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Does early specialisation improve drop jump and Y-balance performance in junior football players?

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ABSTRACT

Sport specialisation has been defined as the intense involvement in a single sport to the exclusion of all other sports. Previous research has raised questions about potential negative consequences of specialising at a young age. The purpose of this study was to examine differences in drop jump and y-balance performance in junior football players based on level of specialisation. This was a cross-sectional observational study involving 35 male footballers aged 10.2 ± 1.1 years. Participants were grouped as high, moderate, and low specialised. Level of specialisation was determined using a survey on their sports participation history. Tests included anterior Y-balance test and drop jumps assessed using the Landing Error Scoring System (LESS). Between-group differences were analysed using one-way analysis of variance and chi-squared analysis with an a priori statistical significance level of $p \leq 0.05$. Hedge's g effect sizes were reported for all results. High specialised players displayed greater left leg relative reach than moderate (mean diff = 10.9% LL; 95% CI [2.2, 19.6]; p = 0.013; Hedge's g = 0.78) but not low (mean diff = 5.0% LL; 95% CI [-4.0, 14.1]; p = 0.218; Hedge's g = 0.39) specialised players. No other significant differences were observed in Y-balance performance. High specialised players displayed fewer LESS errors than moderate (mean diff = 2.75 errors; 95% CI [0.05, 5.48]; p = 0.009; Hedge's g = -0.90), but not low (mean diff = 2.20 errors; 95% CI [-5.05, 0.65]; p = 0.101; Hedge's g = -0.57) specialised players. 'Knee flexion displacement' was the only LESS criterion that differed significantly between groups, with errors more common in moderately specialised players (n = 9) than both high (n = 0) and low (n = 5) specialised players (p = 0.003). These results suggest early specialised junior football players may perform better in the drop jump and y-balance tests than their less specialised counterparts. Results suggest all players may benefit from participation in injury prevention programmes such as the FIFA 11+, in particular moderately specialised players.

1. Introduction

Sport specialisation has been defined as focused, intentional training, year-round, in a single sport (Bell et al., 2021). High rates of specialisation have been consistently reported in young athletes across a number of sports (Bell et al., 2016; Post et al., 2017a; Post et al., 2017b; Zoellner et al., 2022). Proposed reasons for this include a desire to increase chances of future selection, scholarships and opportunities to play professionally (Normand et al., 2017; Post et al., 2019). However, a number of studies indicate that in most sports, athletes do not need to specialise at a young age in order to achieve elite-level performance later in life (Kliethermes et al., 2020; Murata et al., 2022). More so, delayed specialisation has been reported as more common in adult elite-level performers, compared to their sub-elite counterparts (Hornig et al., 2016; Kliethermes et al., 2020).

While some level of specialisation is needed to reach elite and/or professional levels, 'early' sport specialisation has been associated with negative long-term outcomes for youth athletes, including burnout, dropout, and increased risk of injury (Beese et al., 2015; Brenner, 2007; Jayanthi et al., 2015; Wall & Côté, 2007). Various published international consensus statements have discouraged early specialisation (Bergeron et al., 2015; DiFiori et

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al., 2014; LaPrade et al., 2016), but no agreement has been reached on the appropriate age for specialisation, and indeed what constitutes 'early'. Current evidence suggests that specialisation should be delayed until after physical maturation or late adolescence (Jayanthi et al., 2019; LaPrade et al., 2016). Later specialisation promotes exposure to the varied movement and coordination demands needed for young athletes to optimise skill learning (Côté, et al., 2009). Additionally, pre-puberty is the optimal time to learn fundamental, broad motor skills to maximise future potential due to increased neural plasticity (Myer et al., 2011). Thus, delaying specialisation is advised to allow more time for young athletes to develop enhanced competence in a broad range of movement skills (Jayanthi et al., 2019; Myer et al., 2015). In adolescence, young athletes also undergo rapid growth with alterations in neuromuscular control (Beese et al., 2015; DiCesare et al., 2019; DiStefano et al., 2018; Miller et al., 2017). These developmental periods heighten injury risk (van der Sluis et al., 2014), especially if combined with increases in training load and intensity often associated with early specialisation (Brenner & Council On Sports Medicine and Fitness, 2016).

Exposure to varied movements, and being able to respond to a variety of situational demands, is vital in preparing young athletes for future sports performance (Côté et al., 2009). Recent research indicates that following injury and return to sport, football athletes develop movement strategies that allow them to achieve the same outcomes as non-injured players, despite their physical limitations (Hart et al., 2019). Movement strategies will emerge under constraints from different tasks and environments, thus exposure to a greater variety may allow athletes to develop a wider range of movement solutions (Côté & Hancock, 2014; Rudd et al., 2020). When specialising in a single sport, there is a potential reduction in the number of constraints young athletes are exposed to. Specifically, football players favour kicking with their preferred leg, which results in increased stability in the support leg (Atkins et al., 2016). Jump-landing performance may also be enhanced on the non-preferred leg (Read et al., 2018a; Read et al., 2018b), leading to imbalances in force transfer, muscle activation, and motor control (Atkins et al., 2016; Read et al., 2016). However, more studies are needed to elucidate the relationship between early specialisation and movement development, and to examine if movement strategies emerge that may predispose these young athletes to a heightened risk of injury.

Due to the importance of the pre-pubertal period on the development of diverse movement strategies (Myer et al., 2013), more research is required to ensure youth are benefiting from positive development experiences. Additionally, given the high proportion of youth players specialising 'early' in football, and the potential for this to impact on movement skill development, the aim of this study was to investigate if differences exist in the performance of drop jumps (DJ) and Y-balance tests of pre-pubertal football players based on their level of specialisation. Considering existing research, we hypothesised that highly specialised players would demonstrate poorer outcomes than those who were low specialised.

2. Methods

This cross-sectional study included two movement tests and a survey of current and past sport participation. Institutional ethical approval was granted prior to recruitment and data collection. All participants provided written informed assent, and their parents or caregivers gave informed consent. The movement tests included the Y-balance anterior reach distance (absolute and relative to leg length) and DJ assessed using the Landing Error Scoring System (LESS) due to their known associations with injury risk youth populations (Padua et al., 2009; Plisky et al., 2006; Read et al., 2020). Testing took place in the evenings, during normal training times, with participants performing their normal training warmup prior to testing. As participants were in the same teams, it could reasonably be assumed that they performed the same warmup. At each session, the tests were explained to the participants, and they were given time to familiarise themselves to ensure they completed the task as instructed. Familiarisation involved participants practising each test at least four times to minimise variation due to any learning effect (Munro & Herrington, 2011).

1.1. Participants

Thirty-five boys aged 10.2 ± 1.1 years (height: 140.7 ± 8.7 cm; body mass: 36.6 ± 8.6 kg) volunteered to take part. Participants were recruited from a football academy in Auckland, New Zealand (NZ) during the competitive season. Participants were required to be at least 1-year pre-peak height velocity (PHV), and currently free from injury, to minimise maturational and/or injury effects on movement. Additionally, all participants were less than 12 years of age, the most commonly reported chronological age-based threshold for defining early specialisation (Mosher et al., 2020). Limb preference for players was 46% right, 6% left, 48% not reported. A male-only sample was selected to eliminate any differences in movement based on gender, given that differences in knee valgus control during jump landings have been evidenced at all maturational levels (Holden et al., 2019).

The sample for this study was drawn from a broader planned project, with recruitment governed primarily by feasibility. While an a priori power analysis was conducted during the early stages of the wider research program, subsequent changes to the study design and analytic focus rendered it no longer applicable. Nonetheless, a sensitivity analysis (via pwr; Champely, 2020) was performed to determine the smallest effect size that the study was adequately powered to detect. This was based on the primary statistical models being built, given the total sample size of 35, an alpha error rate of 0.05, and 80% power. This analysis indicated that the study was powered to detect Cohen's $f \geq 0.55$ (eta-squared ≥ 0.23), which corresponds to a threshold of a medium to large effect according to conventional benchmarks (Cohen, 1992). Accordingly, readers are encouraged to interpret the results in consideration of the reported effect sizes and confidence intervals as indicators of magnitude and precision of the observed effects.

1.2. Procedure

1.2.1. Maturity assessment

Maturation offsets were calculated using a validated somatic equation (Mirwald et al., 2002). All estimates were based on measures of standing and sitting heights, body mass, and leg length (measured whilst standing in anatomical position, from the anterior superior iliac spine to the medial malleolus) (Miller et al., 2017). This data was used for inclusion/exclusion only, not for any analyses.

1.2.2. Level of specialisation

Sport history questionnaires (Supplementary Material A) were used to determine the current level of specialisation, and which sports boys participated in, at each age since they began football. Questionnaires were completed with the help of a parent and were used to determine how long participants had been specialised (Moesch et al., 2011). The level of specialisation was determined based on their answers to four questions: (1) Is football more important than any other sport?; (2) Do you train more than 8 months of the year in football?; (3) Have you quit other sports to focus on football?; and (4) Have you only ever played football?' Players who answered 'yes' to three questions were classified as highly specialised. Those who answered 'yes' to two questions were classified as moderately specialised, and 'yes' to one or fewer were classified as low specialised. Classification of players was determined after data collection to ensure researchers were blinded to the level of specialisation during testing.

1.2.3. Movement tests

Y-Balance tests were performed on a custom-made Y-balance test kit consisting of a small wooden box with three poles attached in a 'y' shape. A block was placed on each pole that could easily slide along the pole to indicate reach distance. Participants adopted a single-leg stance on the box in the middle with their toes behind a line, and their hands on their hips. They were then instructed to push the block along the pole as far as possible while maintaining balance, without putting weight on the block or placing their foot on the ground. When participants had pushed the block as far as possible, they returned their foot to the centre without touching down. If any of these instructions were not adhered to, participants were asked to repeat that trial. The reach distance was recorded from the box to the back of the block. Only the anterior reach was tested for logistical reasons, and due to its stronger associations with injury risk compared to the posterior medial and lateral directions (Plisky et al., 2006). Limb order was randomised, with three trials on each leg. Absolute anterior reach distances were compared, as well as reach distance relative to leg length (%LL). Reach asymmetry was also calculated, as the percentage difference between legs ([absolute difference between legs ÷ greatest reach distance] × 100).

Drop jumps were performed from a 30cm box with a cross on the floor at a distance half the participant's standing height. Instructions were to drop down, land on the cross with both feet, and perform a vertical jump for maximum height while minimising ground contact time.

Frontal and sagittal plane video (25 frames per second; HDR-CX130, Sony, NY, USA) was recorded (3 m from the front and side of the cross on the floor at a height of 1 m). Cameras were set to record in portrait orientation. Three trials were completed by each participant. Jump-landings were rated using the 17-item scoring system developed by Padua et al. (2015) (Table 1).

Table 1: Landing Error Scoring System criteria.

Time point	Criterion	Rating
Initial contact	Knee flexion more than 30°	0 = Yes 1 = No
	Hips are flexed	0 = Yes 1 = No
	Trunk is in front of hips	0 = Yes 1 = No
	Ankle plantar flexion: lands toe to heel	0 = Yes 1 = No
	Knee valgus: patella is not medial to midfoot	0 = Yes 1 = No
	No lateral trunk flexion	0 = Yes 1 = No
	Stance width	0 = Feet shoulder width apart 1 = Feet wider than shoulder width or narrower than shoulder width
	Feet land symmetrically	0 = Yes 1 = No
Between initial contact and maximum knee flexion	Foot rotation	0 = Feet not internally or externally rotated more than 30° 1 = Feet internally or externally rotated more than 30°
	Knees flex 45° or more	0 = Yes 1 = No
	Hip flexion increases	0 = Yes 1 = No
	Trunk flexion increases	0 = Yes 1 = No
Point of maximum medial knee displacement	Midpoint of patella does not move medial to midfoot	0 = Yes 1 = No
Overall	Amount of trunk, hip, and knee joint displacement throughout	0 = Large (soft landing) 1 = Some (average landing) 2 = Very little (stiff landing)
	Overall impression of softness of landing and frontal- and transverse-plane movement	0 = Excellent (soft, no frontal or transverse plane motion) 1 = Average 2 = Poor (stiff and/or large frontal- or transverse-plane motion)

Individuals were given a score that equated to a count of errors displayed during the trial. A lower score indicated fewer errors and thus better technique. Videos were rated independently by two individuals who were experienced in movement analysis and blinded to the specialisation classification of participants. Intra-rater reliability was assessed using a different data set (ICC = 0.92). Videos were viewed in freely available analysis software (Kinovea v0.9.3), paused at the time point of interest (e.g., initial contact) and replayed as many times as necessary to be confident of the score. One score was given based on the three trials. An error was counted if it was displayed in two or more of the trials. Scores were compared between raters and any differences were discussed. Videos were then reviewed until a consensus was reached.

Jump-landing competence was classified based on previous research (Beese et al., 2015; Padua et al., 2009), as 'excellent' (0-3 errors), 'good' (4-5 errors), 'moderate' (6 errors), or 'poor' (≥ 7 errors). DJ data for some participants were excluded due to technical issues. Participant numbers included in each group for each analysis are reported in the relevant tables.

1.3. Statistical approach

Mean, standard deviations (SD) and 95% confidence intervals (95% CI) are reported for continuous data. A significance level of $p \leq 0.05$ was set a priori and used throughout. Statistical analysis was carried out using R statistical software (R Core Team). One-way analysis of variance (ANOVA) was used to analyse between-group (high, moderate, low) differences in Y-balance and total Landing Error Scoring System (LESS) scores. Normality and homogeneity of variance were checked to ensure assumptions were met. Tukey post-hoc analyses were conducted where appropriate to compare each pair of groups, and outcomes were presented as mean difference and 95% CI. Effect sizes (ES) were calculated from estimated means from the post-hoc analyses, and corresponding standard errors, reported as Hedge's *g*, and classified as 'small' (> 0.20), 'medium' (> 0.50), or 'large' (> 0.80) (Cohen, 1988). The frequency of individual errors in the LESS between groups was analysed for each criterion using chi-squared analysis. Due to the number of comparisons used to compare the individual errors of the LESS, a Bonferroni correction was used (0.05/17), resulting in an alpha level of $p \leq 0.003$ for the chi-squared results.

2. Results

Descriptive statistics are presented in Table 2. Participants were grouped as 'high' ($n = 11$), 'moderate' ($n = 13$), and 'low' ($n = 11$) specialised. There were no significant differences in age ($p = 0.329$), height ($p = 0.208$), body mass ($p = 0.140$), or maturation offset ($p = 0.116$) among groups. The high group had been specialised for an average of 2.0 ± 1.2 years, and the moderate and low specialised groups participated in an average of 2.4 ±1.4 and 2.1 ± 0.8 sports, respectively.

Table 2: Summary descriptive data (mean ± SD [95% CI]).

	Low specialised	Moderately specialised	High specialised	*p*	Hedge's *g*
Age (years)	10.2 ± 1.2 [9.5, 10.9]	10.5 ± 1.1 [9.9, 11.2]	9.8 ± 1.0 [9.2, 10.5]	0.329	-0.16
Height (m)	1.40 ± 9.3 [1.35, 1.45]	1.45 ± 7.2 [1.41, 1.49]	1.40 ± 6.9 [1.35, 1.45]	0.208	-0.37
Body mass (kg)	33.1 ± 5.7 [28.0, 38.2]	40.0 ± 9.7 [35.3, 44.7]	36.0 ± 8.7 [30.9, 41.1]	0.140	-0.49
Maturation offset (years)	-2.6 ± 0.8 [-3.1, -2.2]	-2.1 ± 0.7 [-2.5, -1.6]	-2.6 ± 0.7 [-3.1, -2.2]	0.116	-0.44
Years in football	5.0 ± 1.6 [4.1, 5.9]	6.2 ± 1.6 [5.4, 7.1]	5.1 ± 1.2 [4.2, 6.0]	0.079	-0.52

There were no significant differences in the left ($p = 0.268$) or right ($p = 0.656$) absolute reach distances during the Y-balance test (Table 3). There was a significant difference in relative reach distance on the left leg ($p = 0.015$). Post-hoc analysis showed significantly greater left relative reach in the highly specialised group compared to the moderately specialised group (mean diff = 10.9% LL; 95% CI [2.2, 19.6]; $p = 0.013$; ES = 0.78), but not the low specialised group (mean diff = 5.0% LL; 95% CI [-4.0, 14.1]; $p = 0.218$; ES = 0.39). There was also a significantly greater relative reach on the left leg in low, compared to moderate specialised groups (mean diff = 5.8% LL; 95% CI [0.56, 11.1]; $p = 0.032$; ES = 0.66). Right leg relative reach ($p = 0.105$), absolute ($p = 0.597$), and percentage ($p = 0.462$) asymmetry were not significantly different between groups.

Table 3: Between-group comparisons of Y-balance test and LESS total score performance (mean ± SD [95% CI]).

	Low specialised	Moderately specialised	High specialised	*p*	Hedge's *g*
Absolute reach right (cm)	53.1 ± 4.4 [49.7, 56.6]	53.4 ± 5.5 [50.2, 56.6]	55.1 ± 6.5 [51.7, 58.6]	0.656	-0.03
Absolute reach left (cm)	54.0 ± 3.9 [50.5, 57.4]	51.9 ± 5.5 [48.7, 55.1]	55.7 ± 7.6 [52.2–59.2]	0.268	0.22
Relative reach right (%LL)	73.2 ± 7.4 [67.7, 78.8]	70.5 ± 7.9 [65.4, 75.6]	78.6 ± 11.4 [73.0, 84.1]	0.105	0.18
Relative reach left (%LL)	74.5 ± 4.7 [69.2, 79.8]	69.2 ± 7.2 [63.8, 73.5]	79.6 ± 12.4 [74.3, 84.9]	0.015*	0.40
Absolute asymmetry (cm)	3.38 ± 1.8 [2.21, 4.56]	2.79 ± 2.1 [1.71, 3.87]	2.58 ± 1.9 [1.40–3.76]	0.597	0.18
Percent asymmetry (%)	6.48 ± 3.6 [4.29, 8.67]	5.24 ± 3.9 [3.22, 7.25]	4.60 ± 3.1 [2.42, 6.79]	0.462	0.21
LESS total score	7.20 ± 3.1 [5.58, 8.82]	7.75 ± 2.1 [6.27, 9.23]	5.00 ± 2.3 [3.29, 6.71]	0.051	-0.13

Note: *significant difference between the three groups ($p \leq 0.05$), %LL = percentage leg length.

There was a trend towards a significant difference in total LESS score between groups (p = 0.051) (Table 3). Post-hoc analysis showed fewer errors in the highly specialised group, compared to the moderately (mean diff = 2.75 errors; 95% CI [0.05, 5.48]; p = 0.009; ES = -0.90), but not the low specialised group (mean diff = 2.20 errors; 95% CI [-0.65, 5.05]; p = 0.101; ES = -0.57). There was no significant difference between the moderately and low specialised groups (mean diff = 0.55 errors; 95% CI [-2.11, 3.21]; p = 0.625; ES = -0.15). The highest frequency of poor LESS classification was recorded in the moderate specialisation group, and the lowest in those who were in the high specialised group. The greatest frequency of excellent and good scores were also recorded in high specialised players (Table 4), indicating this group displayed greater competence in the DJ task.

Table 4: Categorisation of LESS performance by specialisation level.

	Low specialised (n = 10)	Moderately specialised (n = 12)	High specialised (n = 9)
Excellent (0–3 errors)	1	0	2
Good (4–5 errors)	3	2	4
Moderate (6 errors)	1	0	1
Poor (≥ 7)	5	10	2

Counts of individual errors between groups did not indicate any significant differences for most criteria (Table 5). A significant difference between groups was only found for 'knee flexion displacement'. Significantly fewer high specialised players (n = 0) received an error for knee flexion displacement (indicating they exhibited a greater range of knee flexion throughout their landing), than in the moderate (n = 9) or low specialised (n = 5) groups (p = 0.003).

Table 5: Counts of errors scored in individual LESS criteria by specialisation level (n and %).

	Low specialised (n = 10)	Moderate specialised (n = 12)	High specialised (n = 9)	X^2	p
Knee flexion initial contact	2 (20%)	2 (17%)	2 (22%)	0.11	0.949
Hip flexion initial contact	0 (0%)	0 (0%)	0 (0%)	0.45	0.798
Trunk flexion initial contact	5 (50%)	5 (42%)	2 (22%)	1.61	0.447
Ankle plantar flexion initial contact	1 (10%)	0 (0%)	0 (0%)	2.17	0.338
Medial knee position initial contact	2 (20%)	1 (8%)	2 (22%)	0.90	0.639
Lateral trunk flexion initial contact	3 (30%)	5 (42%)	3 (33%)	0.35	0.840
Stance width wide	0 (0%)	0 (0%)	0 (0%)	0.45	0.798
Stance width narrow	5 (50%)	6 (50%)	4 (44%)	0.08	0.961
Foot position external rotation	3 (30%)	4 (33%)	2 (22%)	0.31	0.854
Foot position internal rotation	1 (10%)	1 (8%)	0 (0%)	0.90	0.638
Symmetric initial contact	4 (40%)	4 (33%)	1 (11%)	2.01	0.351
Knee flexion displacement	5 (50%)	9 (75%)	0 (0%)	11.82	0.003*
Hip flexion displacement	2 (20%)	2 (17%)	0 (0%)	1.93	0.381
Trunk flexion displacement	6 (60%)	7 (58%)	4 (44%)	0.56	0.756
Medial knee displacement	7 (70%)	8 (67%)	6 (67%)	0.03	0.983
Joint displacement (stiff)	4 (40%)	8 (67%)	1 (11%)	6.69	0.153
Overall impression (poor)	4 (40%)	8 (67%)	2 (22%)	4.26	0.119

Note: *significant difference ($p \leq 0.003$), X^2 = Chi-squared.

3. Discussion

The aim of this study was to investigate if differences exist in the performance of DJ and Y-balance tests in pre-pubertal football players based on their level of specialisation. Given that the most commonly reported age cut-off for 'early' specialisation is 12 years (LaPrade et al., 2016), all highly specialised players in this study would be classified as 'early specialised'. Improved jump-landing strategies were observed in those who were highly specialised, with most players graded as 'excellent' or 'good'.

Highly specialised players also displayed landing strategies associated with reduced injury risk and better Y-balance left leg normalised reach distances. Cumulatively, these findings could suggest that pre-pubertal players who are highly specialised, develop improved jump-landing mechanics and enhanced dynamic stability.

The Y-balance test is an indicator of dynamic balance and active mobility (Plisky et al., 2009; Read et al., 2020). Anterior reach asymmetries have previously been associated with an increased risk of lower limb injury (Plisky et al., 2006; Smith, et al., 2015). Relative reach distance is often used in preference to absolute distance due to variations in limb length between players. In this study, the highly specialised players demonstrated better relative reach on the left leg than the moderately specialised players. Additionally, while not statistically significant, based on the estimated difference and 95% CI (mean diff = 8.1%; 95% CI [-1.0, 17.1]), it is more likely than not that they also had better relative reach on the right leg. These results are contrary to previous evidence in older-aged, specialised youth, where no differences in reach distance based on level of specialisation were found (Miller et al., 2017). These participants were likely post-PHV, while the participants in our study were all pre-PHV, which may explain the difference in results (Read et al., 2020). Age- and maturation-related improvements in balance and postural control are expected in active youths (Nolan, et al., 2005; Read et al., 2020). In our younger (pre-PHV, early specialised) players, increased exposure to activities requiring single-leg balance (such as kicking a ball) may have led to earlier adaptation and stability in unilateral activities, and thus improved performance in those who were highly specialised, however more research is needed to confirm this. Although there were no significant differences in anterior reach asymmetry between groups, the estimated asymmetries for all groups have the potential to exceed 4cm. This is worthy of note given an asymmetry of 4cm or higher in the anterior direction has previously been associated with an increased risk of lower limb injuries in football players, and thus should be considered in designing training programmes to reduce these between-limb differences (Plisky et al., 2006; Smith, et al., 2015).

Previous research has shown an increased risk of ACL injury in youth football players displaying inferior landing mechanics characterised by a higher LESS score (Padua et al., 2015). Contrary to previous research in specialised youth athletes (Beese et al., 2015; DiStefano et al., 2018), the results of our study suggest highly specialised junior (pre-PHV) football players exhibit fewer errors when performing a drop jump landing than moderately specialised players. Additionally, our findings also suggest the highly specialised players had fewer errors than the low specialised players, but these differences were not statistically significant (mean diff = 2.20; 95% CI [-0.65, 5.05]). Previous research has shown either more errors in youth who were highly specialised (DiStefano et al., 2018), or no difference between groups of varying specialisation status (Beese et al., 2015; Peckham et al., 2018). Conflicting findings could be a result of the younger, less mature participants in our study, compared with those in many of the existing studies, who were mostly post-pubertal in their mid- to late-teens (Beese et al., 2015; Peckham et al., 2018). Differences in landing mechanics have previously been observed in athletes at different chronological ages and levels of maturation (Read, et al., 2018a; Read, et al., 2018b). Additional confounding factors could include differences in exposure to quality coaching and/or injury prevention programmes at different levels of specialisation.

Most football coaching in NZ at a junior (under 13) club level is conducted on a volunteer basis, meaning the quality of coaching is likely variable, with little or no formal coach training. In contrast, most if not all academy coaches have undergone some level of coaching qualification. Thus, typically, only when players join academies, or play at higher levels, are they exposed to coaches who may have more experience and qualifications. Thus, many of the young footballers in the current study may have spent considerable time playing football without specific coaching on movement and skill development from a qualified professional. It has previously been suggested that highly specialised players may have better access to quality coaching, potentially greater parental support, and drive to join training academies (McGowan, et al., 2020). This may explain why the highly specialised players performed better in the drop jump task. All participants in the current study were pre-PHV; however, the increased volume of structured training may have led to a synergistic adaptation in utilising the potent stimulus provided by training in players whose neural plasticity is heightened (Read et al., 2021). Muscle pre-activation and reflex control enhance with maturation, but it can also be improved through greater exposure to plyometric training (Read et al., 2021). Given the young age of this cohort, and the relatively short time the high specialised group has focused specifically on football, the benefit of higher-level coaching may emerge quickly (Lloyd et al., 2014; Myer et al., 2013) while the potential negative impacts of specialisation (e.g., repeated movement patterns leading to overuse) may take longer to emerge. It would be interesting to observe this cohort longitudinally to examine how movement competence develops throughout adolescence in a high specialisation sporting pathway.

The poor jump-landing mechanics exhibited by a high percentage of both moderately (83%) and low (50%) specialised players are of concern due to the potential for increased risk of injury. This suggests a greater focus on foundation movement patterns is warranted in this younger age group. Previous research has shown that jump-landing mechanics in pre-pubertal youth are inferior to those post-puberty, in part due to increased strength development and muscle pre-activation in post-pubertal boys (Read, et al., 2018a). Additionally, poorer landing mechanics have been observed in youths with no structured strength and plyometric-training programmes (Noyes et al., 2005). Thus, the moderate and low specialised groups may not be receiving consistent enough training stimuli. While the incidence of injury in pre-PHV cohorts is low, the greater neural plasticity should be considered, and training programmes commencing pre-puberty should be encouraged to take advantage of this with scope to optimise movement strategies later in adolescence where injury risk is higher. This also highlights the importance of the uptake of injury prevention programmes in community-level football (with limited qualified coaches), where many youth football players are getting the majority of their football exposures. Programs like the FIFA11+ have shown promising results in these environments as well as in higher-level programs (Gomes Neto et al., 2017). Injury prevention has been a focus for NZ Football over recent years (New Zealand Football, 2016), which, anecdotally, has led to increased use of FIFA11+. However, there may be a need for more education of community-level coaches to increase

adherence, which is critical to optimise effectiveness and to ensure all players are benefitting from these programmes.

When evaluating the individual criteria in the LESS (Table 5), the main group differences were observed in 'knee flexion displacement' (i.e., the change in knee flexion angle between initial contact and maximum knee flexion). This error (i.e., reduced knee flexion) was more commonly seen in the moderate (75%) and low specialised groups (50%), compared to the high specialised group (0%). There was also a trend for moderate and low specialised players to record errors in 'joint displacement (stiff)'. Stiffer landings are associated with decreased leg extensor strength, and lower muscle pre-activation prior to ground contact, resulting in reduced ability to attenuate ground reaction forces on landing (Cormie, et al., 2010; Read, et al., 2018b). It is plausible that the highly specialised players represent the better athletes who may have joined academies earlier due to their superior physical ability. Regardless, using a stiff landing strategy will result in larger ground reaction forces, and players displaying these jump strategies may be at an increased risk of injury (Pedley et al., 2020). Targeted strength and conditioning programmes focused on plyometric skills, and maturation-appropriate strength training considering the individual's training age and technical competency, could be beneficial.

The high frequency of 'poor' LESS scores in the moderately specialised group was unexpected. While it is beyond the scope of this study to provide mechanistic insights to explain this finding, it could be that the moderately specialised players were in the early stages of a specialised pathway, playing a high volume of football, all year-round, but still playing another sport. Competing in two sports can result in a high overall training load and time commitment, as well as the potential for inconsistencies in training stimuli. Players will also have decreased time available for unstructured free play, and this has previously been reported as an important contributing factor for the development of movement competence in a diverse range of skills and tasks (Barreiro & Howard, 2017; Bergeron et al., 2015).

A strength of this study is that we assessed players who were considered 'early' specialisers, involving children under the age of 12 (> 1 year pre-PHV). Most existing studies have investigated the effects of sport specialisation in participants during their mid- to late-teens, with only some including assessment or control of maturation. Including younger, pre-pubertal players allowed for the examination of potential differences that are occurring as players begin to specialise, minimising the effects of growth and maturation on movement skill. It is common in existing research to investigate sport specialisation across a range of sports (McGuine et al., 2017; Miller et al., 2017; Peckham et al., 2018); however, the effects of specialisation are likely sport-specific. It may be more relevant to investigate individual sports, which we consider an additional strength of this study. The main limitations of this study are the cross-sectional design and relatively small sample size. We observed some significant differences based on the level of specialisation, but the absence of longitudinal data means any causation cannot be established. Additionally, the lack of female participants limits the generalisability of the findings. Further limitations include the reliance on self- and parent-reported sport participation to rate levels of specialisation, potentially introducing recall bias the lack of data on potential confounding factors (training load and exposure to injury prevention programmes), and the lack of kinetic data to give mechanistic insight into LESS data. Additionally, while we have inferred some potential associations with increased injury risk based on movement strategies displayed, more research is needed to prospectively monitor sport specialisation and injuries concurrently.

The results of this study suggest early specialised youth football players may be more competent movers than their less specialised counterparts pre-puberty. Contrary to existing evidence, the boys that were highly specialised displayed superior movement patterns during a drop jump task and better relative anterior reach during the Y-balance test. However, given the number of results that showed no significant difference, it could be argued that there is no disadvantage to being involved in multiple sports at a young age. Results suggest all players may benefit from participation in injury prevention programmes such as the FIFA 11+, in particular moderately specialised players.

Conflict of Interest

The authors declare no conflict of interests.

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