start, turned 180 degrees, and sprinted back 5m[17]. Three trials were performed in each turning direction in a randomised order with one-minute rest between trials. Timing gates were positioned at the 10m mark. Total 5-0-5 completion time (time from timing gate to the cones and back) was recorded. A camera (iPhone 6, Apple Inc., USA) was used to record sagittal plane video of the 5-0-5 task. The camera was fixed to a tripod 3m to the side of the 12.5m mark, at a height of 1m.

*Data Processing*

Radar data were processed to analyse the force-velocity profiles of participants during the sprint trials. Raw radar data were manually screened as described previously[18] to: (i) delete data recorded before and after each sprint; (ii) label trials as 'acceleration runs', thus forcing the velocity-time curve to start through zero; and (iii) remove outliers on the velocity-time curve, likely caused

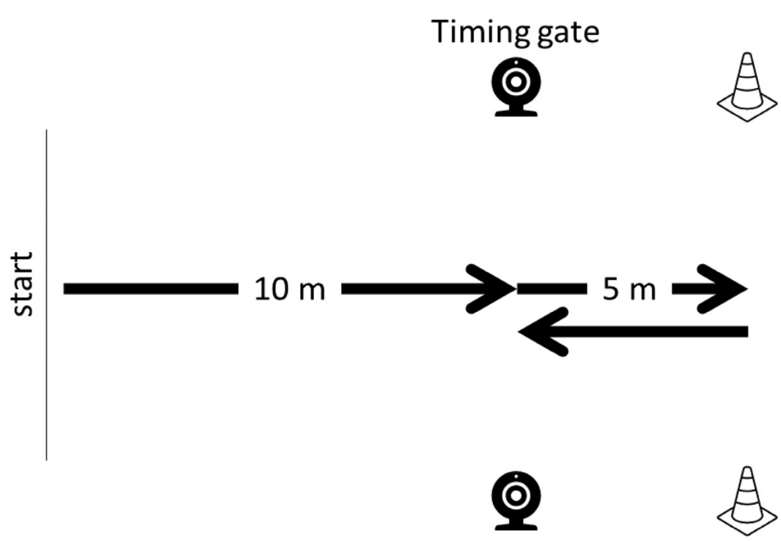


**Figure 1.** Setup for 5-0-5 agility test

by segmental movements of participants during sprinting. Following screening, files were imported into a custom software script (LabVIEW, Build version: 14.0, National Instruments Corp, Austin, TX, USA), which applied a validated method of estimating external horizontal force production[19]. Briefly, the velocity-time data from each trial were fitted with an exponential function via linear least squares regression[20], after which horizontal acceleration was computed via derivation of velocity over time. Horizontal force was estimated as: $F_h=m \cdot a_h+F_{aero}$;where *m* equated to body mass, and Faero corresponded to air drag (computed using estimates of frontal area from height and weight[21]). The ratio (RF) between the force produced horizontally and the resultant ground reaction force (equivalent to body weight over time) was computed as a representation of the technical ability to orient and apply force to accelerate[19].

Horizontal force ($F_h$) data were used to compile linear force-velocity relationships, and a linear relationship between RF and velocity[22]. From the force-velocity relationship, maximum theoretical horizontal force ($F_0$) and velocity ($V_0$) were computed as the intercepts of the linear regression. Maximum horizontal power ($P_{max}$) was calculated as $F_0 \cdot V_0/4$. Finally, the slope of both the force-velocity relationship ($SF_v$) and the RF/velocity relationship (DRF) were reported, with the latter corresponding to the decrease in the ratio of force with increasing velocities[22].

Change of direction deficit (CODD) was calculated as the time taken to complete the 5-0-5 distance minus the fastest 10m split from the 30m sprint[23,24]. Given 5-0-5 time is mostly linear sprinting, with only 31% of the time spent on the actual COD, faster linear sprint times have an advantage when just examining total 5-0-5 time[24]. The CODD allows the comparison of COD ability without being biased by differences in linear sprinting speed. This gives an indication of pacing coming into the COD task[23]. Asymmetries in COD ability were calculated as the absolute difference between the time taken for COD in each direction (COD left-COD right), recorded as the difference in seconds and also expressed as a percentage of COD time in the fastest direction (COD left-COD right/fastest COD * 100).

Two-dimensional video data from the 5-0-5 task were analysed using open-source software (Kinovea Version 0.9.5). Each trial was viewed in slow motion as many times as needed by a single researcher (Kappa= 0.59-0.70). Assessment criteria (yes/no) examined braking strategy in the penultimate foot contact via trunk inclination (was the trunk inclination in the intended direction of travel?), and heel ground contact (was there heel ground contact during the penultimate foot contact?). We adapted the methods of previous research[13], whereby only the lateral-view variables were used as indicators of penultimate foot contact braking strategy.

### *Statistical Analyses*

Mean and 95% confidence intervals (95%CI) are reported for all data. A significance level of $p \leq 0.05$ was used throughout. Between-group differences in all continuous variables were analysed using a linear mixed model built in R (R Core Team) using the *lme4* package. 'Group' (specialised and diverse) and 'trial' (1, 2, 3) were used as fixed effects, and 'participants' as random effect. The emmeans package was used to calculate estimated means and differences. Dichotomous variables (backward trunk inclination and heel contact) were analysed using Chi-squared analysis. Effect sizes (ES) were calculated using estimated means and standard error, and reported as Hedges' *G* and classified as small (0.20-0.49), medium (0.50-0.79), or large (≥0.80)[25].

## RESULTS

No between-group differences were observed for maturation offset (mean difference= 0.35 years [-0.44–1.13]; *p*=0.37), age (mean difference= 0.72 years [-0.27–1.7]; *p*=0.15), mass (mean difference= 0.49 kg [-7.56–8.54]; *p*=0.90), or height (mean difference= 0.68 cm [-6.21–7.56]; *p*=0.84).

### *Sprint Performance*

There were no significant between-group differences for any sprint performance variables (Table 1). However, there were moderate ES in SFV (mean difference= -0.09; 95% CI = -0.21–0.03; ES=-0.52) and DRF (mean difference= 0.01; 95% CI = -0.002–0.012; ES=0.50).

### *Change of Direction Performance*

There were no significant between group mean differences in COD performance variables and ESs were trivial (Table 2). The specialised group did display significantly greater asymmetry in COD total time (absolute, ES = 0.91, *p*=0.01 and percentage, ES = 0.90, *p*=0.01). There was a significantly greater

**Table 1.** Between-group comparisons of sprint variables.

| | Specialised mean (95%CI) | Diversified mean (95%CI) | Difference (95%CI) | *p*-value | Effect size (Hedges' *G*) |
|---|---|---|---|---|---|
| 0-10m (s) | 1.84 (1.76–1.92) | 1.88 (1.79–1.96) | -0.04 (-0.15–0.08) | 0.41 | -0.22 |
| 0-30m (s) | 4.46 (4.26–4.65) | 4.56 (4.35–4.77) | -0.10 (-0.39–0.19) | 0.35 | -0.24 |
| $v_{max}$ (m/s) | 7.94 (7.54–8.34) | 7.85 (7.34–8.35) | 0.10 (-0.55–0.74) | 0.44 | 0.10 |
| $F_0$ | 457 (406-509) | 480 (416-545) | -23.2 (-106-59.3) | 0.42 | -0.20 |
| $RelF_{max}$ (N/kg) | 6.99 (6.46–7.52) | 7.26 (6.59–7.93) | -0.28 (-1.13–0.58) | 0.30 | -0.23 |
| SFv | -1.22 (-1.30–-1.15) | -1.14 (-1.23–-1.04) | -0.09 (-0.21–0.03) | 0.06 | -0.52 |
| $P_{max}$ | 971 (823-1119) | 987 (801-1173) | -15.8 (-253-222) | 0.86 | -0.05 |
| $RelP_{max}$ (W/kg) | 14.8 (13.1–16.4) | 14.9 (12.8–17.0) | -0.18 (-2.87–2.5) | 0.84 | -0.05 |
| RF | 0.48 (0.45-0.50) | 0.49 (0.46-0.52) | -0.01 (-0.05-0.03) | 0.53 | -0.17 |
| DRF | -0.076 (-0.080–-0.072) | -0.081 (0.086–-0.076) | 0.01 (-0.002–0.012) | 0.06 | 0.50 |

*$V_{max}$= peak velocity; $F_0$= theoretical maximal horizontal force; $RelF_{max}$= peak relative horizontal force; SFv= slope of force velocity curve; $P_{max}$= peak horizontal power; $RP_{max}$= peak relative horizontal power; RF= ratio of horizontal force production to ground reaction force; DRF= RF/velocity relationship*

**Table 2.** Between-group comparisons of change of direction ability.

| | Specialised mean (95%CI) | Diversified mean (95%CI) | Difference (95%CI) | *p*-value | Effect size (Hedges' *G*) |
|---|---|---|---|---|---|
| 505 Left (s) | 2.49 (2.41–2.57) | 2.49 (2.40–2.58) | 0.00 (-0.12–0.12) | 0.43 | -0.0001 |
| CODD Left (s) | 1.23 (1.14–1.32) | 1.22 (1.12–1.31) | 0.01 (-0.12–0.14) | 0.82 | 0.07 |
| 505 Right (s) | 2.48 (2.39–2.58) | 2.52 (2.41–2.62) | -0.03 (-0.17–0.11) | 0.33 | -0.15 |
| CODD Right (s) | 1.22 (1.13–1.32) | 1.24 (1.14–1.35) | -0.02 (-0.16–0.12) | 0.78 | -0.09 |
| Asymmetry (s) | 0.11 (0.08-0.14) | 0.05 (0.01-0.08) | 0.06 (0.02-0.11) | 0.01* | 0.91 |
| Asymmetry (%) | 8.98 (6.46-11.51) | 3.89 (1.10-6.69) | 5.09 (1.32-8.85) | 0.01* | 0.90 |

**= statistically significant; CODD= change of direction deficit*

frequency of backwards trunk inclination on the penultimate step turning to the left in the specialised group, than in the diverse group (difference=77% [54–99%]; *p*=0.01). However, there were no significant differences between groups in trunk lean turning to the right (difference=13% [-32–59%]; *p*=0.55), or frequency of heel contact in the penultimate step (*p*>0.05). Additionally, a greater frequency of heel contact was observed in the specialised group when turning to the left (difference=33% [-18–83%]; *p*=0.21). This trend was smaller and reversed when turning to the right (i.e., it was observed more often in diversified than specialised players (difference=25% [-21–71%]; *p*=0.30).

## DISCUSSION

The aim of this study was to investigate differences in sprint and COD performance between specialised and diversified male youth football players. Consistent with previous research there were no differences in performance outcomes[4,6]; however, players following a specialised pathway displayed greater asymmetries in COD speed. While not as clear, the estimates (and their uncertainty based on the associated confidence intervals) are also compatible with potential differences in sprint and COD strategy (SFV, DRF, penultimate foot contact in COD) compared to players on a diversified pathway. Thus, specialisation may have a greater effect on task execution than performance outcome alone.

Asymmetries in COD speed have been reported previously[26], and could affect on-field performance in football due to the need for turning proficiency in either direction. Increased asymmetry in specialised players may be due to a greater frequency of direction change actions biasing one side in certain playing positions[27]. In contrast, a diversified player may have had greater exposure to COD tasks in both directions, and more variance in task-specific actions. This increased variation may have reduced the magnitude of limb dominance, leading to less asymmetry. It may be beneficial to expose specialised players to different positions throughout their involvement in youth football development programmes to ensure they develop proficiency in both directions. Additionally, specialised players may benefit from using alternate sports/activities in training, including unilateral plyometric and resistance training to ensure potential between-limb imbalances in force production and stretch shortening cycle function are minimised.

Qualitative analysis of COD task completion strategy indicated the diversified group used a more upright trunk posture at the penultimate foot contact before changing direction. This strategy has been associated with decreased efficiency in deceleration and reacceleration depending on the next direction of travel[23,28], but also decreased risk of knee injury[29]. The combination of backwards trunk inclination and heel strike may contribute to improved performance in COD tasks[28]; however, both have also been associated with increased braking forces[29]. Thus, knee alignment and thigh eccentric strength levels are important to allow quick deceleration and avoid injury. More frequent heel contact in the penultimate foot strike was observed in specialised players when turning towards the left. In a specialised football environment, with high exposure to football-specific COD tasks in training and matches, technical approaches like modified trunk inclination may inherently be developed to optimise completion time. To our knowledge, there is no research that has examined differences in performance and technical ability in a 5-0-5 COD task between sports, but these results suggest that the increased trunk angle and heel strike used by the specialised players support more efficient COD task completion. The trunk posture adopted by the diversified players, while less efficient, decreases mechanical loading of the knee. This may be a strategy to either protect the knee, or these players may lack the requisite eccentric strength to perform this task with a more extended trunk position during this movement[28,29]. In the absence of varied movement demands and targeted strength and conditioning, the approach strategies of the specialised group should be monitored to ensure players have sufficient strength to decelerate safely and reduce the risk of injury.

Only small non-significant differences in sprint completion time between groups were shown in the current study, but more clear divergences in the strategies used to achieve these outcomes were present. Due to variations in exposure to sprint activities and drills[30], diversified participants may utilise different sprint techniques to those seen in the specialised group who will have been exposed to a reduced number of constraints imposed by a single sport, in this case football. Differences in strategy can influence sprint speed, and this was observed in the force-velocity profiles[31]. While not statistically significant, our estimates suggest enhanced mechanical efficiency, and higher horizontal force production were more likely in the specialised players. The force-velocity curve showed an increased slope (ES= -0.52), which indicates a more force-oriented approach that may lead to improved acceleration[31]. Mechanical efficiency with which athletes apply horizontal force and maintain horizontal force production while increasing speed can be assessed by calculating the ratio of horizontal force to ground reaction force, and its relationship with velocity (DRF)[12]. Specialised players are likely to experience more short-distance sprints through higher volumes of football training and competition, and thus may have developed a more efficient strategy, which allows greater horizontal force production in a shorter time, than their diversified counterparts.

## CONCLUSIONS

Strategies used by specialised youth football players tended to be those associated with increased efficiency in both the sprint and COD. This suggests there may be some benefit for diversified players to participate in more targeted, football-specific sprint and COD training, as well enhancing sprint and COD mechanics. Some of the strategies displayed by the specialised group (increased braking forces and asymmetries during COD) have been associated with increased injury risk and should be monitored and managed by ensuring players participate in appropriate strength and conditioning. Specific strategies should include an increased focus on eccentric leg and hip strength, unilateral strength and plyometric training, as well as varied sport and training exposure. Training should include variation in tasks (including sprint and COD) and different constraints to encourage the exploration of a greater number of movement solutions and thus supporting enhanced movement variability.

The results of this study indicate engagement in a specialised football development pathway does not lead to significantly increased sprint or change of direction speed in youth football players. There were differences in task completion strategy identified. Most notably, specialised players displayed greater COD asymmetry, combined with improved technique as evidenced by a posteriorly inclined trunk position during the penultimate foot contact. During sprinting, improved horizontal force production and mechanical effectiveness were also found in the players who followed a specialised pathway. The mechanisms that underpin these potential differences warrant further investigation.

## FUTURE RECOMMENDATIONS

A strength of this study was the use of technical measures alongside performance outcomes to examine the task completion strategy used. A limitation was that while the tests used are relevant to football performance, they do not assess football-specific skills, which may result in differences based on development pathways. Additionally, the use of the force-velocity profile in determining sprinting strategy has recently been brought into question 32. In future it may be sufficient to examine performance-time traces combined with assessment of spatiotemporal characteristics and qualitative differences in strategy. Since football performance is impacted by several other physical, physiological, and technical factors, future research may wish to examine a more diversified player profile. In addition, while the sample size was small, our data provides a preliminary indication of potential differences that may be worth investigating further. Future studies may also benefit from including analysis based on player position; however, this information was not available in the current investigation. Finally, the design was cross-sectional, capturing information at a single time point. Prospective studies are needed to evaluate the development of tactical skills and physical performance through different development pathways.

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## CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

## FUNDING

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## ETHICAL APPROVAL

Institutional review board approval was granted by the University’s Ethics Committee (AUTEC# 19/113), informed parental consent and participant assent were obtained prior to data collection

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## REFERENCES

1. Bell DR, Snedden T, Biese K, et al. Consensus definition of sport specialization in youth athletes Using a delphi approach. Journal of athletic training. 2021;56(11):1239-51. doi:10.4085/1062-6050-0725.20
2. Côté J, Baker J, Abernethy B. Practice and play in the development of sport expertise. In: R. Eklund, Tenebaum G, eds. Handbook of Sport Psychology. 3 ed. Wiley; 2007:184-202.
3. Zoellner A, Whatman C, Sheerin K, Read P. Prevalence of sport specialisation and association with injury history in youth football. Physical Therapy in Sport. 2022/10/29/ 2022;58:160-166. doi:10.1016/j.ptsp.2022.10.013
4. Murata A, Goldman DE, Martin LJ, Turnnidge J, Bruner MW, Côté J. Sampling between sports and athlete development: A scoping review. International Journal of Sport and Exercise Psychology. 2021:1-25. doi:10.1080/1612197x.2021.1995021
5. Huijgen BCH, Elferink-Gemser MT, Lemmink KAPM, Visscher C. Multidimensional performance characteristics in selected and deselected talented soccer players. European Journal of Sport Science. 2014;14:2-10. doi:10.1080/17461391.2012.725102
6. Kliethermes SA, Nagle K, Cote J, et al. Impact of youth sports specialisation on career and task-specific athletic performance: a systematic review following the American Medical Society for Sports Medicine (AMSSM) Collaborative Research Network’s 2019 youth early sport specialisation summit. British Journal of Sports Medicine. 2020;54(4):221-230. doi:10.1136/bjsports-2019-101365
7. McGowan J, Whatman C, Walters S. The associations of early specialisation and sport volume with musculoskeletal injury in New Zealand children. journal of Science and Medicine in Sport. 2020;23(2):139-144. doi:10.1016/j.jsams.2019.09.002
8. Hornig M, Aust F, Güllich A. Practice and play in the development of German top-level professional football players. European Journal of Sport Science.

2016;16(1):96-105. doi:10.1080/17461391.2014.982204
9. Salin K, Huhtiniemi M, Watt A, Mononen K, Jaakkola T. Contrasts in fitness, motor competence and physical activity among children involved in single or multiple sports. Biomedical Human Kinetics. 2021;13(1):1-10. doi:doi:10.2478/bhk-2021-0001
10. Fransen J, Pion J, Vandendriessche J, et al. Differences in physical fitness and gross motor coordination in boys aged 6–12 years specializing in one versus sampling more than one sport. Journal of Sports Sciences. 2012;30(4):379-386. doi:10.1080/02640414.2011.642808
11. Johnson D, Williams S, Bradley B, Cumming SP. Can we reduce injury risk during the adolescent growth spurt? An iterative sequence of prevention in male academy footballers. Annals of Human Biology. 2023/01/02 2023;50(1):452-460. doi:10.1080/03014460.2023.2261854
12. Morin JB, Samozino P. Interpreting power-force-velocity profiles for individualized and specific training. International Journal of Sports Physiology & Performance. 2016;11(2):267-72. doi:10.1123/ijspp.2015-0638
13. Dos'Santos T, McBurnie A, Donelon T, Thomas C, Comfort P, Jones PA. A qualitative screening tool to identify athletes with 'high-risk' movement mechanics during cutting: The cutting movement assessment score (CMAS). Physical Therapy in Sport. 2019;38:152-161. doi:10.1016/j.ptsp.2019.05.004
14. Jayanthi NA, LaBella CR, Fischer D, Pasulka J, Dugas LR. Sports-specialized intensive training and the risk of injury in young athletes: a clinical case-control study. American Journal of Sports Medicine. 2015;43(4):794-801. doi:10.1177/0363546514567298
15. Mirwald RL, Baxter-Jones ADG, Bailey DA, Beunen GP. An assessment of maturity from anthropometric measurements. Medicine and Science in Sports and Exercise. 2002;34(4):689-694. doi:10.1097/00005768-200204000-00020
16. Miller MM, Trapp JL, Post EG, et al. The effects of specialization and sex on anterior Y-balance performance in high school athletes. Sports Health. 2017;9(4):375-382. doi:10.1177/1941738117703400
17. Cuthbert M, Thomas C, Dos'Santos T, Jones PA. The application of change of direction deficit to evaluate cutting ability. Journal of Strength and Conditioning Research. 2019;33(8):2138-2144. doi:10.1519/jsc.0000000000002346
18. Simperingham KD, Cronin JB, Pearson SN, Ross A. Reliability of horizontal force–velocity–power profiling during short sprint-running accelerations using radar technology. Sports Biomechanics. 2019;18(1):88-99. doi:10.1080/14763141.2017.1386707
19. Samozino P, Rabita G, Dorel S, et al. A simple method for measuring power, force, velocity properties, and mechanical effectiveness in sprint running. Scandinavian Journal of Medicine & Science in Sports. 2016;26(6):648-58. doi:10.1111/sms.12490
20. Furusawa K, Hill AV, Parkinson JL. The dynamics of "sprint" running. Proceedings of the Royal Society of London. 1927;102:29-42. doi:10.1098/rspb.1927.0035
21. Arsac LM, Locatelli E. Modeling the energetics of 100-m running by using speed curves of world champions. Journal of Applied Physiology. 2002;92(5):1781-1788. doi:10.1152/japplphysiol.00754.2001
22. Cross MR, Brughelli M, Samozino P, Morin J-B. Methods of power-force-velocity profiling during sprint running: A narrative review. Sports Medicine. 2017;47(7):1255-1269. doi:10.1007/s40279-016-0653-3
23. Nimphius S, Callaghan SJ, Bezodis N, Lockie RG. Change of direction and agility tests: Challenging our current measures of performance. Strength and Conditioning Journal. 2017;40(1):1-13. doi:10.1519/SSC.0000000000000309
24. Nimphius S, Callaghan SJ, Spiteri T, Lockie RG. Change of direction deficit: A more isolated measure of change of direction performance than total 505 time. Journal of Strength & Conditioning Research. 2016;30(11)doi:10.1519/JSC.0000000000001421
25. Cohen J. Statistical power analysis for the behavioural sciences. 2 ed. Routledge; 1988:567.
26. Bishop C, Read P, Brazier J, et al. Effects of interlimb asymmetries on acceleration and change of direction speed: A between-sport comparison of professional soccer and cricket athletes. Journal of Strength & Conditioning Research. 2021;35(8):2095-2101. doi:10.1519/jsc.0000000000003135
27. Bloomfield J, Polman R, O'Donoghue P. Physical demands of different dositions in FA Premier League soccer. Journal of Sports Science & Medicine. 2007;6(1):63-70.
28. Dos'Santos T, McBurnie A, Thomas C, Comfort P, Jones PA. Biomechanical determinants of the modified and traditional 505 change of direction speed test. Journal of Strength & Conditioning Research. 2020;34(5):1285-1296. doi:10.1519/jsc.0000000000003439
29. Jones P, Barber O, Smith L. Changing pivoting technique reduces knee valgus moments. 2015:
30. Haugen TA, Breitschädel F, Seiler S. Sprint mechanical variables in elite athletes: Are force-velocity profiles sport specific or individual? PLOS ONE. 2019;14(7):e0215551. doi:10.1371/journal.pone.0215551
31. Jiménez-Reyes P, Garcia-Ramos A, Párraga-Montilla JA, et al. Seasonal changes in the sprint acceleration force-velocity profile of elite male soccer players. Journal of Strength & Conditioning Research. 2022;36(1)doi:10.1519/JSC.0000000000003513
32. Ettema G. The Force-Velocity Profiling Concept for Sprint Running Is a Dead End. Int J Sports Physiol Perform. Jan 1 2024;19(1):88-91. doi:10.1123/ijspp.2023-0110