Talent Development & Excellence

Official Journal of the

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               Jörg Schorer

Editors-in-Chief: Albert Ziegler
                 Jiannong Shi
This journal

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## Contents

Identification and Development of Talent in Sport – Introduction to the Special Issue  
*J. Baker and J. Schorer*  
119

A Multi-Factorial Examination of the Development of Skill Expertise in High Performance Netball  
*D. Farrow*  
123

The Development of Fast Bowling Experts in Australian Cricket  
*E. Phillips, K. Davids, I. Renshaw and M. Portus*  
137

A Look Through the Rear View Mirror: Developmental Experiences and Insights of High Performance Athletes  
*J. P. Gulbin, K. E. Oldenziel, J. R. Weissensteiner and F. Gagné*  
149

The Role of Ecological Constraints on Expertise Development  
*D. Araújo, C. Fonseca, K. Davids, J. Garganta, A. Volosovitch, R. Brandão and R. Krebs*  
165

Relative Age and Birthplace Effects in Division 1 Players – Do They Exist in a Small Country?  
*R. Lidor, J. Côté, M. Arnon, A. Zeev and S. Cohen-Maoz*  
181

Anthropometric, Physiological and Selection Characteristics in High Performance UK Junior Rugby League Players  
*K. Till, S. Cobley, J. O’Hara, C. Chapman and C. Cooke*  
193

Canadian Women’s Ice Hockey – Evidence of a Relative Age Effect  
*P. L. Weir, K. L. Smith, C. Paterson and S. Horton*  
209
Identification and Development of Talent in Sport – Introduction to the Special Issue

Joseph Baker\(^1\) and Jörg Schorer\(^2\)

Identifying and developing talented individuals is an important element of education, music, and art, but no field has embraced the concept as tenaciously as sport. Indeed, understanding the qualities that underpin elite or expert performance and facilitating their development is the cornerstone of the sport sciences. Organized programs of talent identification and development (TID) can be traced to the 1950s. The earliest successes came from countries of the Eastern Block such as the German Democratic Republic, the Soviet Union, Romania and Bulgaria with Australia, China and the United States demonstrating more recent success.

Perhaps due to this success, many countries have adopted national or sport-specific talent identification programs. In recent years, countries such as Australia, for the Sydney Olympic Games in 2000, and the United Kingdom, for the London 2012 Games, have orchestrated vast talent identification and development programs. In Australia, a deliberate programming approach was taken and resulted in an improvement in overall medals from 27 in 1992 to 41 in 1996 and 58 in 2000 (an increase of 114% in just 8 years). The notion that increased resources (financial and otherwise) will produce increased results is not particularly noteworthy; however, the more interesting question considering the enormous expense of programs such as this is ‘how do we determine success or failure’? Several reviews of talent development (e.g., Abbott, Button, Pepping, & Collins, 2005; Régnier, Salmela, & Russell, 1993) have suggested that the process of TID is fundamentally flawed, but despite this view national sport governing bodies continue to invest substantial resources to this effort.

Due to the considerable attention given to issues of TID worldwide, the intent of this special issue was to provide a reflection of the high caliber research currently being conducted with the hopes of improving the understanding of researchers, coaches, and policy makers working in this domain. Thanks to the excellent work of our colleagues, we believe we have succeeded. In addition to contributions from top research labs throughout the world (the ‘usual suspects’ in these types of special issues), we have contributions from researchers working within existing TID programs reporting their successes and failures. Collectively, this research will not only improve the dissemination of knowledge from the academic centre to the TID front lines, but it will also be important for identifying the strengths and weaknesses of current approaches.

Readers of the special issue will notice two clear trends in TID research. The first is the significant theoretical variability. The first four papers in this issue argue on the basis of models by Ericsson (Farrow), Simonton (Phillips et al.), Gagné (Gulbin et al.), and Bronfenbrenner (Araújo et al.). The next three papers (Lidor et al.; Till et al.; Weir et al.) explore what Baker and Horton (2004) termed ‘secondary influences’ on athlete development. This diversity in theoretical foundations reflects the inherent complexity of this research topic and the variety of approaches taken in TID research. This variety is also represented in the methodological approaches taken by researchers in this field. In addition to traditional expert/non-expert approaches (Farrow), this special issue includes qualitative interviews (Phillips et al.), large scale surveys (Gulbin et al.) secondary analysis of existing data (Lidor et al.; Weir et al.) and quasi-longitudinal investigations (Till et al.) in addition to the more ethnographic examination considered by Araújo et al.

Readers will also notice the obvious imbalance towards issues of talent development rather than talent identification. Four of the seven papers in this issue clearly focus on

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issues of development, ranging from the influence of different forms of training (Gulbin et al. and Phillips et al.) and the importance of perceptual cognitive skill (Farrow) to the value of unconventional practice environments (Araújo et al.). Examinations of secondary factors such as relative age and size of birthplace (Weir et al. and Lidor et al.) are relevant to both talent development and talent identification (if only to show the limitations of current approaches), but only the Till et al. study examining characteristics of athletes in the UK's rugby talent development program could be classified as an examination of talent identification. Despite the international attention given to issues of talent identification, it remains a thoroughly under-researched topic, at least as compared to talent development (or athlete development generally).

Most importantly in our view, we would like to thank the reviewers of the manuscripts considered for this special issue. Without their constructive feedback this special issue would not have been possible. They are presented in alphabetical order:

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Joseph Baker  Jörg Schorer
References


A Multi-Factorial Examination of the Development of Skill Expertise in High Performance Netball

Damian Farrow

Abstract: Expertise advantages have been demonstrated in a variety of perceptual-cognitive and perceptual-motor components of sport performance. However, comparatively little research has examined the relative contribution of such components in the prediction of talent and the subsequent implications for development. This study sought to address this issue by examining the relative contribution of pattern recall, decision-making, netball passing, and reactive agility skills to netball expertise. Four skill levels were examined; the Australian open squad, Australian 21 and under (21U), 19 and under (19U) and 17 and under (17U) squads. A combination of MANCOVA and discriminant analysis revealed that pattern recall, decision making accuracy and passing skill explained the greatest amount of between-group variability (77.6%) successfully distinguishing the open squad from the other squads and the 21U squad from the 19U and 17U squads. The findings are discussed in relation to both theoretical and practical implications for talent development and progression toward elite performance.

Keywords: expertise, skill, development, netball

Understanding the relative importance of those factors that separate the elite athlete from lesser skilled performers is a necessary precursor to the design of evidence-based talent development programs. When watching a team invasion sport, such as netball, it is clear that a premium is placed on the capacity of players to simultaneously search and process numerous information sources whilst executing the skills of the game with adaptability and precision. These demands highlight the importance of examining the perceptual-cognitive and perceptual-motor components of such sports.

Skilled performers differ from their lesser-skilled counterparts on a range of perceptual-cognitive and perceptual-motor qualities (Mann, Williams, Ward, & Janelle, 2007). Sports-specific tests of pattern recognition and recall have been consistently used to demonstrate an expert advantage (Allard, Graham, & Paarsalu, 1980; Starkes, 1987; Williams & Davids, 1995). Consistent with their cognitive psychology origins (Chase & Simon, 1973) such tasks typically demonstrate that expert’s can more accurately recall and recognize structured patterns of play from their domain than novices. This has been linked to the experts more sophisticated domain-specific knowledge structures (e.g., chunks) that are stored and retrieved efficiently from long term memory (Ericsson & Kintsch, 1995). The process of perceiving sports-specific patterns as chunks rather than individual items (i.e., as offensive or defensive patterns instead of individual players) allows an expert to process the relevant patterns at a faster rate, an advantage often demonstrated in decision making tasks (Helsen & Starkes, 1999). Despite the tasks perceptual-cognitive underpinnings, the expertise differences apparent in sport suggest potential talent identification and development benefits from such testing (e.g., Mann et al., 2007; Starkes, 1987; Ward & Williams, 2003; Williams & Davids, 1995).

However, sport talent identification and development also rightly places a premium on motor skill expertise. Demonstration of the skilled performer’s capacity to execute the...
primary skills of the sport more proficiently than lesser skilled players has proven a logical and valuable starting point for talent identification (Pienaar, Spamer, & Steyn, 1998). However, more sensitive approaches are also available that have the potential to demonstrate differences between performers who on the surface seem to be of a similar skill level. A variety of research has demonstrated the expert’s superiority when required to perform the primary skills of their sport under a dual task load (e.g., Parker, 1981; Smith & Chamberlain, 1992). Superior dual-task performance is noteworthy, as it implies that the performer has been able to automate control of the primary skill, allowing spare attentional capacity to be devoted to other aspects of the task (Abernethy, 1988; Fitts & Posner, 1967). In the case of netball, this may relate to searching the court for preferred passing opportunities, with a player’s expertise evident in better decision making choices. More recently, it has also been demonstrated that when the perceptual and motor components of a task are coupled, such as in a reactive agility test, this improves the likelihood of skill differences emerging as the task representativeness is higher (Abernethy, Thomas, & Thomas, 1993; Farrow, Young, & Bruce, 2005, Williams & Ericsson, 2005).

Despite clear expertise differences being repeatedly demonstrated in all the capacities discussed previously (Mann et al., 2007) there is relatively little research that has directly examined the value of such components in the identification, prediction and development of talent (Williams & Reilly, 2000). There are numerous reasons for the above situation. The strong influence of task-specific practice on the development of expertise (Ward, Hodges, Starkes, & Williams, 2007) renders early talent identification of skill somewhat limited as a performer’s capacities can change relatively quickly in response to practice. A second issue is the need to ensure the tests of skill employed are representative of the demands imposed on the performers in the real world setting otherwise expertise effects may be negated or reflective of non-critical processes (Abernethy et al., 1993). Third, and perhaps most critically, there is a need to adopt multi-dimensional test batteries if we are to truly capture skilled performance (Wrisberg, 1993). Despite the pioneering efforts of Starkes (1987) such designs are conspicuous by their absence (see Abernethy, Neal, & Koning, 1994; Elferink-Gemser, Visscher, Lemmink, & Mulder, 2004; Helsen & Starkes, 1999; Pienaar et al., 1998; Ward & Williams, 2003 for exceptions) yet offer an opportunity to determine the relative contribution of a range of measures purported to be important to the development of skill expertise and in turn start to guide future talent development programs.

Previous multivariate research has typically focused on the importance of general visual function relative to sport-specific perceptual-cognitive skills through the measurement of skilled and lesser skilled performer’s across various age levels (Helsen & Starkes, 1999; Ward & Williams, 2003). For example, Ward and Williams (2003) examined the perceptual-cognitive measures of pattern recall, anticipation, and situational probability usage in skilled and less skilled soccer players ranging in age from 9 to 17 years. Skill was most clearly distinguished by the related measures of anticipation and situational probability while pattern recall performance was most strongly predicted by the age of the participants. While such research provides valuable information concerning the progress of these capacities over the age and/or developmental stages examined, there remains a paucity of information concerning the development of sports-specific perceptual-cognitive and perceptual-motor skills in players at the “pointy end” of the player development pathway. It is typical to see large effect sizes when investigating experts and novices but as the difference between skill and experience is reduced, large effects are less frequent (Raab & Johnson, 2007). This is particularly pertinent to the current investigation where the focus is on determining what qualities separate players in a national representative team from those players in that team’s feeder programs. This is a crucial question for talent development, as identification of those factors that differentiate between relatively similar levels of skill expertise allows the design of a more systematic talent development pathway that can focus on the factor/s known to limit progression.
The aim of this study was to examine the development of perceptual-cognitive and perceptual-motor skill in highly-skilled netball players ranging from the 17 years and under (17U) National development squad to the open national team. Two main research objectives were addressed: (1) Determine which perceptual-cognitive and perceptual-motor skills differentiate performers of differing skill levels; and (2) determine the relative contribution of these different test components in classifying the squad membership (skill level) of the players. Based on previous perceptual-cognitive research that has predominantly focused on the demonstration of differences between experts and novices (Mann et al., 2007), it was predicted that each test would discriminate the open squad from the other squad, however the relative magnitude of these differences may not be as large as previous expert-novice investigations. Specifically, it was expected that differences were most likely to emerge in the decision making, passing skill and reactive agility tests due to their greater context specificity evoking processing challenges more akin to the actual performance setting, whereas pattern recall would present a more simplistic challenge, containing less task specificity (Mann et al., 2007). Given the relative closeness in skill level and playing experience of the 21U, 19U and 17U performers it was less clear what qualities would separate these groups.

Methods

Participants

A total of 73 skilled netball players representing one of four Netball Australia national squads were examined. In descending fashion the most skilled participants were members of the open team (N=17, age M=25.39 yrs, SD=4.52) who possessed an average of 17.50 (SD=4.00) years playing experience; 21 years and under squad (N=25, age M=19.25 yrs, SD=1.09), who possessed an average of 11.80 (SD=2.70) years playing experience; 19 years and under squad (N=15, age M=18.49 yrs, SD=0.94) who possessed an average of 10.90 (SD=1.20) years playing experience; and 17 years and under squad (N=16, age M=17.08 yrs, SD=0.51) who possessed an average of 10.10 years (SD=1.60) of playing experience. A key assumption was that the player’s squad representation was reflective of their skill level, irrespective of age. This is supported by the selection policy of the sport such that if a 17 year-old player (for example) was considered sufficiently skilled to be a member of the open team they would be selected accordingly. Informed consent was obtained for all participants in the research.

Tasks and Procedures

The testing battery consisted of two perceptual-cognitive tests; pattern recall and decision-making and two perceptual-motor tests; passing skill under single and dual-task load and reactive agility.

Pattern Recall Test. The pattern recall test comprised four practice trials and 18 video test trials of segments of typical patterns of play emanating from national netball league games. The video segments were displayed on a 100 cm plasma screen and consisted of up to approximately 10 s of game footage. The task required participants to recall the position of all players (both attack and defence), as they appeared at the time when the segment ended. Recall was demonstrated by marking individual player positions onto a scaled representation of the court. The patterns contained between 7–10 players. Scoring involved the use of overlay grids illustrating the locations of the players for each video segment. A ring around each player location showed an error zone of 1% of the total area of the playing surface. Any response identified within any part of this zone was considered correct. Responses falling outside this zone were considered incorrect. Any extra players recorded or players forgotten by the participant on the response sheet were considered as an error. At the completion of scoring a pattern, a percentage accuracy figure was generated that considered both the recall of attacking and defensive players separately.
**Decision Making Test.** After five practice trials, 15 decision making situations from national league games were presented on a computer monitor through a customised computer program called "AIS React". Participants were required to determine the best offensive disposal choice from the information available. Players did this by clicking the computer mouse on the player they would pass the ball to. Decision making accuracy was defined as the percentage of correct responses. The correct response was determined by the national head coach. Team-specific patterns/styles of play were not used to guide the response, ensuring the task was equivalent for all squads examined. Decision making speed (ms) was also calculated by recording the time from the moment the clip was occluded until when the mouse was clicked by the participant on their intended response.

**Passing Skill: Dual-Task Test.** The test procedure consisted of three phases. The primary task involved the participant interacting with a near life-size video projection of four netball players (2 team-mates/attackers and 2 opponents) to create a 3 vs. 2 competition for the ball. Consistent with many invasion team-sports, the patterns consisted of the two attackers trying to dodge and free themselves from their defender and then lead into space to receive the pass (from the participant). One of the two attackers projected on screen would always get free of their immediate opponent and lead toward the participant either to the left, centre, or right of screen and hence become the preferred passing option. The participant was required to shoulder pass as accurately as possible (instructed to “hit the hands”) to the “free” team-mate (not defended). The participant was then required to re-gather her pass as it rebounded off the screen and return to the starting position ready for the next trial. A 1.5 s inter-trial interval ensured that the test was relatively continuous. The participant was given six practice trials followed by 18 test trials. A video record of the participant completing the task permitted post-hoc analyses of decision-making accuracy and resultant passing accuracy to be completed.

The secondary task chosen was a single-choice vocal reaction time test. Before being used as the secondary task in the dual-task condition, vocal reaction time was recorded in isolation from the primary task. Ten auditory tones were emitted from a customised computer program (AIS React) at irregular foreperiods. The participant was instructed to say the word “tone” as quickly as possible, into a lapel microphone, upon hearing the tone. The microphone was connected to a customised software program that recorded reaction time (RT) in ms for each of the 10 trials so as to provide a baseline measure to be used in comparison to the dual-task performance.

The dual-task test condition involved the participant completing the same primary task, with the order of trials randomised, in addition to listening to a series of auditory tones. Participants were instructed to maintain their primary task performance but also monitor the tones and when a specified target tone was emitted (a tone of 660 Hz relative to 440 Hz) say the word “tone” as quickly as possible. The target tone was played twice before commencement of the test condition to ensure that participants were familiar with it. Tones (500 ms in length) occurred once within every two second time interval and the target tone occurred randomly (to the participant) on 10 occasions within the 100 second test with the participants RT recorded on each occasion.

Passing accuracy was measured in two dimensions. First, pass selection or whether the pass was thrown to the correct leading player (recorded as correct or incorrect). Alternately, the second measure provided a more precise indication of the accuracy of each pass. The video record of each player’s performance was replayed and an accuracy chart overlayed at the moment the ball hit the projection screen (see Figure 1). The chart rewarded three points to a pass that hit the player’s hands or was within 30 cm (equivalent to a ball and a half in width) of this target area. Balls that landed outside this central area, either too high or too wide scored 1 point. Balls that hit below knee level scored no points, as did any balls that landed outside the scoring panels. Balls that hit the boundaries of the scoring panels received the higher of the two possible scores if the ball was on the side.
of the player’s direction of travel. A ball that hit the projection screen after it had occluded was considered to have been passed too late and therefore received no points. Secondary task performance was examined by comparing the baseline RT performance of the players to the RT’s generated during the passing task.

**Reactive Agility.** Participants completed the required movement pattern (Figure 2) within two test conditions, first a reactive test condition followed by a planned test condition. Testing was completed on a regulation indoor netball court surface. Four dual beam timing gates (Swift Technologies) were placed on the court surface to allow collection of two movement time splits, a shuffle time and a sprint time, resulting from completion of a netball specific agility pattern (Figure 3).

An ‘Infocus’ projector (LP790) was used to project a 2.20m video image of a skilled netball player standing approximately 1.80 m tall completing a variety of passes directed to either the left or right and in line with a set of light gates. The footage was filmed from a defensive player’s perspective and was then edited so it consisted of the player running into the centre of the screen, receiving a pass and then executing a pass that was occluded at the point of ball release. A laptop computer containing customised software (AIS React) was connected to the projector and interfaced with the light gates to play the digital video footage and record the movement time splits of the participants. A digital video camera (25 Hz) was positioned 5m behind the participant and was able to provide a synchronised record of the participant’s change of direction movement relative to the moment of ball release (display occlusion).

Within the reactive test condition instead of moving in a pre-determined fashion typical of most agility tests, the participants were required to react to the pass produced by the player in the video display. The following instructions were read to the subject:

You will see an attacking opponent on screen who will pass the ball in the direction of either the left or right finish gates. Your task is to react to this player as you would in a game situation by moving as quickly as possible to where you think the pass is being directed in an attempt to intercept the pass. The footage will be stopped at the moment of ball release, however you are free to sprint forward whenever you think you know where the ball will be directed. The footage contains all sorts of pass types, including fakes. You will now receive four practice trials to familiarise yourself with the test requirements and ask any questions.
Figure 2. Example of the reactive agility test being performed.

Figure 3. Reactive agility test set-up.
Following the above explanation, the athlete received four practice trials and 12 interactive video test trials. Importantly, to minimise the impact of test familiarity, athletes were not able to watch each other being tested.

Four response measures were obtained from a combination of the timing gates and the video record. Shuffle time was defined as the movement time (MT) from the start of the test until the completion of the sidestepping component and the first metre of forward movement (or from the start gate to gate 2). Sprint time was defined as the time it took subjects to complete the final 4.1 m sprint (or from gate 2 to gate 3 or 4). Total time was the addition of shuffle time and sprint time and provided a measure of the complete agility performance. Decision time (DT) of the participants was recorded through the post-hoc inspection of the video-footage (50 Hz). DT was the difference in time between ball release by the passing player (on the video projection) and the first definitive foot contact of the participant that initiated her final direction of travel in an attempt to intercept the pass. This was considered to reflect the subject’s assessment of the perceptual display and time to make a decision as to which direction to respond. To generate DT, frame by frame analysis (1 frame=40 ms) of the video record determined the difference between the time of display occlusion and that of movement initiation.

The planned test condition was designed to replicate the movement requirements of the reactive condition with the key difference being that the participant knew the direction of travel before commencing the test and hence was not required to respond to a video stimulus. The same measures as used in the reactive test condition were extracted from this test with the exception of DT (for more specific details concerning this test see Farrow et al., 2005). This test has previously demonstrated good test-retest reliability with an intraclass correlation of r=.83 (see Farrow et al., 2005).

Data Analyses

Separate multiple analyses of covariance (MANCOVAs) were used for each of the four tests to evaluate the combined effects of the dependent variables on each test, with alpha set at 0.05 and relevant assumption testing completed (i.e., normality, linearity, homogeneity of variances and of regression slopes). For each MANCOVA, skill level (open, 21U, 19U, 17U) was entered as a between-subjects factor and participant age was entered as a continuous covariate to factor out the effects of participant age. Any significant main effects or interactions were followed up with a Bonferroni corrected post-hoc comparison. A standard discriminant function analysis (DFA) was then completed with all the measures entered together (reactive agility excluded due to insufficient sample size) to determine which variables were most predictive of skill level and how accurately the model predicted group membership.

Results

Pattern Recall

While the covariate age was not significant, Wilks lambda $\Lambda=.97$, $F(2, 67)=0.83, p=.34, \eta_p^2=.03$, MANCOVA demonstrated significant between group differences for pattern recall, $\Lambda=.26, F(6, 134)=3.40, p=.04, \eta_p^2=.13$. Significant between group effects were found for both pattern recall of attacking players, $F(3,68)=3.58, p=.02, \eta_p^2=.13$ and defensive players, $F(3,68)=4.39, p=.01, \eta_p^2=.16$. The open squad’s attack recall was superior to the 19U squad ($p=.01$), while their defensive recall was superior to all other squads (21U $p=.02$, 19U $p=.01$, 17U $p=.01$). There were no other skill level differences (Table 1). A separate ANOVA revealed that there was a significant difference between the types of recall, $F(1,69)=205.02, p=.01, \eta_p^2=.74$ with attacking players recalled more accurately ($M=67.45$) than defenders ($M=55.74$). The interaction between skill level and recall type was not significant, $F(3,69)=2.26, p=.09, \eta_p^2=.09$. 


Table 1. Percentage Recall (Unadjusted Means and Standard Deviation, Adjusted Means and Standard Errors) as a Function of Skill Level

<table>
<thead>
<tr>
<th>Group</th>
<th>Attack Recall (%)</th>
<th>Defence Recall (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unadjusted</td>
<td>Adjusted</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Open</td>
<td>79.57</td>
<td>6.55</td>
</tr>
<tr>
<td>U21</td>
<td>66.64</td>
<td>12.57</td>
</tr>
<tr>
<td>U19</td>
<td>59.88</td>
<td>8.85</td>
</tr>
<tr>
<td>U17</td>
<td>63.69</td>
<td>6.80</td>
</tr>
</tbody>
</table>

Table 2. Decision Making Accuracy and Speed (Means and Standard Deviations, Adjusted Means and Standard Errors) as a Function of Skill Level

<table>
<thead>
<tr>
<th>Group</th>
<th>DM Accuracy (%)</th>
<th>DM Speed (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unadjusted</td>
<td>Adjusted</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Open</td>
<td>64.71</td>
<td>10.82</td>
</tr>
<tr>
<td>U21</td>
<td>57.98</td>
<td>10.03</td>
</tr>
<tr>
<td>U19</td>
<td>46.00</td>
<td>11.83</td>
</tr>
<tr>
<td>U17</td>
<td>47.64</td>
<td>12.39</td>
</tr>
</tbody>
</table>

Decision Making

While the covariate age was not significant, $\Lambda=.97$, $F(2, 67)=0.83$, $p=.43$, $\eta_p^2=.02$, MANCOVA demonstrated significant between group differences in decision making performance, $\Lambda=.64$, $F(6, 136)=5.56$, $p=.01$, $\eta_p^2=.19$. Significant main effects were found for both decision making accuracy, $F(3,68)=7.90$, $p=.01$, $\eta_p^2=.26$ and speed, $F(3,68)=4.23$, $p=.01$, $\eta_p^2=.16$. The open squad possessed superior accuracy to the 19U ($p=.01$) and 17U squad ($p=.01$) as did the 21U squad (19U: $p=.01$, 17U: $p=.01$). In relation to decision making speed, the 21U squad responded faster than the 19U ($p=.02$) and 17U squads ($p=.02$; Table 2). Correlations were completed post-hoc to examine whether a speed-accuracy trade-off may have existed within some of the group responses (Table 2). These analyses revealed that there was a significant positive correlation between decision accuracy and speed for the 21U group ($r=.40$, $p=.04$). None of the other comparisons revealed significant correlations ($p>.20$).

Passing Skill

**Reaction Time (Table 3).** A key assumption that must be met before the impact of dual-task loading can be investigated is that baseline measures on the secondary task when completed in the absence of the primary task are equivalent between groups. ANCOVA revealed that this assumption was met as there was no significant difference between the groups on their baseline RT performance, $F(3,68)=0.57$, $p=.63$, $\eta_p^2=.02$. Age was not significant as a covariate, $F(1,68)=0.79$, $p=.37$, $\eta_p^2=.01$. However, while the main effect demonstrated that all squads reaction times slowed significantly from the single to dual-task condition, $F(1,68)=3.94$, $p=.05$, $\eta_p^2=.05$ there was no significant squad by test occasion interaction, $F(3,68)=1.52$, $p=.21$, $\eta_p^2=.06$. 
Passing Performance (Table 3). MANCOVA revealed that there were no significant between group differences in passing skill, \( \Lambda = .75, F(12, 172) = 1.64, p = .08, \eta_p^2 = .09 \), nor was the covariate of age significant, \( \Lambda = .96, F(4, 65) = 0.57, p = .68, \eta_p^2 = .03 \). The specific main effects were as follows: single task passing accuracy, \( F(3,68) = 2.32, p = .08, \eta_p^2 = .09 \), dual-task passing accuracy, \( F(3,68) = 2.22, p = .09, \eta_p^2 = .09 \), single task pass selection, \( F(3,68) = 0.87, p = .45, \eta_p^2 = .03 \) and dual-task pass selection, \( F(3,68) = 2.32, p = .08, \eta_p^2 = .09 \).

Reactive Agility (Table 4)

Analyses for this test did not include the 17U squad as there were insufficient participant numbers (\( n = 7 \)). MANCOVA demonstrated no significant between group differences for reactive agility performance, \( \Lambda = .76, F(14, 74) = 1.77, p = .69, \eta_p^2 = .13 \) nor was age significant as a covariate, \( \Lambda = .97, F(7, 37) = 0.16, p = .99, \eta_p^2 = .03 \). The specific main effects were as follows: reactive shuffle time, \( F(2,43) = 0.45, p = .64, \eta_p^2 = .02 \), reactive sprint time, \( F(2,43) = 0.57, p = .57, \eta_p^2 = .03 \), reactive total time, \( F(2,43) = 1.53, p = .23, \eta_p^2 = .03 \), planned shuffle time, \( F(2,43) = 0.66, p = .52, \eta_p^2 = .03 \), planned sprint time, \( F(2,43) = 0.17, p = .89, \eta_p^2 = .01 \), planned total time, \( F(2,43) = 0.83, p = .44, \eta_p^2 = .03 \) and decision making time, \( F(2,43) = 3.36, p = .04, \eta_p^2 = .13 \).

Table 3. Passing Skill Performance (Top Panel: Means and Standard Deviations, Bottom Panel: Adjusted Means and Standard Errors) as a Function of Skill Level

<table>
<thead>
<tr>
<th>Group</th>
<th>Pass Selection (%)</th>
<th>Pass Accuracy (%)</th>
<th>Reaction Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single (M, SD)</td>
<td>Dual (M, SD)</td>
<td>Single (M, SD)</td>
</tr>
<tr>
<td>Open</td>
<td>88.49 (.57)</td>
<td>91.32 (.51)</td>
<td>75.55 (9.09)</td>
</tr>
<tr>
<td>U21</td>
<td>88.38 (6.64)</td>
<td>85.66 (8.05)</td>
<td>67.32 (7.98)</td>
</tr>
<tr>
<td>U19</td>
<td>85.09 (6.30)</td>
<td>83.35 (5.42)</td>
<td>63.33 (10.26)</td>
</tr>
<tr>
<td>U17</td>
<td>86.02 (8.33)</td>
<td>88.51 (7.69)</td>
<td>67.06 (10.62)</td>
</tr>
<tr>
<td></td>
<td>M SE (M, SE)</td>
<td>M SE (M, SE)</td>
<td>M SE (M, SE)</td>
</tr>
<tr>
<td>Open</td>
<td>85.64 (2.49)</td>
<td>89.36 (2.53)</td>
<td>75.49 (3.45)</td>
</tr>
<tr>
<td>U21</td>
<td>88.51 (1.38)</td>
<td>86.15 (1.40)</td>
<td>67.33 (1.92)</td>
</tr>
<tr>
<td>U19</td>
<td>85.33 (1.63)</td>
<td>83.91 (1.86)</td>
<td>63.35 (2.54)</td>
</tr>
<tr>
<td>U17</td>
<td>86.50 (1.99)</td>
<td>89.61 (2.02)</td>
<td>67.09 (2.76)</td>
</tr>
</tbody>
</table>

Table 4. Reactive Agility Performance (Top Panel: Means and Standard Deviations, Bottom Panel: Adjusted Means and Standard Errors) as a Function of Skill Level

<table>
<thead>
<tr>
<th>Group</th>
<th>Reactive Test Condition</th>
<th>Planned Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shuffle Time (s) (M, SD)</td>
<td>Sprint Time (s) (M, SD)</td>
</tr>
<tr>
<td></td>
<td>M SE (M, SE)</td>
<td>M SE (M, SE)</td>
</tr>
<tr>
<td>Open</td>
<td>2.43 (.14)</td>
<td>1.12 (.14)</td>
</tr>
<tr>
<td>21U</td>
<td>2.47 (.16)</td>
<td>1.15 (.08)</td>
</tr>
<tr>
<td>19U</td>
<td>2.52 (.12)</td>
<td>1.15 (.09)</td>
</tr>
<tr>
<td></td>
<td>M SE (M, SE)</td>
<td>M SE (M, SE)</td>
</tr>
<tr>
<td>Open</td>
<td>2.45 (.05)</td>
<td>1.10 (.04)</td>
</tr>
<tr>
<td>21U</td>
<td>2.47 (.03)</td>
<td>1.16 (.02)</td>
</tr>
<tr>
<td>19U</td>
<td>2.51 (.05)</td>
<td>1.16 (.03)</td>
</tr>
</tbody>
</table>
A standard discriminant function analysis (DFA) was completed to determine how accurately the model predicted group membership from the variables examined in the tests of pattern recall, decision making and passing skill (reactive agility was excluded due to insufficient sample size). Two significant functions accounted for 90% of the between group variance. The first function, χ²(24)=85.57, p=.01 accounted for 77.6% of the variance with the standardized canonical discriminant function coefficients (β) demonstrating that the open squad participants were discriminated from all other skill groups through the following variables: pattern recall of defensive players (β=.439), pass accuracy (single task; β=.420), decision making accuracy (β=.374) and pattern recall of attacking players (β=.343). The second significant function, χ²(14)=25.52, p=.03 explained a further 12.3% of variance with the U21 participants being discriminated from U19 and U17 participants on the variables of decision making speed (β=.677) and accuracy (β=.459). The model accurately predicted 31.3 to 70.6% of the skill group membership demonstrating that in all cases the percentage of players correctly classified into their squad exceeded chance levels (see Table 5).

**Discussion**

The current study was designed to (1) determine which perceptual-cognitive and perceptual-motor skills could distinguish netballers of differing skill levels; and (2) determine the relative contribution of these different test components in classifying the squad membership (skill level) of the players. Consistent with previous research (Helsen & Starkes, 1999; Ward & Williams, 2003) performance on the pattern recall and decision making tasks, in particular, were able to demonstrate strong expertise effects. These variables and that of single task passing skill were then in turn able to account for 77.6% of between group variance, despite all players having amassed significant amounts of practice and being considered “skilled”.

Of interest was that the pattern recall task, the measure predicted to provide the smallest degree of expertise difference, in fact provided the strongest effect. The open squad was distinguished from all of the remaining squads due to their superior capacity to perceive the netball specific patterns of play as chunks rather than individual items, pointing to this as a critical element of expert performance developed through extensive task-specific practice (Williams & Davids, 1995). Currently considerable debate exists over the role of pattern recall in the prediction of skilled performance (Farrow, McCrae, Gross, & Abernethy, 2010; Williams & Davids, 1995; Williams & Ericsson, 2005). Whether such a task actually evokes the same processes that a performer relies on in the actual performance setting has been questioned (Ericsson, Patel, & Kintsch, 2000; Ericsson & Williams, 2005; Farrow et al., 2010). While not a direct examination of the above question, the current findings do support the value of pattern recall testing and suggest that the processing required to complete the task may be tapping into a key element of expertise. It is possible that the strategic nature of netball and the fact that the game requires certain playing positions to stay within specific thirds of the court increases the importance of pattern recall processes relative to some other invasion sports where pattern recall may be less important.
The current decision making results were consistent with previous research which has demonstrated that an expert decision maker’s prediction skills could be distinguished from a non-expert decision maker even though they may both be playing in the same elite competition (Berry, Abernethy, & Côté, 2004). The open squad’s accuracy was superior to the 19U and 17U squad’s but not the 21U squad. Furthermore, the 21U squad was discriminated from the 19U and 17U squads (who were only 1-2 years younger and less experienced) both in relation to decision making accuracy and speed. The relatively strong performance of the 21U squad is noteworthy. Collectively, the results suggest that decision making skill becomes a critical discriminatory factor at a relatively specific stage of netball development and is not linked to biological age (McMorris, 1999). Consistent with findings explaining anticipatory skill development for cricket batting (Weissensteiner, Abernethy, Farrow, & Müller, 2008), it is likely that the speed and complexity of the game played at the 21U level is a significant step up from the younger age groupings and these playing demands heighten the importance of being able to rapidly operationalise information search and option selection processes. Future research could consider which aspects of the decision making process (search strategy or option generation) become critical or need to be specifically fostered at this stage of development (Raab & Johnson, 2007).

Collectively, the perceptual-cognitive performance of the higher-skilled groups highlights the importance of developing training programs for sub-elite talent that promote a domain specific knowledge-base, and foster an ability to rapidly encode and interpret patterns in a game-specific manner. An interesting future direction containing both theoretical and practical significance would be to complete a pattern recall training program using instructional conditions designed to promote differing visual search strategies (Raab & Johnson, 2007). This would allow more direct comment on the relationship between pattern recall and decision making, or the encoding specificity (Tulving & Thompson, 1973) of such processes to game performance, and ultimately determine whether such training is a useful addition to existing talent development programs.

The dual task paradigm was employed to examine the level of automaticity the players had developed in their passing skill. In contrast to predictions, no significant between-group effects were found. However, single-task passing accuracy was a significant contributor to the prediction of skill level differences confirming the open squad’s general status as the most skilled group. Hence, while these results are not consistent with previous research that has demonstrated the efficacy of a dual-task paradigm to distinguish between levels of skill (Abernethy, 1988; Parker, 1981) they do highlight that single task performance was a strong contributor to the prediction of skill level (Pienaar et al., 1998). A possible explanation for this relates to the relative complexity of the current single task condition which involved both decision-making and motor execution whereas the majority of previous research has typically examined these components in isolation (e.g., Parker, 1981). As a result, such testing would not be discounted from future talent identification batteries for the sport of netball.

In contrast to expected predictions and previous research (Farrow et al., 2005), the overall results of the reactive agility task did not reveal expertise differences. A number of factors may have contributed to this result. First, Farrow et al. (2005) maximized their chance to demonstrate an expertise effect with a more traditional experimental design, comparing performances of highly-skilled netball players with unskilled players, as opposed to the current study. Second, there was evidence to suggest that the open squad possessed faster decision making times relative to the 21U squad (see Table 4) however this did not translate into faster agility performance. While the trend for higher skilled player’s to extract critical anticipatory information, most likely in the form of postural cues, earlier than lesser skilled players is well established in such time-stressed situations (e.g., Williams, 2000) there is much less evidence directly demonstrating the connection between perceptual speed and overall sport-specific movement speed as examined in
the current task. Consequently, there are a number of implications for the development of the perceptual and motor skills tapped in the reactive agility task. Consideration as to whether there is a critical age-band where this capacity is most amenable to development has yet to be thoroughly examined. Further, the link between perceptual skill advantages and resultant sport-specific movement outcomes remains under-developed, primarily due to the perceptual-cognitive experimental paradigms typically used to examine these issues and hence present fruitful areas for future research (Abernethy et al., 1993; Williams & Ericsson, 2005).

The success of the discriminant function model to accurately predict squad membership at greater than chance levels provides support for the efficacy of the test battery. That is, the tests of pattern recall, decision making, and to a lesser degree passing accuracy, are examining components of performance that can be considered critical factors for predicting relatively subtle differences in talent within the sport of netball. As can be noted in Table 5 there was some classification overlap with squad’s adjacent to one another providing shared classification. This is not surprising given the relatively close nature of the skill level, age, and years of netball experience examined, particularly in relation to the under-age squads. However, 70% of the open squad players were correctly classified, with a further 24% of the remaining players coming from the 21U squad and only one player from the 17U squad. Such a result provides further support for the predictive value of the tests conducted.

In conclusion, it can be recommended that the current test battery is a useful tool for objectively distinguishing between the perceptual-cognitive and perceptual-motor skills of a group of skilled netball players. As a result a number of future directions in this program of research are currently underway. Those components identified as possessing the greatest predictive potential are now being examined with a broader range of process-tracing measures in an effort to further understand the underlying mechanisms supporting the more skilled players’ performance. Similarly, the most successful individual’s are being more closely evaluated, for instance, the 17U player who was classified as an open squad member. In the very near future a critical mass of players will have systematically progressed through the respective playing squads providing longitudinal data that will permit further examination of the predictive value of these measures over time, a feature lacking in extant expertise research (Abernethy et al., 1993; Raab & Johnson, 2007).

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The Development of Fast Bowling Experts in Australian Cricket

Elissa Phillips\textsuperscript{1,2,3,*}, Keith Davids\textsuperscript{2}, Ian Renshaw\textsuperscript{2} and Marc Portus\textsuperscript{3}

Abstract: In this paper, we highlight key concepts from dynamical systems theory and complexity sciences to exemplify constraints on talent development in a sample of elite cricketers. Eleven international fast bowlers who cumulatively had taken more than 2,400 test wickets in over 600 international test matches were interviewed using an in-depth, open-ended, and semi-structured approach. Qualitative data were analysed to identify key components in fast bowling expertise development. Results revealed that, contrary to traditional perspectives, the athletes progressed through unique, nonlinear trajectories of development, which appears to be a commonality in the experts’ developmental pathways. During development, individual experts encountered unique constraints on the acquisition of expertise in cricket fast bowling, resulting in unique performance adaptations. Specifically, data illustrated experts’ ability to continually adapt behaviours under multifaceted ecological constraints.

Keywords: expertise, skill acquisition, dynamical systems theory, talent development

In sport, the probability of an individual achieving expert levels of performance has traditionally been regarded as dependent on innate talent or prolonged exposure to environmental stimuli promoting learning and development (Howe, Davidson, & Sloboda, 1998). Research in this area has traditionally been dominated by the nature (biological) and nurture (environmental) debate, a dialogue crossing many domains in science (for a review see Davids & Baker, 2007). More recently, these polar perspectives on sports performance have become entwined, with suggestions that genes and environments have co-varying and interacting effects (Baker & Davids, 2007). The perception that universal correlates of expert performance exist has come under increasing criticism (Durand-Bush & Salmela, 2002). Although there are some common factors that appear to underpin development of expertise, multi-disciplinary models (e.g. Simmonton, 1999) have highlighted talent development as a nonlinear process and predict that a range of developmental trajectories over different timescales can lead to achievement of sporting expertise. These models have criticised traditional talent identification programmes for overemphasising early identification and for not considering variations in maturation rates of developing performers (Abbott, Button, Pepping, & Collins, 2005).

To exemplify, a multi-disciplinary, emergenic and epigenetic model of talent development was proposed by Simonton (1999). He suggested that talent emerges from multiplicative and dynamic processes and is likely to operate as an intricate system beyond the scope of the polarised nature–nurture debate. His mathematical equations formally operationalised how potential components might contribute to talent development. Recently, such formalisms were conceptualised within the sports expertise domain from a dynamical systems theoretical perspective (Phillips, Davids, Renshaw, & Portus, 2010), capturing expertise acquisition as a noisy and nonlinear process. This theoretical model proposed expert skill acquisition as emerging from an interaction between constraints related to the

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specific individual, task and environment. Individual performer constraints included personal factors such as psychological, physiological and anthropometric characteristics. Task constraints were considered specific to the sports discipline for each developing athlete and environmental constraints included socio-cultural factors, such as family support, access to facilities and cultural trends in sport participation. It was argued that the range of interacting constraints impinging on each athlete is unique and shapes the acquisition of expertise in sport, resulting in the expectation of varying developmental pathways between individuals. Several key features of the model require empirical investigation including constraints on rates of expertise acquisition and the notion of individual development trajectories in expert athletes. In this paper we examine development trajectories of elite fast bowlers in cricket to consider the model’s efficacy. It was expected that performance solutions emerging from developing expert fast bowlers are shaped by the confluence of interacting personal, task and environmental constraints. The ability of the developing athlete to adapt to constraints, and produce functional performance solutions will affect their rate of learning and development.

Complex dynamical systems are highly integrated and can be exemplified by an individual athlete as well as the athlete-environment relationship. These systems can transit between different organisational states (the dynamics), as internal and external constraints, operating at different time scales and described by the same physical principles, change (acting as information for the system). This process of development and change can be observed to occur within systems at different levels (e.g., in an expert individual when 'rate limiters', such as cognitive and physical sub-systems, become mutually entrained to drive the system to new states of organisation, i.e. expertise). It can also occur between systems and the environment (e.g., distinct constraints leading to the emergence of different behaviours in individual experts as they co-adapt to each other's performance innovations; Phillips et al., 2010). Through a process of entrainment, like co-adapting biological organisms seeking to optimize their relative ‘fitness’ on an evolutionary landscape, rate-limiting sub-systems of performers can become dependent on what is occurring in other key sub-systems. A phase transition in expertise levels of athletes might, therefore, be facilitated by a change in the relationship between an athlete's sub-systems or with other performers. This change may emerge as a result of development, experience and physical or mental practice/training, which might push the whole system to a state of non-equilibrium. In nonlinear dynamics, if a system is driven to the edge of its current basin of attraction, the probability of a new state of organization emerging (e.g. a new level of expertise) increases, due to a breaking of symmetry in initial system structure. This occurrence exemplifies the process of 'self-construction' that Kauffmann (1993) defined in systems that evolve over time. Phillips et al. (2010) highlighted how expert skill acquisition can be promoted by exploiting dynamical tendencies within athletic systems and between athletes, by creating diverse learning environments, encouraging late specialisation into sport (e.g. from approximately 13-15 years of age; Côté, Baker, & Abernethy, 2007) and facilitating discovery learning processes.

A significant first step in investigating the nature of interacting constraints that have shaped performance development in individuals is to study the experiential knowledge of current experts in a selected sport and assess how the data fit the model of interacting constraints on performance development. This approach requires a case study methodology which enables a deep analysis of individual performers' developmental histories. Some previous research has attempted qualitative analyses of elite athletes to identify physical, psychological, environmental, and social factors that constitute elite performance (Weissensteiner, Abernethy, & Farrow, 2009). Favourable factors included: extensive mental preparation, focus and commitment, clear goal setting, support from family or friends and opportunities to participate in residency programmes. An important observation was related to similarities and differences in the athletes' perceptions. Without providing a detailed theoretical interpretation of these factors, Weissensteiner
and colleagues (2009) proposed the existence of different pathways and strategies as they developed towards expertise (Durand-Bush & Salmela, 2002).

The current paper raises questions on the dynamics of expertise acquisition and the developmental trajectories of expert athletes. The purpose of this study was to investigate the utility of a multi-dimensional model of expertise development using the sport of cricket as the task vehicle. The developmental pathways or trajectories of elite cricketers, specifically nationally selected and established fast bowlers in Australia, were explored to identify the major constraints perceived by them to be important in the development and maintenance of expert performance. To achieve our aim of studying developmental trajectories of expert fast bowlers, it was decided to focus on experiences of the most accomplished experts. Such an approach needed to include analysis of their achievements at the highest level of performance and to explore the potential basis of performance longevity. Open-ended interviews have been previously used to examine competencies among elite performers to derive factors associated with the development and maintenance of success in a skill (Durand-Bush & Salmela, 2002). Allied to this method of obtaining information, grounded theory allows exploration of concepts as they emerge, and inductive hypothesizing of theory relating to the development of expertise (Glaser & Strauss, 1967).

Method

Participants

Eleven past or present Australian international elite fast bowlers who had taken more than 2,400 international test wickets in over 600 international test matches were interviewed. Elite fast bowlers were selected for analysis because there has been very little previous work on the acquisition of expertise and performance development in that sport domain. Most previous work on cricket fast bowlers has tended to focus on injuries and their prevention (Bartlett, Stockill, Elliott, & Burnett, 1996). Participant demographics are shown in Table 1. Specifically, the fast bowlers satisfied the predetermined criteria of: (a) capability of producing an average bowling speed of greater than 130 km/hr or classification as fast or fast-medium bowlers by members of the Cricket Australia Technical Fast Bowling Group; (b) having taken at least 75 international test wickets; and (c) having bowled in at least 20 international test matches.

Data Collection and Analysis

Participants were contacted through a letter of invitation in cooperation with Cricket Australia. They were informed of the purpose and potential benefits of the study, and given details of their expected involvement and interview content. All semi-structured qualitative interviews were conducted by the primary researcher, with ten occurring face-to-face and one by telephone. All interviews were recorded on an mp3 storage device and lasted between 40–70 minutes. Pilot work consisted of interviews with two elite fast bowlers outside the precise inclusion criteria for the main study. This work was conducted to review and refine interview content, semantics and order of questions for the interview guide, which was adapted to the cricket fast bowling context from previous expertise and talent development research in sport (Côté, Ericsson, & Law, 2005; Weissensteiner et al., 2009).

Table 1. Participants Age and Performance Statistics

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Test wickets</th>
<th>Test matches</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>44.0</td>
<td>10.6</td>
<td>222.4</td>
</tr>
</tbody>
</table>
At the onset of interviewing, participants were reminded of the purpose of the inquiry and signed a consent form. Specific topics of investigation included: (a) identification of significant others contributing to experts’ development; (b) engagement in physical activities, cricket related and otherwise; and (c) identification of potential ‘rate-limiters’, defined as specific factors which might hinder the overall development of fast bowling skills. After rapport building conversations and broad questions to familiarise them with the inquiry theme, participants were asked about their developmental experiences and factors believed to hinder or contribute to their own fast bowling development. Self-reported data were collected in an open-ended way without prescribing categories for describing how participants might have become expert. Probe questions were used to encourage participants to expand on responses and provide depth to articulated perceptions.

All interviews were transcribed verbatim with grammatical changes to improve the flow of the text if needed. A copy of the interview transcripts was emailed to each participant to authenticate that the information accurately reflected their perceptions (Miles & Huberman, 1994). They were asked to provide their written comments directly on the transcripts. Only a few minor changes were made to the transcripts.

Data were analysed by the main researcher in NVivo software (QRS NVivo 8) using inductive reasoning. Open coding of each participant's transcript allowed concepts and themes to emerge from the data (Côté, Salmela, Baria, & Russell, 1993). Ideas or concepts were coded and used to conceptualize categories and/or sub-categories. Once a new theme or concept had emerged from a transcript, the remaining transcripts were deductively analysed for the same theme. Themes expressed by two or more participants were considered significant. This process was flexible so that categories could be adjusted and refined during analysis, until theoretical saturation occurred and the themes conceptualized all of the data (Strauss & Corbin, 1998).

In line with Miles and Huberman (1994) procedures used to maximize reliability and control research bias included: (a) engaging in peer concept mapping sessions with co-authors; (b) verification of data by participants, who were emailed interview transcripts and asked if they were in agreement with the content and to make amendments if needed. Triangulation of data was implemented with the use of public document analysis (e.g., scrutiny of authorised autobiographies) and the perception of participant coaches where possible (Miles & Huberman, 1994). Only minor changes to the transcripts of two participants were made.

Results

Data revealed that a significant commonality expressed in the perceptions of the group of experts were nonlinearities in development trajectories and their unique adaptations to constraints during expertise acquisition. The existence of numerous different trajectories to expertise was highlighted. Experts came from a range of social backgrounds and expertise evolved under unique, interacting task, individual and environmental constraints. Here we discuss a number of specific emergent themes and provide participant observations and comments as exemplar evidence:

Significant Others Contributing to Experts’ Development

Support Networks. From adolescence onwards, support networks, including family members, coaches, and team mates, were perceived as important. Parents and siblings were supportive in many different ways. Some parents preferred to play a less dominant role, adopting more of a facilitating role such as with transport assistance, while others were regular practice partners:

Oh look, certainly my dad. He was the one that would always take me up to the nets. He'd bowl to me for hours on end and then I'd bowl to him for hours on end. He said he noticed a big difference as I was getting older he was finding it harder and harder to face me because I was getting quicker and quicker and it got to the point where he couldn't face me anymore. So that was a good gauge for me.
Seven experts had parents who were actively involved in sports themselves. There was also a range of family interest in cricket, with some individuals coming from strong sporting families, with parents actively competing themselves:

We moved around a bit because dad was a school teacher and his philosophy in life was if you got into a new town and you got hooked up with a sporting club it was just easier to meet people. So we were always pretty sports orientated, football and cricket became part of the way of life.

Some experts came from backgrounds where family members had little or no knowledge of cricket, but sought involvement with their children in a common activity, while other experts formed relationships with teachers at school providing coaching and support throughout early development:

I never really realised how important sport was as far as a support structure to me, considering that my mother brought us up on her own. And it really taught me the lessons in discipline and values, in teamwork and all these things that I think it helped me out.

Senior Teammates and Competition. All participants stressed the importance of opportunities to play with older cricket players, and the challenge of this environment. They felt the club structures protected them when required but also gave them the opportunity to play a more challenging level of cricket both in big cities and smaller locations. Many declared there was no specific fast bowling coaching available, so often senior team mates filled this gap, acting as coach-mentors:

Playing senior cricket and being around blokes that knew [about fast bowling] certainly enhanced it... I think that the higher level you play at an earlier age the more chance you've got to improve. Whereas if you stay in under fourteen's till you're old then the under sixteen's till you're too old and then just start playing senior cricket, the guys that do that, their development just seems just a little bit slower.

National Idols. Nine fast bowlers spoke of the role of idols in attracting them to cricket and providing motivation. The importance of cricket as an Australian way of life meant there were strong TV role models, with high participation rates seen as normal.

You know the Australia cricketers mean so much. Dennis Lillee was my favourite player by a mile. So I think he had a huge impact on me, he was a great bowler, great charisma, it was when it started to get marketing.

Engagement in Physical Activities

The Role of Unstructured Practice Activity in Available Spaces in Cricket. All experts mentioned the importance of “backyard” cricket in their development (for additional insights in cricket see Cannane, 2009). This activity was often undertaken with siblings and friends, in an unstructured environment allowing skill development in all aspects of the game, and with a strong focus on enjoyment, participation and competition:

The primary school was about four doors down [from the family home]; all the kids in the neighbourhood would just play cricket at every opportunity. So I think that unstructured play is very important as well.

Multiple Sports Involvement. Ten of the eleven experts called themselves ‘sporting kids’, two focused on one winter and one summer sport only, while the remainder tried every sport they were allowed to. Several participants reached state representative level in more than one sport, including basketball, athletics, tennis, Australian rules football and rugby:

I played a fair bit of representative tennis throughout [my state], travelling around, it was always something I enjoyed. I played a little bit of golf, well quite a bit of golf when I was younger... When cricket took off, I was also playing a lot of representative basketball and travelling around. I guess I was always pretty competitive by nature and played different types of representative sports.

Late Specialisation. Some experts were not involved in structured cricket until their teens, typically viewing this experience as beneficial to their development. Eight out of
eleven experts did not specialise as fast bowlers until later in development and considered themselves all-rounders (batters and bowlers), while others always classified themselves as fast bowlers and felt the desire to bowl fast:

I can honestly say I didn’t come into cricket as a kid saying ‘I want to be a fast bowler,’ it just sort of happened because you know I had talent both bat and ball but I didn’t really sort of start to bowl fast so to speak until I sort of got to about 16, 17 when I really sort of shot up, grew about four or five inches, very quickly filled out a bit and all of a sudden bowled a yard or two quicker than I did the year before.

Yeah, I was always a fast bowler. I used to bat a little higher up in the country, you know. But, yeah, I loved bowling, being a fast bowler, and that was what I always was.

**Rate Limiters and Catalysts for Variable Trajectories in Fast Bowling Skill Development**

**Locality of Development.** In line with previous research (Côté, MacDonald, Baker, & Abernethy, 2006), birthplace effect data revealed experts from small cities and rural settings were over-represented in the group (shown in Table 2). This is of significant interest in our group, as most of the population, sporting opportunities and resources are concentrated in a few urban centres in Australia. Five of the participants grew up in rural towns or small cities, providing support for the view that smaller conurbations may provide better opportunities for talent development in sport than larger cities. Fast bowling experts felt the smaller communities provided them with more space for physical activities.

<table>
<thead>
<tr>
<th>Number</th>
<th>Town/City population</th>
</tr>
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<tbody>
<tr>
<td>3</td>
<td>&lt; 50,000</td>
</tr>
<tr>
<td>2</td>
<td>&lt; 300,000</td>
</tr>
<tr>
<td>6</td>
<td>&gt; 1,000,000</td>
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However, experts who grew up in the city also had access to open spaces to develop their skills, including local parks, school grounds, and backyard facilities:

Oh look, I think I did what every other kid did, play you know like backyard, front yard, bowling at the garbage bin. I remember setting up under our house where I grew up drawing some stumps on the brick wall paint and just bowling for hours and hours at it. I didn’t know any different.

Sibling competition was noted as important in some, but not all cases. Often community neighbours or friends were often involved in backyard cricket and numerous hours of play:

He’s [brother] only 18 months older than me, so we played lots of sports together. Competing in the backyard, he was always better than me, he was always faster. I think I may have got a competitive outlook on life from trying to beat my older brother all the time.

We would go down the park, we took things pretty seriously in the park. We would always pick up teams and play test matches and things like that so that would be after school, or on the weekends whenever we could.

**Seeking Out New Challenges: The Evolving Athlete.** Experts actively sought out challenges to optimise their development. This tendency to seek new challenges formed the basis of adaptivity and longevity, requisite for maintaining expertise in later life. Experts sought new challenges in a variety of ways, the more obvious being movement between clubs and cities. While smaller cities may have less structured and more spacious, safe sports environments which may facilitate development in junior sport, all athletes from smaller cities either commuted or eventually moved to larger cities to increase the competition and chance of future success. For two participants this move occurred during high school years and they remained in the city once they had finished high school and had left home.
I knew that to further my cricket I couldn't stay down [there] and that's no disrespect to the level I was playing or the team I was playing for. I knew that if I wanted to get better I had to go down and play in Sydney.

Some athletes moved states to attend University or to further their career at this stage. It was felt that some states had too many bowlers, or bowlers were labelled as not being able to get any further or make state representative squads, thus experts moved locations to make opportunities for selection:

I was twenty-four and I'd developed a reputation in district cricket here but I didn't seem to be able to get to the next level... I just seemed to be a district cricketer and people just thought 'oh he can bowl fast but they're not going to play him.' So I went across there and that's where I got the opportunity. I think you find a lot of people change states.

Coaching and Individual Learning. Through self report, participants alluded to personal characteristics that helped to shape their performance during early development. Being independent and always being open to new ideas and striving to learn and improve were seen as critical throughout the fast bowling development pathway. Being from a country background was believed to lead to greater hardness and toughness by a number of the participants:

I think growing up in the bush makes you a little bit tougher too. Working on the land, driving the tractor and putting crops in when I was 9 and 10 years of age, and I think the other thing [was that] I didn't mind being by myself, I was happy with who I was. I think the most important thing was I was just enjoying it; going out and having fun and just being relaxed. I think, maybe playing in the bush and travelling so far [to play cricket] you have got to be prepared to sacrifice a few things.

While fast bowlers mentioned a lack of coaches during this phase, they also spoke of learning based on experiences and self discovery:

I always found that I learnt best by doing something and learning, having the kinaesthetic process of doing something for me to learn. Yeah, to feel it so that if it was a mistake then I'd change it and I always felt that whether it's swinging the ball or correcting technique, relying on instinct to do that. And I think that suited me and helped me a lot through that process, there wasn't anyone directing saying 'you've got to do this, this is the way to bowl and this is the way you fix that and do that.

Often individual constraints such as height, percentage of fast twitch fibres, style of bowling and specific experiences resulted in the emergence of different types of pace bowler style. Experts expressed the importance of building technique on their own unique intrinsic dynamics (i.e. a system’s unique dispositions for behaviour shaped by interactions of genes, development, and learning experiences). For many of the experts, the lack of formal coaching at youth level helped this exploratory process as it enabled coordination to emerge through discovery learning without over-prescriptive coaching.

The thing the bowlers [have] got to realise is that no one's got the same bowling action, everyone is unique and that's the greatest thing about sport. So to me, what a coach should be doing is actually encouraging them to be themselves; bowl the way they should ... Don't try and bowl like [several Australian Fast Bowlers], bowl the way that you've been brought on earth to bowl. You know, bowl your normal action but do everything you possibly can to make sure that's taking as much stress of your back as you possibly can.

At older ages when players were at a more advanced stages of learning, refinements in techniques could be made by more expert coaches at the cricket academy level. A number of participants expressed the importance of the Cricket Australia Academy. The importance of this development programme was captured by access to mentors, learning about what it meant to be a professional cricketer, training ethics, understanding techniques, game tactics, and discovery learning. Retrospectively experts highlighted the importance of 'knowing your body' and how to balance workload issues, particularly during adolescence:

Before going to the cricket academy, training was basically non-existent. I would just turn up and roll my arm over in the nets or have a hit; no real clear plan; it was just something you had to do to play on the weekend. I guess going to the cricket academy really showed me what I had to be prepared to do, training-wise. You know: have plans and goals and set things like that, whereas beforehand there was not too much thought to it.

Additionally, experts highlighted that one important role of the academies was to provide access to their idols, iconic ex-professional players and coaches who could pass on experiential knowledge to developing players.
Psychological Attributes and Dealing with Injury. Psychological attributes were highlighted: Intrinsic motivators, strong work ethic, sacrifice, resilience, self-confidence, passion as well as athletic skill, development of pre-ball and pre-game routines, game tactics, dealing with pain and pressure.

To be successful, I think at a higher level it's all about attitude, and the guys that are prepared to work harder, prepared to listen, always looking to learn, I think, will always have more potential.

I loved it [pressure]. I always felt my strength in the game was the mental side of the game. I felt I was mentally strong, I was happy with who I was and could handle things pretty well. When I played my first game for New South Wales I was just loving it, I wasn’t nervous, I didn’t put any pressure on myself, I just went out there and enjoyed it as much as I could.

Injuries were a prominent hurdle for aspiring bowlers to overcome and often contributed to the reasons why some athletes took time out from bowling. Several spoke about the determination it took to come back from injuries:

The doctor told me when I was 18, you know you have got a complete fracture through your lower back. You know you won't be able to bowl fast again, you will be actually lucky to run properly without pain, you might want to work on your batting or you might want to choose another sport. And I was like, this is what I was thinking to myself, I don’t buy that. ... So I said to the doctor, look I will be going away and doing everything that you ask me but I will see you when I’m playing my first test match for Australia, and left it like that.

Discussion

The developmental trajectories of expertise acquisition can be conceptualised in a framework including dynamical systems theory and the complexity sciences as we highlight below. In this study, it was evident from the data that the unique constraints impinging on numerous levels of the system can be looked at on many levels, (including differences in familiar support, birthplace locality, specialisation late in sport, formal development programme support, different rates of maturation), resulting in varying non linear pathways to fast bowling excellence. Data identified a key role for unstructured practice activities in optimal learning. Experts surrounded themselves with strong support networks advantageous to cognitive, physical and emotional development, and importance of key cultural constraints was exemplified. The level and type of support required changes at different timescales and is unique to each individual. Developing experts resembled complex evolving systems, by harnessing nonlinear transitions in performance, through seeking out new challenges, exposure to optimal learning designs, self discovery and rich support networks in the acquisition of expertise.

Structurally different components can be coordinated together to achieve the same goal (see Liu et al., 2006 for a detailed explanation on degeneracy). This concept underpins the adaptability and nonlinear trajectories of expertise acquisition. Sub-system interactions continually shape each individual athlete's intrinsic dynamics or dispositions for behaviour. Because of variations in each athlete’s intrinsic dynamics, individual rates of skill acquisition are likely to progress at different time scales (Liu, Mayer-Kress, & Newell, 2006). In the data, this effect was observed in different stages of specialisation and involvement in numerous sports until late in adolescence (e.g., Vayeens et al., 2009). The different rates of learning were influenced by key constraints which acted as ‘rate limiters’, causing systems to find new functional performance solutions (Handford, Davids, Bennett, & Button, 1997). Rate limiters can be defined as system controllers, i.e. components or sub-systems which limit the development of an individual (Thelen & Smith, 1994). For example, in cricket, going through a growth spurt may act as a rate limiter both psychologically and physically, which inhibits athletes from demonstrating the skills that they had already acquired through practice and experience. Performance decrements may in turn affect motivation and performance opportunities (associated with non selection). An important challenge is to create talent development programmes which consider the effects of different rates of learning and growth and maturation, and identify
the rate-limiting constraints which are influencing each specific expert system in order to manipulate them and facilitate transitions to a new performance level (Cobley, Baker, Wattie, & McKenna, 2009).

Results provided strong support for previous research highlighting the importance of unstructured practice activities, such as ‘backyard’ cricket (Weissensteiner et al., 2009; Cannane, 2009). Backyard cricket was encouraged by cultural constraints, providing experts’ with the capacity to adapt movements to emerging task and individual constraints. This unstructured play was also important for promoting enjoyment, participation and competition at various stages of development. These early experiences shaped the intrinsic dynamics and movement patterns of developing experts, as they naturally discovered creative movement solutions in unstructured play.

Abundant beneficial cultural constraints were identified by experts, such as the ease of access to playing fields and the accommodating climate in Australia which encourage skill development. The importance of Cricket in most Australian families meant that numerous hours of play and practice were effortlessly accrued, particularly during adolescence. The sheer number of children participating in sport, the excellent television coverage, and support networks within local sports and school communities, all aided development of sporting and cricket skills on many levels.

While deliberate play (in the form of less structured practice activities) was found to be important, early deliberate practice in fast bowling skill specifically did not receive the same support in the sample. The majority of experts did not specialise in fast bowling until their late teen years. However, all experts spoke of the abundance of opportunities for general cricket participation (structured and unstructured play) that they enjoyed throughout adolescence. Several experts were not even involved in structured cricket until late in their teens. Because of the high injury rates associated with workload issues endured by fast bowlers during maturation, some reported that this late exposure to structured cricket may have been beneficial for them. This perception directly contrasts with the notion of the need for high levels of early deliberate practice, considered important in other sport performance domains (Coté et al., 2007).

The existence of strong support networks was evident in all experts, although the sources of support varied, as did the level of dependency of the expert. Sources varied but included siblings, parents, extended family, neighbours, community, teachers, coaches, team mates, best friends and senior players. Dynamics of the support system was unique to each individual. Some parents, particularly fathers, were very ‘hands on’ in their support of cricket development, even those without coaching or cricket experience. Others had little or no involvement and in these cases, experts formed relationships with teachers at school, peers or senior club players providing coaching and support at various stages of their development.

All participants stressed the importance of opportunities to play with older cricket players, and the challenge of this environment. The practice and performance environments made sure players were continually challenged and always on the edge of stability, forcing them to constantly adapt their behaviours and increase their level of performance. They also felt the club structures protected them when required but also gave them the opportunity to play a more challenging level of cricket, both in big cities and smaller locations. Many affirmed there was no specific fast bowling coaching available, so often senior team mates filled this gap. These ideas bring into question the relevance of birth date effects by arguing that these constraints on expertise could be manipulated, depending on the dynamics of development environment, where backyard, and structured cricket environment are not necessarily age-specific. Qualitative data suggested that introducing younger players to play with older, more experienced players may create a controlled, supportive, mentored learning programme.

In the sample, all athletes from smaller cities either commuted or eventually moved to larger cities to increase the competition and chance of future success. This aspect of the
data raises questions on the putative ‘place of birth’ effect in the literature (e.g., Côté et al., 2006), suggesting that ‘place of development’ may provide a more powerful constraint on expertise development (Schorer, Baker, Lotz, & Büsch, 2010). Schorer and colleagues (2010) focused on population size of early developmental environments and found some support for disadvantages for populations that are too large or small. However, a more detailed analysis of what place of development actually entails, which has more to do with a range of tangible factors such as athletic infrastructure, opportunities for personal and athletic development (e.g., resourcefulness and resilience), competition opportunities, access to facilities, coaching and community support networks may be more valuable. Experts in this study were born in many different localities, but they all sought to optimise learning by partaking in high levels of competitive cricket, often associated with playing with seniors in larger conurbations. Several experts felt the benefits of smaller cities included earlier access to adult competition, and all saw the potential benefit of moving to larger cities to increase competition in their post-school years. For two participants this move occurred during high school years and they remained in the city once they had finished high school and had left home. These movements suggested the need to examine ‘place of development’ effects in conjunction with birth place, as this interaction may provide greater insights on the constraints of performance development.

Support for the experts’ drive to optimise learning was evident in the search for advantages even outside training or games. Many players became students of the game, who sought knowledge through various sources including: biographies, watching television, reading books, listening to coaches and/or idols. This information provided the basis of their profound domain-specific, adaptive ‘game’ intelligence. Additionally, the prominence of certain psychological characteristics including commitment, self-confidence, work ethic, resilience, determination and sacrifice supports previous research (Holt & Dunn, 2004; Weissensteiner et al., 2009).

Conclusion
In this paper, we have observed strong support for previous theoretical models (Abbott et al., 2005; Phillips et al., 2010; Simonton, 1999) proposing that expertise acquisition can be construed as a messy, noisy and nonlinear process. It was evident that the unique interacting constraints impinging on numerous levels of complex, athletic systems resulted in varying nonlinear trajectories to fast bowling expertise. The key role of unstructured practice activities, optimising learning processes, strong support networks, and effects of cultural constraints were highlighted in fast bowling development. The difference between ‘place of birth’ effects and ‘place of development’ effects were discussed, suggesting the need for a more complex analysis of developmental histories. Additionally, birth date effects may have been mediated by opportunities for younger players to play with older, more experienced players (in a supportive environment). This experience creates a controlled, supportive, mentored learning programme, dissimilar to a ‘survival of the fittest’ situation as might currently be perceived to exist in youth sport, which may facilitate talent de-selection rather than development (Abbott et al., 2005). Further work is needed to elucidate the rich interacting personal, task and environmental constraints that shape expertise acquisition in a range of different sports.

References


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A Look Through the Rear View Mirror: Developmental Experiences and Insights of High Performance Athletes

Jason P. Gulbin\textsuperscript{1*}, Karen E. Oldenziel\textsuperscript{1}, Juanita R. Weissensteiner\textsuperscript{1} and Françoys Gagné\textsuperscript{2}

Abstract: This paper chronicles the key developmental experiences and insights of 673 high performance Australian athletes (including 51 Olympians), across 34 sports. A customised survey was developed around Gagné’s (2009) holistic model of talent development which enabled athletes to report in a contextually relevant way. Key thematic variables demonstrated that high performance athletes are characterised by diverse and high level sports participation prior to specialisation, a vast investment and commitment to practice, access to high quality coaching, substantial parental support, an early and enduring passion for sport, and resilience to overcome and bounce back from any obstacles. These factors are contrasted at each of the junior and senior competition development milestones, with theoretical and practical implications specific to athlete and national talent identification system development discussed.

Keywords: talent, identification, pathway, expertise, coaching, Olympian, elite

An important step in improving the outcomes and cost efficiency of elite athlete development is to have a comprehensive understanding of the factors which contribute to the evolution of talent. It is well documented that a number of individual elements can affect an athlete’s progression and transition along the performance continuum. For example, developing from a novice to an elite athlete is heavily influenced by elements such as natural ability (Bray et al., 2009; van Rossum & Gagné, 1994; Gagné, 2009), social environment (i.e., parents, siblings, peers etc.; Bloom, 1985; Côté, 1999; Côté, MacDonald, Baker, & Abernethy, 2006), developmental sporting experiences (i.e., investment in play and practice; Côté, Baker & Abernethy, 2003; Côté & Hay, 2002; Ericsson, Krampe, & Tesch-Römer, 1993; Schorer, Cobley, Büsch, Bräutigam, & Baker, 2009), chance factors (Gagné, 2003, 2009), coaching support and resource provision (Baker & Horton, 2004; Côté, Salmela, Trudel, Baria, & Russell, 1995; Gilbert, Côté, & Mallett, 2006; Hollings, 2002), sport commitment (Scanlan, Carpenter, Schmidt, Simons, & Keeler, 1993), motivation (Ryan & Deci, 2000), and mental toughness (Jones, Hanton, & Connaughton, 2002).

However, in addition to these individual elements which contribute to development, it is equally important to understand how the broader environment can also modulate development. For example, talent development is affected by the phenomenon of deliberate programming which entails significant strategic planning and implementation of high performance sporting programs (Bullock et al., 2009). Similarly, understanding and quantifying the contextual environments through which the individual can express their potential can also lead to more optimal developmental opportunities and progressions (de Bosscher, de Knop, van Bottenburg, & Shibli, 2006; Henriksen, Stambulova, & Roessler, 2010).

Models of talent development which are holistic and are inclusive of both nature and

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nurture are not bountiful in the literature. Prevailing sport talent models such as Ericsson and colleagues' (1993) theory of deliberate practice and Côté's (1999) developmental model of sport participation have really been "sub-set" models of talent development that have been established from small samples sizes and anchored in age related individual behaviours which are not necessarily generalisable to broader, 'real-life' holistic sport environments. For example, Gulbin (2008) has demonstrated that contemporary applied talent identification techniques are not always reflected within current talent identification and development models, while other field practitioners also note the disconnect between theory and practice (Vaeyens, Güllich, Warr, & Philippaerts, 2009).

In contrast, Gagné's (2009) updated Differentiated Model of Giftedness and Talent (DMGT) presented in Figure 1, provides a constructive, multi-dimensional and dynamic theoretical framework of talent development. The central premise of the DMGT proposes that 'gifts' or natural abilities (intellectual, creative, social, perceptual, and physical aptitudes) are developed into talents or 'systematically developed competencies' (knowledge and skills) via long-term informal and formal learning and practice activities, catalysed through intrapersonal (physical and psychological factors), environmental (milieu, significant persons, provisions and influential events) and chance factors (refer to Figure 1). Vaeyens, Lenoir, Williams and Philippaerts (2008) stated in their review of the model, that the DMGT, “recognises the potential respective influences of nature and nurture and takes into account the dynamic and multidimensional features of sport talent” (p. 707). Fittingly, Gagné's model provides a logical and sensible framework to investigate the holistic elements of talent development, with the additional attractiveness of a simplified number of catalysts driving the model.

Therefore, a large pool of high performance athletes with established sports talent competencies were asked to look back at their experiences of their athletic development and to provide additional insights which could help refine talent development pathways for the next generation of athletes. The aim was to capture and chronicle a more plausible and generalisable account of talent development by applying Gagné’s framework to the development, validation and administration of a customised National Athlete Development Survey (NADS).

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**Figure 1. Gagné's Differentiated Model of Giftedness and Talent (2009).**
Method

Instrument – The National Athlete Development Survey

The NADS was designed to retrospectively document the talent development experiences of each athlete prior to, and throughout their involvement in competition. The survey was divided into five distinct sections with questions reflecting the elements of Gagné’s model. The sections were; ‘summarising your participation in sports’; ‘focusing on your sport’; ‘stepping up to senior competition’; ‘general questions’; and ‘socio-demographic’ questions (although data have not been reported from this section in the present study). Competition levels were used to anchor questions which reflected the common belief by national sporting organisations that it is the foundation stone of success and progression (Sotiriadou & Shilbury, 2009), as well as intuitively assisting athletes with major milestone recall.

Within the survey, the Athlete Development Triangle (Figure 2) was a key referral tool for athletes and was used to depict the increasing competition demands as an athlete moves from base to apex and the proportionate decrease in absolute numbers of competitors as a result of the ascent up the sporting pathway. The various competition levels that athletes may have experienced are illustrated via the progressive competition boxes depicted on the far right hand side of the triangle and the relevant representation at local, regional, state or national level of competition detailed throughout the developmental trajectory.

Figure 2. The Athlete Development Triangle delineating the progressive levels of competition as well as the inter-relationships between junior and senior representative experiences. Junior competition (left hand side) is defined as age restricted competition to Level III (Pre-elite competition) i.e., this is the highest level a junior athlete can reach within this triangle model. Senior competition as defined by the right hand side of the triangle, includes all competition levels i.e., the apex of the triangle is exclusive to national senior representatives with a further sub-division depicting athletes who proceed to World Championship and Olympic-level representation.
The triangle illustrates and differentiates between junior and senior competition experiences (i.e., via the left or right hand side of the triangle respectively). In order to refine the instrument, the survey underwent substantial drafting, editing and a pilot-phase incorporating twenty six emerging talented sprint cyclists, five Paralympic winter sports and nine ex-elite athletes across a broad range of sports who possessed substantial experience in high performance sports administration and coaching. A copy of the survey is available from the researchers on request.

**Participants and Procedures**

In total, 2081 surveys were distributed to all Australian Institute of Sport (AIS) and the majority of State Institute and Academy of Sport (SIS/SAS) scholarship holders. This network represents the major supporting framework for Australia’s high performance sporting system (Bloomfield, 2003). Different survey distribution methods were used for the AIS-based programs and SIS/SAS programs. Groups of athletes at the AIS typically benefitted from the support of one of the researchers to assist with survey completion in comparison with a predominant individual mail-out method for athletes within the SIS/SAS system.

Participation in the study was purely voluntary and non-coercive encouragement was employed to maximise the survey completion rates. Completion of the survey took on average 60 minutes and each survey was de-identified (i.e., no name was supplied) in order to ensure privacy and anonymity. Ethics approval of the research protocol was granted by the AIS Human Research Ethics Committee.

**Analysis of Data**

Data from the completed surveys were entered verbatim and without interpretation by professional data entry specialists. Data were analysed using the statistical software program SPSS (2006, version 15.0). Descriptive statistics summarising group data and developmental comparisons (e.g., mean, standard deviation and percentages) were calculated. Comparative analyses were conducted using multiple methods of analysis including ANOVA, t-tests, correlation and where required non-parametric techniques (Chi-square). Statistical significance for all analytic methods was accepted at $p<0.05$. Specific to the univariate analyses partial eta-squared ($\eta_p^2$) values were computed to determine the proportion of total variability attributable to each factor. Following usual convention, $\eta_p^2$ values <.04 were considered small; those in the range .05 -.14, medium; and those >.14, large (Cohen, 1988). For analyses conducted using t-tests, Cohen’s $d$ was calculated to determine effect size with a $d$ of .20 considered small, a $d$ of .50 medium and a $d$ of .80 considered to be a large effect (Cohen, 1988). For analyses using Chi-square, Cramer’s $V$ ($\phi$) was calculated to estimate effect size and interpreted according to Cohen (1988).

As the survey relied extensively on the retrospective recall of the athletes, measures were employed to assess the authenticity of the data provided by the athletes. To assess reliability, four redundant questions were replicated throughout the survey. Spearman correlation coefficients for the redundant items in the survey ranged from 0.79 to 0.94 ($p<0.001$ for all four items), demonstrating a high concordance between the responses and better than the 0.70 range expected of lifetime activity recall (Friedenreich, Courneya, & Bryant, 1998). To determine concurrent validity, the responses of a consenting sub-sample of athletes ($n=44$) to eight standardised questions were compared with responses from their parents obtained through telephone interviews. Prior to survey completion, these athletes were invited to forfeit their anonymity by providing the contact details of one of their parents nominated as ‘knowing most about their sporting development’. Dependant on the type of variable, correlation coefficients were calculated using either Pearson or Spearman analyses. The correlations for the questions asked separately to both parents and athletes varied between $r=0.99$ and $r=0.26$, with six out of
Table 1. Measures of Validity for the National Athlete Development Survey (n=44)

<table>
<thead>
<tr>
<th>Item</th>
<th>Correlation r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of parent</td>
<td>0.99</td>
</tr>
<tr>
<td>Age when started competing at Level 1 in current sport</td>
<td>0.87</td>
</tr>
<tr>
<td>Age first attained current level in scholarship sport</td>
<td>0.78</td>
</tr>
<tr>
<td>Hours per week training at current level</td>
<td>0.68</td>
</tr>
<tr>
<td>Township size during secondary school education of athlete</td>
<td>0.65</td>
</tr>
<tr>
<td>Hours per week training when started competing at Level 1</td>
<td>0.61</td>
</tr>
<tr>
<td>Parent interest in sport</td>
<td>0.34</td>
</tr>
<tr>
<td>Total number of sports athlete participated in</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Eight questions having correlations greater than $r=0.60$ ($p<0.001$) (please refer to Table 1 for details). This variability in concordance could be attributed to the nature of retrospective techniques (e.g., Côté, Ericsson, & Law, 2005), or may be related to the fact that parents may not always be the best source of information to verify the broad cross-section of questions asked. For instance, sourcing the athletes' previous developmental teachers, coaches or training peers may have been more appropriate for some questions, however this was logistically impractical.

Upon completion of the survey, athletes were asked to state their level of motivation specific to completing the survey task. Seventy percent of respondents reported having a medium to high motivation after completion of the survey, suggesting that the majority responded in an effortful way.

Results

Six hundred and eighty one athletes completed the survey. However, for the analysis, eight surveys were excluded based on inconsistency or incoherence, resulting in a total sample size of 673 athletes (male $n=385$, 53%; female $n=288$, 47%). The response rate for AIS based athletes was 59% ($n=333$), while the lower response rate for collective SIS/SAS based athletes ($n=340$ or 23%) probably reflects the survey distribution methods and the comparatively larger SIS/SAS pool.

The athletes on average were 19.9 years old ($SD=4.7$). Thirty-four different sports were represented within the participant sample. Twenty-one percent of the participant sample competed at an ‘Advanced’ competitive level, 44% at a ‘Pre-elite’ level of competition and 33% at an ‘Elite’ level of competition, including 51 Olympians (8%; refer to Table 2 for the number of athletes sourced within each competitive level for each of these sports). The sample also included 186 athletes that had represented Australia at both junior and senior levels. Sixty-four percent of these athletes had also competed in a Junior World Championship.

Each sport was further categorised dependant on its type; individual or team-based. Forty-one percent of respondents were on scholarship for an individual sport whilst 59% were on scholarship for a team sport.

Developmental Processes

Onset and Rate of Development. Specific to their scholarship sport, 641 athletes indicated the age at which they experienced each competition level for the first time. Table 3 summarises the average ages of athletes when they first reached each respective competition level specific to individual and team sports. On average, athletes were 8.4 years of age ($SD=4.0$), when they first played their sport (i.e., non-competitively) and then began to compete in their chosen sport at a Junior level by 10.2 years of age ($SD=3.2$). As
Table 2. Number of Athletes per Current Competition Level for Each Sport (n=673)

<table>
<thead>
<tr>
<th>Sport</th>
<th>Level II</th>
<th>Level III</th>
<th>Level IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Advanced competition</td>
<td>Pre-elite competition</td>
<td>Elite competition</td>
</tr>
<tr>
<td>AFL</td>
<td>2</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>Archery</td>
<td>0</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Athletics</td>
<td>1</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>Baseball</td>
<td>9</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Basketball</td>
<td>8</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Boxing</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Canoeing</td>
<td>2</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Cricket</td>
<td>2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Cycling</td>
<td>1</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>Diving</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Equestrian</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Golf</td>
<td>7</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hockey</td>
<td>8</td>
<td>24</td>
<td>23</td>
</tr>
<tr>
<td>Judo</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Lawn bowls</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Netball</td>
<td>3</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Orienteering</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Rowing</td>
<td>4</td>
<td>9</td>
<td>24</td>
</tr>
<tr>
<td>Rugby league</td>
<td>20</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Rugby union</td>
<td>11</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Sailing</td>
<td>0</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Shooting</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Soccer</td>
<td>35</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>Softball</td>
<td>0</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Squash</td>
<td>1</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Swimming</td>
<td>0</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Taekwondo</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Tennis</td>
<td>4</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Triathlon</td>
<td>1</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Volleyball</td>
<td>15</td>
<td>27</td>
<td>20</td>
</tr>
<tr>
<td>Water polo</td>
<td>4</td>
<td>30</td>
<td>18</td>
</tr>
<tr>
<td>Weightlifting</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Winter sports</td>
<td>1</td>
<td>2</td>
<td>7</td>
</tr>
</tbody>
</table>

depicted in Table 3, it took approximately two years for an athlete to progress to the next highest competition level and approximately six years on average to progress from their first Local Junior competition experience to represent their country as a junior athlete. On average, athletes began their senior competition experiences at 15.5 years of age (SD=2.7) and a further 4.1 years was then required to become a Senior National representative. In order to then reach an Olympic-level of competition, an additional 4.1 year investment was required at a Senior National and International level. On average, a total commitment of 8.2 years was required for an athlete to progress from their initial foray in senior level competition to an Olympic-level of competition.

To develop from a Junior Local level to a Junior National level, it took on average 4.9 years for an individual sport, while for team sports it took approximately 6.7 years. It is possible that this in part was due to the fact that team-based athletes commenced Junior competition significantly earlier than athletes in individual-based sports $F(1, 577)=30.77$, $p<.001$, $\eta_p^2=0.05$. 

<table>
<thead>
<tr>
<th>Competition levels</th>
<th>Total group</th>
<th>Individual athletes</th>
<th>Team sport athletes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>0. Play / leisure</td>
<td>8.4</td>
<td>3.96</td>
<td>9.2</td>
</tr>
</tbody>
</table>

**Junior:**
- Local (Basic): 10.2 | 3.17  | 11.1 | 3.14  | 9.6**| 3.05  |
- Regional (Advanced): 12.0 | 2.44  | 12.2 | 2.83  | 11.9 | 2.17  |
- State (Advanced): 13.8 | 2.15  | 13.7 | 2.59  | 13.9 | 1.80  |
- National (Pre-elite): 16.2 | 1.74  | 16.0 | 2.09  | 16.3 | 1.40  |

**Senior:**
- Local (Basic): 15.5 | 2.68  | 16.2 | 3.50  | 14.9**| 1.65  |
- Regional (Advanced): 16.6 | 2.97  | 17.2 | 3.92  | 16.0**| 1.58  |
- State (Pre-elite): 17.7 | 3.01  | 18.1 | 3.65  | 17.3*  | 1.93 |
- National (Elite): 19.6 | 3.14  | 19.6 | 3.49  | 19.5 | 2.63  |
- World Championships (Elite): 21.5 | 4.23  | 21.4 | 4.70  | 21.8 | 3.22  |
- Olympics (Elite): 23.7 | 4.41  | 24.2 | 4.94  | 22.9 | 3.19  |

Note: n(total group)=641, n(individual)=267, n(team)=374. * significantly different from individual athletes, p<.05. ** significantly different from individual athletes, p<.001.

<table>
<thead>
<tr>
<th>Competition levels</th>
<th>Total group</th>
<th>Individual athletes</th>
<th>Team-sport athletes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Junior:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I. Basic</td>
<td>4.9</td>
<td>4.26</td>
<td>6.4</td>
</tr>
<tr>
<td>II. Advanced</td>
<td>8.8</td>
<td>5.90</td>
<td>11.1</td>
</tr>
<tr>
<td>III. Pre-elite</td>
<td>13.8</td>
<td>7.72</td>
<td>15.5</td>
</tr>
<tr>
<td>Senior:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I. Basic</td>
<td>11.1</td>
<td>8.23</td>
<td>15.2</td>
</tr>
<tr>
<td>II. Advanced</td>
<td>14.6</td>
<td>8.82</td>
<td>18.4</td>
</tr>
<tr>
<td>III. Pre-elite</td>
<td>18.3</td>
<td>9.28</td>
<td>21.9</td>
</tr>
<tr>
<td>IV. Elite</td>
<td>21.8</td>
<td>8.57</td>
<td>23.0</td>
</tr>
</tbody>
</table>

Note: n(total group)=655, n(individual)=271, n(team)=384. * significantly different from individual athletes, p<.01. ** significantly different from individual athletes, p<.001.

**Developmental Practice Investment.** With reference to their scholarship sport, 655 athletes estimated their weekly practice investment for each competition level (Table 4). As expected for all athletes, the amount of practice hours per week was significantly different within all junior competition levels (Junior Basic – Advanced t(552)=20.97, p<.001, d=0.81; Junior Advanced – Pre-elite t(410)=18.56, p<.001, d=0.77) and within all senior competition levels (Senior Basic – Advanced t(309)=11.34, p<.001, d=0.34; Senior Advanced - Pre-elite t(299)=13.30, p<.001, d=0.42; Senior Pre-elite – Elite t(220)=10.80, p<.001, d=0.47). As demonstrated in Table 4, athletes on average began training 4.9 hours per week (SD=4.3) at a Junior Basic competition level, and steadily increased their time commitment at each competition level up to 21.8 hours per week (SD=8.6) by the Senior Elite level. When considering individual and team sports separately, the analysis revealed that the individual athletes trained significantly more than the team-based athletes at every level defined in the triangle (refer to Table 4). The biggest differences occurred...
among the Senior Basic, \( F(1, 374)=86.48, p<.001, \eta_p^2=0.19 \), Advanced, \( F(1, 353)=79.06, p<.001, \eta_p^2=0.18 \), and Pre-elite levels, \( F(1, 362)=79.63, p<.001, \eta_p^2=0.18 \), with individual athletes training 15.2, 18.4 and 21.9 hours per week respectively in comparison with team-based athletes who typically trained 8.0, 10.9 and 14.0 hours per week. At an Elite competition level (Senior National level), team-based athletes demonstrated a substantial 43% (i.e., six hour) increase in their training commitment beyond their Pre-elite (or State level) commitments, whilst their individual-based counterparts, typically limit their increase in practice to one hour (5%) for the same transition.

**Number, Timing and Level of Other Sport Experiences.** In addition to their scholarship sport, athletes participated on a regular basis (i.e., once a week for at least six consecutive months) in three other sports (SD=1.8). Some athletes (10%) indicated a regular involvement in six or more sports, while 6% did not regularly participate in any other sports than their scholarship sport. In terms of the timing of these experiences, the overall trend in sports participation was for athletes to participate in two sports prior to experiencing their scholarship sport for the first time, and one other sport thereafter. Interestingly, the majority of athletes (57%) had reached an Advanced level of competition in at least one other sport, whilst 19% and 3% had achieved a Pre-elite or Elite level of competition in another sport apart from their scholarship sport.

**Natural Abilities**

Athletes were asked to indicate whether prior to engaging in any form of regular competition for the first time (Level 0), did they or others notice whether they 'possessed outstanding talent for sport' (that is, 'well above children your age'). Sixty three percent \((n=419)\) confirmed that this was the case, with 'school personnel' most responsible for this observation (42%), followed by their 'parents' (33%), and then 'themselves' (11%).

Suspending academic debate regarding which athletic traits are considered natural and which are acquired through environmental interaction, 'coordination' (77%) and 'sense of the game' (73%) were the typical natural abilities self-reported by the athletes across all sports, with more than half of them demonstrating other early stand out traits related to 'mental strength' (59%), 'physical strength' (58%), 'speed' (56%), and 'endurance' (52%).

**Environmental Catalysts**

**Coaching Influence and Quality.** Athletes reflected on the perceived influence coaching had on their progress during the various competition levels, and rated the specific qualities they felt were most important. At least two-thirds of athletes indicated that coaching was 'critical and highly influential' to their talent development at every competition level defined in the Athlete Development Triangle. As competition levels increased, so too did the perceived importance of coaches (Junior: Level I \((n=599)=67\%\), Level II \((n=595)=83\%\), Level III \((n=441)=87\%\); Senior: Level I \((n=389)=63\%\), Level II \((n=365)=81\%\), Level III \((n=374)=89\%\), Level IV \((n=257)=92\%\)). In addition to determining whether coaches are 'critical and highly influential', athletes were asked to indicate the most important coaching qualities for each of the separate competition levels they felt enabled them to develop and progress as an athlete. Results revealed that the 'ability to motivate and encourage' was the most important quality of a coach at preliminary competition (Junior and Senior Basic competition and Junior Advanced; refer to Table 5). At the lowest level (Junior Basic competition) 'teaching ability' was the second most important quality of a coach. In contrast, 'detailed knowledge of the sport' was the most important factor at the higher levels (Senior Advanced, Junior and Senior Pre-elite, and Senior Elite competition), as well as a 'strong insistence on perfection'.

**Family Involvement and Support.** Table 6 summarises the participation of parents and siblings in competitive sports. Experience in competitive sport was a commonality within the families of high performance athletes. Eighty-two percent of the fathers, 66% of mothers, and more than 83% of siblings of the athletes had participated in competitive
sports. Interestingly, high performance sport also tended to run in families, with 35% of fathers having competed at Senior State or Junior National or Senior National competition level (i.e. Level III or IV). Similarly 18% of mothers and 24% of older siblings had achieved this same level.

Table 7 reveals the very positive and active support of parents towards the sporting activities of their children. This is sustained at all levels of competition and in very few cases (<~5%) do parents exhibit anything less than a 'mostly positive support' environment for their children.

Table 5. Coaching Qualities Most Responsible for Athlete Progression

<table>
<thead>
<tr>
<th>Qualities of coaching</th>
<th>Junior Basic</th>
<th>Junior Advanced</th>
<th>Junior Pre-elite</th>
<th>Senior Basic</th>
<th>Senior Advanced</th>
<th>Senior Pre-elite</th>
<th>Senior IV Elite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detailed knowledge of the sport</td>
<td>9</td>
<td>15</td>
<td>21</td>
<td>14</td>
<td>26</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Strong insistence on perfection</td>
<td>4</td>
<td>11</td>
<td>17</td>
<td>10</td>
<td>16</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Ability to motivate/encourage</td>
<td>32</td>
<td>21</td>
<td>16</td>
<td>22</td>
<td>17</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Teaching ability</td>
<td>18</td>
<td>20</td>
<td>13</td>
<td>13</td>
<td>15</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Confident and relaxed style</td>
<td>14</td>
<td>12</td>
<td>11</td>
<td>17</td>
<td>10</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Took personal interest in me</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Understanding of competition demands</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Stressing balance between life &amp; sport</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Coach did not contribute</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Note: All results are expressed as a percentage. n(Jr I)=457, n(Jr II)=498, n(Jr III)=392, n(Sr I)=273, n(Sr II)=303, n(Sr III)=324, n(Sr IV)=231.

Table 6. Participation of Parents and Siblings in Competitive Sports

<table>
<thead>
<tr>
<th></th>
<th>% Participated in competitive sports</th>
<th>% Still competing</th>
<th>% Experienced Level III</th>
<th>% Experienced Level IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Father (n=646)</td>
<td>82</td>
<td>10</td>
<td>27</td>
<td>8</td>
</tr>
<tr>
<td>Mother (n=663)</td>
<td>66</td>
<td>13</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Siblings older (n=667)</td>
<td>84</td>
<td>33</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Siblings same age (n=13)</td>
<td>92</td>
<td>70</td>
<td>46</td>
<td>8</td>
</tr>
<tr>
<td>Siblings younger (n=523)</td>
<td>83</td>
<td>62</td>
<td>12</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 7. Parents' Attitude Towards Sporting Activities of Their Children

<table>
<thead>
<tr>
<th>Competition Levels</th>
<th>Generally negative attitude</th>
<th>Slight tendencies towards the negative</th>
<th>Mostly indifferent, with occasional support</th>
<th>Mostly positive support</th>
<th>Very positive and active support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junior:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I. Basic (n=592)</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>19</td>
<td>76</td>
</tr>
<tr>
<td>II. Advanced (n=591)</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>16</td>
<td>80</td>
</tr>
<tr>
<td>III. Pre-elite (n=439)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>17</td>
<td>81</td>
</tr>
<tr>
<td>Senior:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I. Basic (n=384)</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>21</td>
<td>73</td>
</tr>
<tr>
<td>II. Advanced (n=361)</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>19</td>
<td>74</td>
</tr>
<tr>
<td>III. Pre-elite (n=370)</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>21</td>
<td>75</td>
</tr>
<tr>
<td>IV. Elite (n=252)</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>19</td>
<td>77</td>
</tr>
</tbody>
</table>

Note: All results are expressed as a percentage.
Intrapersonal Catalysts

Obstacles to Progress. From a list of 13 factors, athletes were asked to report whether they encountered any significant obstacles retarding their talent development. Results revealed that more than half (53%) of the athletes experienced a significant obstacle retarding their development at their current level of competition, with the highest ranking obstacles differing according to competition level. For example, at Level I, the environmental catalysts of ‘quality coaching’ and ‘training facilities’ were the top ranked obstacles cited by athletes. Conversely, the athletes at their current level of competition cited ‘self belief’ and the extrinsic element of ‘financial support’ as the top two ranked retarding factors.

Athletes were asked to indicate if at any stage during their sporting development, they felt compelled to quit their sport. The findings revealed that a large majority of athletes did not consider quitting during their career (Junior: Level I=92%, Level II=89%, Level III=87%; Senior: Level I=89%, Level II=86%, Level III=77%, Level IV=70%). However, as athletes entered higher competition levels, the percentage of athletes who considered quitting increased. For example, at a Junior Basic competition level, 8% considered quitting their sport and this figure increased to 30% by a Senior Elite level of competition. The most important reasons that athletes offered in regard to grounds for quitting at a Junior level (Basic and Advanced competition level), were ‘conflict with other leisure activities’ (21% and 31% respectively), ‘discouraged by the daily effort’ (23% and 16% respectively) and lack of interest because of ‘poor performances’ (15% and 20% respectively). At Senior Basic and Advanced competition levels, ‘poor performances’ (both 23% at Basic and Advanced competition level) and ‘financial problems’ (18% and 19% respectively) were the main reasons why athletes contemplated quitting.

When the higher competition levels are taken into account, ‘conflict with studies/work’ (20% at a Junior Pre-elite level, 21% at a Senior Pre-elite and 24% at a Senior Elite level) were the main reasons why athletes considered quitting. The second most important reason for quitting at the higher levels varied depending on the level defined in the triangle. Junior athletes at a Pre-elite competition level indicated that their second most important reason for potentially quitting was because they are ‘discouraged by the daily effort’ (18%), whereas the senior athletes at the same level considered quitting because of ‘poor performances’ (21%). Senior athletes at an Elite level of competition considered quitting because of ‘repetitive injuries and illness’ (19%).

Motivation to Advance to Higher Competition Levels. Athletes were asked to list their two most important reasons as to why they elected to be involved with a specific competition level throughout their sporting development. Table 8 provides the relative frequency of the answers provided by the athletes (reason 1 and 2 collapsed). As Table 8 indicates, ‘love to practice the sport’ was an important motivation for continuing athletes’ competition experiences, exhibiting a stable trend throughout all competition levels. Athletes also revealed that it was not necessarily a conscious decision to advance to a certain competition level, but rather, it sometimes happened ‘automatically’ (although this trend decreases with increasing competition levels). Furthermore, ‘high natural abilities’ for sport were an important reason for advancement within both Junior and Senior Basic and Advanced competition levels, while the ‘desire to prove something to myself’ became a more common reason for participation at the higher levels (Pre-elite and Elite competition levels).

Passion. Eighty-seven percent of athletes (n=585) reported that they were ‘definitely passionate about their sport’ whilst 12% confided that they were not passionate, but sport was ‘still very important in their life’, and 1% indicated that they were definitely not passionate about sport, as sport was only ‘one interest among others’. On average, athletes who were definitely passionate about their sport became aware of their passion at the age of 11.8 years old (SD=4.4).
Personality. Athletes \(n=641\) were asked to consider twelve personality characteristics and compare themselves against athletes that they were training and competing with at the time of completing the survey. 'Being competitive' (79%), 'being coachable' (78%) and 'showing perseverance and determination when facing obstacles' (78%) are the main traits that the athletes considered themselves to be above average and most different from their peers. Similarly, more than half of the athletes felt that they compared more favourably than their peers in the areas of 'getting along with team members' (71%), 'being a perfectionist' (67%), 'showing resilience' (62%), 'having the patience to practice again and again the same skills' (62%), 'tolerating the pressure during competition' (60%), 'being autonomous' (57%), 'remaining totally focused during practice or competition' (55%), and 'being able to react positively to criticism' (54%). Interestingly, only the minority (46%) felt that 'being a good loser' was a personality trait that outranked their colleagues.

When the Olympians \(n=51\) were compared to the non-Olympic cohort \(n=589\), Olympians scored significantly higher for 'having the patience to practice again and again the same skills', \(\chi^2(4, n=634)=10.50, p<.05, \phi=.13\), 'showing perseverance and determination when facing obstacles', \(\chi^2(4, n=636)=14.98, p<.01, \phi=.15\), 'being autonomous', \(\chi^2(4, n=636)=17.85, p<.005, \phi=.17\), 'being competitive', \(\chi^2(4, n=636)=9.35, p=.05, \phi=.12\), 'showing resilience', \(\chi^2(4, n=636)=23.97, p<.001, \phi=.19\), 'tolerating the pressure', \(\chi^2(4, n=635)=9.64, p<.05, \phi=.12\), and 'remaining totally focused during practice or competition', \(\chi^2(4, n=635)=13.75, p<.005, \phi=.16\).

Chance Events

Fifty-one percent of the cohort \(n=343\) described one or more (up to three) chance events considered to have impacted their talent development in a 'modest', 'sizeable', or 'major' way. Sixty-three percent of all chance events described by participants were considered to have a 'major impact' on their development. Approximately three out of four chance events (74%) were perceived by athletes as having a positive effect on their development and included positive experiences with teachers at school (16%), a chance meeting with the 'right' coach (14%), encouragement or motivation from others or positive self-analysis (13%), and good fortune experienced through competition opportunities or selection (13%). Twenty-two percent of chance events were perceived to have a negative influence on talent development with injuries the prominent cause of bad luck (16%), with acute injuries accounting for 10% of chance events or 45% of bad luck. The remaining 4% of events described were rated as initially being bad luck (i.e., an injury), but later turning out to have a positive influence on talent development.

Table 8. Motivation to Advance to Higher Competition Level

<table>
<thead>
<tr>
<th>Motivations to enter</th>
<th>Junior I Basic</th>
<th>Junior II Advanced</th>
<th>Junior III Pre-elite</th>
<th>Senior I Basic</th>
<th>Senior II Advanced</th>
<th>Senior III Pre-elite</th>
<th>Senior IV Elite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Love to practice the sport</td>
<td>24</td>
<td>32</td>
<td>27</td>
<td>29</td>
<td>28</td>
<td>28</td>
<td>27</td>
</tr>
<tr>
<td>Happened automatically</td>
<td>38</td>
<td>27</td>
<td>25</td>
<td>30</td>
<td>27</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>Desire to prove something to myself</td>
<td>1</td>
<td>6</td>
<td>11</td>
<td>5</td>
<td>10</td>
<td>18</td>
<td>21</td>
</tr>
<tr>
<td>Love the feeling of winning</td>
<td>3</td>
<td>7</td>
<td>11</td>
<td>8</td>
<td>13</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>High natural abilities</td>
<td>16</td>
<td>21</td>
<td>18</td>
<td>18</td>
<td>17</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>Bow to outside pressures</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Desire to be with friends</td>
<td>9</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Dreaming of becoming famous</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Dreaming of becoming rich</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: Data presented is a percentage of completed questions. All results are expressed as a percentage. \(n(Jr I)=586, n(Jr II)=587, n(Jr III)=434, n(Sr I)=380, n(Sr II)=356, n(Sr III)=362, n(Sr IV)=247\).
Discussion

In this paper, we have described the preliminary findings of an empirically based, global measure/instrument of talent development within sport. The National Athlete Development Survey proved to be effective in recording the development pathways and experiences of a large sample of high performance Australian athletes \( (n=673) \) which included 51 Olympians. Data obtained through its administration, provided a valuable and realistic insight into the development of sporting talent which incorporates a diverse range of sports (34 in total). The Athlete Development Triangle featuring an inherent flexibility within its design to account for progression, digression and direct crossover (i.e., junior to senior) in competition levels made it possible to establish a more meaningful and realistic map of the journey to an elite status than has been provided in the literature to date. Well entrenched pyramidal-type models illustrating the progressive pathway from mass participation to sporting pinnacle, greatly oversimplify the geometrical developmental trajectory with the limited “up” and “out” pathway (Green, 2005; Kirk & Gorely, 2000). Understanding and attending to these nuances is critical for maximising the rate and absolute delivery of high performance athletes to national sporting systems.

The findings revealed a number of commonalities and some interesting differences dependant on sport type across the cohort. Consistent with recent multi-disciplinary studies (Bailey & Morley, 2006; Weissensteiner, Abernethy, & Farrow, 2009) and Gagné’s Differentiated Model of Giftedness and Talent (2003, 2009), progression to an elite level of competition is multi-factorial requiring a favourable synchronisation of extrinsic, contextual factors (i.e., diverse and high level sports participation prior to specialisation in their scholarship sport, a vast investment in practice, high quality of coaching, positive chance factors) and intrinsic factors (i.e., strong intrinsic motivation, an early and enduring passion for the sport, a strong commitment to practice and resilience to overcome and bounce back from career obstacles).

A number of published investigations exploring the development of elite athletes have typically focussed on a small cohort of athletes across a limited range of sports (Bloom, 1985; Côté, 1999; Côté & Hay, 2002). Findings from these approaches are not necessarily reflective of the broader sports system or athlete population (macro-environment), but rather a narrow purview of the sports specific context (micro-environment) which limits the ability to generalise results. Therefore, the sample size for this study represents a significant advance in the literature and has the capacity to capture and chronicle a more ecologically valid and generalisable account of the developmental journey.

It should be acknowledged that there is partial concordance with Côté’s (1999) model of sports participation with the athletes in the current study characterised by early sport sampling preceding sports specialisation, and a significant investment in practice as competition level increased (Table 4). While the data are supportive in general, Côté’s concept of specialisation occurring in a chronologically prescriptive range of 13 to 15 years does not account for the high performance scholarship holders in the present study which have come from initiatives designed around later specialisation such as talent transfer (Gulbin, 2008; Vaeyens et al., 2009).

Broadly, the elements of Gagné’s model (2009) provided a legitimate framework to condense what is a complex choreography and interplay of traits, behaviours and catalysts throughout the athlete development process. The data harvested through the NADS tool confirmed the presence of ‘gifts’ or ‘natural abilities’, which were catalysed by ‘environmental’, ‘intrapersonal’ and ‘chance’ factors, which influenced a ‘developmental process’ that resulted in rare sporting competencies or achievements.

Natural abilities were reported to express at an early age (approximately 8 years old at Level 0) when the capacity to significantly out-practice or out invest one’s peers in sporting play is arguably diminished. These findings are somewhat limited by the
strength of self-reporting, so more detailed follow up is required to verify specific lifestyle behaviours to more precisely account for why athletes exhibited specific attributes and outperformed children of the same age during these formative developmental years. However, the relatively large acknowledgement (40%) that school personnel appear to have an eye for precocious talent ought not be lost on talent identification practitioners. Primary school personnel potentially represent a major front-line force in the identification of athletes potentially suited to high performance sport in future years.

Specific to coaching, it was interesting to note that as competition levels increased, the required qualities of coaches to optimally support the development of the athletes in their care, changed from more pedagogical qualities (‘ability to motivate/encourage’ and ‘teaching ability’) to more technical qualities (‘detailed knowledge of the sport’ and ‘strong insistence on perfection’). Given these data demonstrate the critical importance of coaching on development at all competition levels and the development of sport passion prior to adolescence, matching the key attributes of coaches with competition level is of paramount importance. Appointing coaches on the basis of availability only, without due consideration of the aforementioned coaching qualities, will continue to hinder the development of young talented athletes. Similarly the consideration of non-sports specific generalists who have these preferred delivery qualities, may prove to be clever coaching appointments to improve the retention and promotion of athletes, and potentially expand coaching talent stocks.

Sports must be proactive in matching up quality talent with quality coaches. Given the favourable ‘major impact’ attributed to the chance meeting with the right coach, such serendipitous events are inefficient for sports to realise a fortuitous athlete–coach interaction when these can often be planned in advance. Indeed, such an approach is the cornerstone of talent identification programs, whereby quality athletes are inducted into a highly specialised talent development program under the auspices of an expert coach (Bullock et al., 2009; Vaeyens et al., 2009).

In regard to intrinsic motivation, the findings of the present study refute the generalised parallel with music and academia that in order to develop high level expertise in the sporting domain, (that is, the ‘deliberate practice’ model, Ericsson et al., 1993) training and practising is not overly enjoyable. It was clearly evident from the findings that high performance athletes ‘love’ to train and compete in their sport and this appears to underlie their commitment and drive to excel in their chosen sport. Intrinsic motivators such as ‘love of practice’, ‘desire to keep improving’ and ‘desire to prove something to myself’ were key drivers for advancement and continuity at higher competition levels even despite the finding that 53% of athletes had experienced a significant obstacle which had retarded their development some time during their sporting career. The vast majority of respondents (87%) confided that they were very passionate about their sport, indicating that sport ‘is amongst the most important things in life’, ‘something they felt they couldn’t live without’ and ‘something they would sacrifice a lot to keep doing’. Such passion was typically apparent by 11.8 years of age and was maintained with increasing competition levels. While it is not socially desirable to acknowledge being interested in fame and money, such a small proportion of extrinsically motivated athletes is consistent with the notion that intrinsic motivation is vital for fine-tuned performances in sport (Ryan & Deci, 2000; Vallerand, Ryan, & Deci, 1987).

The findings revealed that the Olympic cohort scored significantly higher than non-Olympians in the areas of ‘having the patience to practice again and again the same skills’, ‘showing perseverance and determination when facing obstacles’, ‘being autonomous’, ‘being competitive’, ‘showing resilience’, ‘tolerating the pressure during a competition’, ‘remaining totally focused during practice or competition’ and ‘being a perfectionist’. This is quite an interesting finding given that the non-Olympians in this investigation are likely to be Olympians ‘in-waiting’. One can only speculate whether the higher scores reflected in the aforementioned traits are required to be developed or enhanced in order to become an Olympian, or as a result of being an Olympian.
The findings of the present study have important theoretical and practical implications for researchers and talent identification and development practitioners. For instance, the data revealed considerable sporting versatility when considering the sporting backgrounds and high level achievements of the present cohort in sports other than their scholarship sport. Fifty seven percent of athletes had reported that they had reached an Advanced level of competition in at least one other sport apart from their scholarship sport, while 19% and 3% had reached a Pre-elite or Elite level. This finding certainly augurs well for future initiatives involving the ‘recycling’ of athletes through talent transfer programs (Gulbin, 2008; Vaeyens et al., 2009).

It is important to acknowledge that this paper restricted its scope of delivery and does not reflect the wealth and coverage of data obtained through the administration of the questionnaire to this particular cohort. The intention of the researchers was not to provide an exhaustive review of every variable related to talent development within this paper, but to address those aspects deemed to be of practical and strategic significance. This includes the provision of empirical evidence to guide the structure, delivery, and initiatives of coaches, educators and national sporting organisations to improve both the identification and development of talent within Australia.

Key companion papers will follow which will (i) explore in detail the developmental pathways (trajectories and magnitude) of the elite cohort of athletes featured in this investigation using the Athlete Development Triangle as a reference; (ii) contrast high performance experiences with non-elite cohorts through case-control comparisons; (iii) examine talent development specific to sports membership and predominant energy system used; (iv) examine the relative contribution of familial sports participation and support to talent development; (v) quantify an athlete’s typical practice investment across differing sports and athlete categorisations (early, middle and late bloomers), and (vi) develop further insights into quantifying the relative contribution of the key catalysts attributed to the talent development process as defined by Gagné (2009) by undertaking appropriate factor analyses.

References


The Authors

Jason Gulbin (born 1966) is the General Manager for the Australian Sports Commission’s National Talent Identification & Development (NTID) program. He holds a B.Ed. in Post Primary Physical Education (1990) and was awarded his PhD in the field of exercise physiology at Griffith University (Gold Coast) in 1999. His research interests focuses on multidisciplinary, applied talent identification and development themes with a particular interest in maximising the efficiency of the talent development pathway for athletes, coaches and sports.

Karen Oldenziel (born 1978) graduated in the talent development area within Movement Sciences at the University of Groningen in the Netherlands. She was employed as a Research Assistant by the former Australian Institute of Sport’s National Talent Search Program from 2002 to 2004. During this time, Karen was responsible for the administration, collection and analysis of the National Athlete Development Survey, which became the foundation for this paper. Back in Holland, Karen has undertaken data-analyses for the Consumer Safety Institute, and currently works as the Manager for the Information, Communication and Technology Team of the High Court in the Netherlands.

Juanita Weissensteiner (born 1968) is the Research Coordinator for the National Talent Identification and Development program based at the Australian Sports Commission. Juanita’s doctoral dissertation (University of Queensland, 2008) explored the development of expertise specific to batting in the sport of cricket and featured a complementary mix of qualitative and quantitative research methods across multiple sports science disciplines (psychology, skill acquisition, anthropometry, sociology/pedagogy, biomechanics and motor control). Her main interest in research is the refinement of multi-factorial, multi-disciplinary and pluralistic methods specific to the examination of expertise.

Professor François Gagné is a French Canadian from Montreal, Quebec. He obtained in 1966 his PhD in Educational Psychology from the University of Montreal. Dr. Gagné has spent most of his professional career in the department of Psychology, at l’Université du Québec à Montréal (UQAM). After a decade of research on student evaluations of teaching, he became interested in talent development in the late 1970s. Although his research brought him to study a variety of subjects within the field of gifted education (e.g., attitudes toward the gifted and their education, peer nominations, developmental profiles), he is best known internationally for his theory of talent development, the Differentiated Model of Giftedness and Talent (DMGT), which has been endorsed by various educational authorities as their framework to define their target population and plan intervention provisions.
The Role of Ecological Constraints on Expertise Development

Duarte Araújo¹*, Cristina Fonseca¹, Keith Davids², Júlio Garganta³, Anna Volossovitch¹, Regina Brandão⁴ and Ruy Krebs⁵

Abstract: The role of ecological constraints on the acquisition of sport expertise is gaining attention in sport science, although more research is needed. In this position paper we provide an ecological explanation for expertise acquisition, as alluding to qualitative data that support the idea that unconventional, even aversive, environmental constraints may play an important role in the development of world-class athletes. We exemplify this argument by profiling the role of unconventional practice environments using association football in Brazilian society as a task vehicle. Contrary to the traditional idea that only deliberate training and development programmes can lead to the evolution of expertise, we propose how expert performance might be gained through highly unstructured activities in Brazilian football, that represent a powerful and little understood implicit environmental constraint that can lead to expertise development in sport.

Keywords:
ecological psychology, environmental constrains, development, expertise, association football

Sport expertise develops through interactions between an individual and specific performance environments (Davids & Baker, 2007; Farrow, Baker, & MacMahon, 2008). There have been some attempts to explain facilitative and structured characteristics of the environment (e.g., material facilities, coaching, family support networks) in the acquisition of expertise (Côté & Fraser-Thomas, 2008; Davids & Baker, 2007). In this position paper, we argue that the environment–performer interaction is most important in this process, contrary to the traditional organismic asymmetry (Dunwoody, 2006) observed in theoretical explanations of expertise acquisition in sport. The converse of this argument is that ‘environmental asymmetry’ will also not provide an adequate explanation of expertise acquisition. We argue that research on expertise, which has examined the role of environmental constraints in formally organized sports training programs, might be limited in scope (Davids & Baker, 2007; Starkes, Helsen, & Jack, 2001). In some societies more informal and even aversive environmental constraints exert a powerful, and little understood, influence on the acquisition of expertise in specific sports. Here we examine one example, football in Brazil, but expertise researchers need to identify other similar examples, such as ice hockey and basketball in the United States, or cricket in India and Australia (Phillips, Davids, Renshaw, & Portus, in press; Weissensteiner, Abernethy, Farrow, & Müller, 2008). Due to differences in athlete backgrounds, evidence suggests that the acquisition of expertise follows idiosyncratic pathways (Phillips, Davids, Renshaw, & Portus, 2010). In our analysis, we examine ecological theories and empirical research in a

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How to Understand Sport Expertise: The Role of Ecological Psychology

A recent review concluded that: (i) the expert's advantage is selective to only some components of performance; (ii) experts use different sources of information to control their actions compared to non-experts; and (iii), practice and developmental experiences of experts differ from non-experts (Abernethy, 2008). With regard to the last point, Côté and Fraser-Thomas (2008) argued that coaching, play and practice are key variables that significantly influence the skill acquisition process. They highlighted the need to consider in skill acquisition, not only training time and specialized practice, but also physical and psycho-social constraints, such as injuries and enjoyment. They concluded that there were many unresolved questions regarding the amount and type of play and practice activities required at different stages of an athlete's progression towards expertise. Indeed, Davids and Baker's (2007) review highlighted that an increasing number of studies have considered the important influence that environmental constraints have on the acquisition of sport expertise. For example, the historical emphasis that a nation or community places on a particular sport can have a significant influence on international competitive success (e.g., Canada with ice hockey, Kenya with distance running, Brazil with football, Jamaica with sprinting, Australia with Cricket). Clearly, more research is needed to clarify the role of socio-cultural constraints in the acquisition of sport expertise. Currently, much more research has been conducted on specific practice environment variables such as the quantity and type of practice, and access to social and physical resources (Davids & Baker, 2007). Analysis of environmental constraints may be interpreted through the framework of ecological psychology (Araújo & Davids, 2009).

From an ecological perspective, it is important to understand how some individuals are able to interact with environmental constraints in a specific performance context, functioning effectively with available physical and social resources (Araújo, 2007). Therefore, an important part of exhibiting expertise involves realizing actions, which are consistent with socio-cultural mores (Barab & Plucker, 2002). Social, historical, and possibly other external processes need to be considered as integral constraints on skilled action. The performance of an expert should be conceived as being influenced by an interaction of external and internal constraints (Barab & Plucker, 2002). Only through acknowledgement of the ecological nature of expert performance can meaningful practice contexts be designed. In this analysis, Bronfenbrenner's bioecological framework may provide a useful start point.
The Role of Ecological Constraints on Expertise Development

Bronfenbrenner’s Bioecological Model to Guide Research on Expertise Development

To understand sport expertise, multi-scale and multi-disciplinary theoretical descriptions are needed (for a good example see Phillips et al., 2010). Bronfenbrenner’s bioecological model (e.g., Bronfenbrenner & Morris, 2006) provides an evolving theoretical framework for analysing how the environment shapes human development throughout the lifespan (see also Bronfenbrenner, 2005). An important characteristic of the model is its interdisciplinarity and its integrative focus on youth, as well as policies and programs for enhancing youth development. Bronfenbrenner was also influenced by systems theory in biology, emphasizing interaction, change and stability over the lifespan. He explicitly acknowledged the importance of time for understanding human development (Krebs, 2009).

The defining four interactive dimensions of the bioecological model are process (e.g., quality of practice according to the individual), person (e.g., somatotype), context (e.g., parents involvement) and time (e.g., a practice session, a career; Bronfenbrenner & Morris, 2006; see Figure 1). Davids and Baker (2007) noted effects of interacting constraints on the development of expert performance, despite variations in genetic structure, since high heritability of particular traits is clearly influenced by environmental components. For example, the approach of Weissensteiner et al. (2009) is generative in its methodological approach, and has emphasized the role of critical constraints. This is an invaluable contribution to our understanding of expertise in sports, which provides conceptualization beyond the limitations of existing research (see e.g., Williams & Reilly, 2000). However, their approach contrasts with the approach taken in this article in several meta-theoretical aspects. For example the model presented by Weissmentreiner et al. (2009) interpreted the individual athlete and the environment as separate and interactive. This dualist approach is characterized by viewing the socio-cultural background as sustaining individual characteristics (e.g., cognitive, perceptual and technical). An ecological approach focuses on individual adaptability in evolutionary functional contexts and views the individual and environment as equally contributing to the relevant scale of analysis for understanding human behaviour and performance. In line with this focus, expert performers are not seen as an aggregate of attributes, factors or components, but

Figure 1. Pictorial description of Bronfenbrenner’s bioecological model. N.B.: Concerning the context, only microsystems are physically located. The others are “system forces”, i.e., describing how other microsystems influence the person and the particular microsystem under analysis. The mesosystem is formed by other microsystems frequented by the person. The exosystem is formed by the microsystems that are not frequented by the person under analysis, i.e. those which influence the microsystem under analysis. The macrosystem is a network of microsystems of a certain culture delimited by the researcher. Beyond the person and the context, the bioecological model includes time and process. Process describes the characteristics of person-context interactions over time. Also, person and context change over time.
active individuals engaged in dynamical transactions with their functionally-defined environments (Araújo, 2007). Also, it is important to note that although Weissensteiner et al. (2009) discussed the role of the environment, they did not directly present explicit processes for how interactions between individuals and a particular environment might occur. When they referred to attributes and factors, they described components that exist in an individual, with allusions to context simply being the foundation for the possession/acquisition of expertise, not its ontological existence. Much of the discussion in Weissensteiner et al.’s (2009) study concerned how context enriches the internal factors acquired by performers, i.e., how the environment “molds essential player characteristics for task success” (p. 280). This “identification of the important components” (p. 291) contrasts sharply with how individuals and contexts co-determine each other through ecological practice (Barab & Plucker, 2002). Instead of a performance that is dependent on the internal functioning of linked components, which interact but are not co-determinate, both individual and environment have the potential to be impacted and transformed by the interactions. The ecological dynamics approach that may be initiated with Bronfenbrenner’s bioecological model (Bronfenbrenner & Morris, 2006) views dynamics as dominated by these interactions, by highlighting the capability for self-organization and expression of emergent properties. Apart from exhibiting this organismic asymmetry (Dunwoody, 2006) at a meta-theoretical level the studies of Weissensteiner et al. (2008, 2009) provided important evidence for the role of informal environmental constraints on the development of sport expertise.

In highlighting this issue in their work, we draw attention to Bronfenbrenner’s views about the environment, in which he emphasises the interactions between the individual and the behavioural process, along historical and personal timescales (see Figure 1). Therefore, examples from the existing literature about the nature of environmental constraints on the acquisition of expertise, particularly related to Brazilian football, are interpreted with insights from the bioecological model. In 1979, Bronfenbrenner conceptualized the environment in terms of nested systems: the microsystem, mesosystem, exosystem and macrosystem. These nested sub-divisions form the basis of our exposition in the following section of the paper.

**Bronfenbrenner’s Microsystem**

The foundation of the bioecological framework is the microsystem, defined as a pattern of activities, social roles, and interpersonal relations experienced by the developing person in a given setting with particular features that influence engagement with the immediate environment. Therefore, effects of the physical environment in football, such as the quantity and the quality of practice, facilities, types of surfaces, or ball materials afford exploration that influences development. This topic is explored on this article using Brazilian football practice as a task vehicle to show how uncommon, even aversive, social and self-generated exploration can be.

Previous research has proposed the importance of the power law of practice as the basis for performance improvement (Newell & Rosenbloom, 1981). Although this apparent power law characteristic of practice has been exposed as an artefact of group analyses, more recently, it has been argued that the amount of deliberate practice – intense practice requiring concentrated effort to specifically improve performance – is predictive of expertise attainment (Ericsson, Krampe, & Tesch-Römer, 1993; Ericsson, 2007). Other work has suggested that it is not simply the total amount of practice that is important, but also the nature of experiences during practice that is critical to the acquisition of expertise (Côté, Baker, & Abernethy, 2007). It has been observed that experts do spend more time overall in practice, but also devote more time participating in specific activities which are most relevant for developing essential skills for the highest level of performance. Recent evidence (e.g. Côté et al., 2007) in several sports suggested that although deliberate practice may be critical, so too may be exposure, during development, to many hours of games that resemble sports – the concept of deliberate play (Côté & Hay, 2002). Deliberate
play consists of activities, such as “street matches/backyard games”, that encourage adaptive skill, creativity and improvisation and role-playing rather than pure sport skill repetition, where enjoyment rather than skill improvement, is the main participant motive. This idea fits with data from long-term studies of Soviet and Russian swimmers demonstrating that athletes with better results in international adult competitions undertook smaller training volumes and had poorer results in age-group competitions when younger (Barynina & Vaitsekhovskii, 1992; Bulgakova, Popov, & Partyka, 2002; Platonov, 1994).

The approach advocated by Ericsson and his colleagues (1993), where expertise is simply the end result of amassing a putative number of hours of deliberate practice, has come under some criticism. For instance, this approach reinforces the idea that specialization during early stages of development is necessary in order to attain elite performance as an adult. Early specialization is defined by an early start age in sport, an early involvement in one sport, an early involvement in high intensity formalised training, and an early involvement in high competitive sport (Baker, Cobley, & Fraser-Thomas, 2009). In fact, the early specialization approach has also been associated with several negative consequences in developing athletes (Baker, 2003), including the risk of burn out and dropping out of sport (Petlichkoff, 1993, see also Côté, Baker, & Abernethy, 2003). Moreover, there have been some inconsistent associations between early specialization and expertise acquisition (see Baker et al., 2009). Research indicates that sport is not the only domain where these inconsistencies have been observed. In the music domain there is a growing interest in informal learning that, according to Wright and Kanellopoulos (2010, p. 73), is defined as an “attempt to be immersed in intense situations of non-formal learning, and therefore results in the creation of non-traditional social learning environments, combining interactive, non-linear and self-directed processes”. Moreover, qualitative data have indicated the existence of more than the one (i.e., traditional) route for music learning (Cope, 2002) and evidence suggests that musicians combine formal and informal learning strategies in their practice (Folkestad, 2005). Folkestad (2005) highlighted that in formal learning situations, both teacher and student are directed towards how to make music, whereas in the informal learning situations musicians are directed towards how to play music, raising the question of: should performers “learn to play or play to learn?” It seems that the relationship between practice and proficiency is more complex than originally thought, and depends on more than simply assessing the number of hours spent deliberately practicing.

There is some indicative evidence for the success of players who have received little systematic coaching. For instance, as stated by Salmela and Moraes (2004), Brazilian Football is quite intriguing, since many players aged 16 to 17 years, have received little, or any, structured coaching, in contrast to a multitude of unstructured football experiences played on the streets. Fonseca and Garganta (2008) interviewed elite players, elite coaches and sport scientists, in order to garner perceptions about the implications of unstructured football played on the street for game skill learning. In general, elite players revealed that they had widely experienced unstructured street football from very young, and they considered this type of activity at least as important as structured training, undertaken in later years. Moreover, all the interviewees corroborated the perception that unstructured football played on the street improved skill learning. The pleasure and the passion that a child gains from playing football and the possibilities for exploration, creativity and goal achievement under unpredictably variable performance conditions, were considered essential for developing football expertise. Players interviewed also considered that unstructured street football allowed them to become familiar with assorted features of the game, because it is feasible for players to try many skills in different conditions without fear of ridicule or recrimination from observing coaches. According to Rinus Michels (2001), designated by FIFA (Fédération Internationale de Football Association) as the Coach of the Twentieth Century, unstructured football played on the streets is a most natural learning environment. He argued that it is played daily in a
competitive form, under all sorts of conditions. He noted that, it is rare to see young players busy practicing isolated technical or tactical drills in an explicit way. On the contrary, learning almost always occurs implicitly within the competitive form of the street game, where children can learn from their mistakes, unaware of the technical, tactical, psychological and physiological abilities they are developing through their less formalized scrimmages. Indeed many generations of world-class Brazilian football players have mentioned the value of their early specialization in football through exposure to enjoyable, uncoached and unconventional practices. Importantly, their early specialization is in agreement with the definition of Baker and colleagues (Baker et al. 2009). However, these experiences contrast with traditional practices, mainly because of its variable, unstructured way of practicing, with high intensity, from an early age, and with an abundance of unplanned competitive situations (see Table 1). This kind of practice also differs from the notion of “deliberate play” highlighted earlier (Coté & Hay, 2002), in that these activities were not games that resembled football, but they were real football experiences practiced under changing ecological constraints. Similarities in the nature of the specific task goals, as well as a number of rules and conditions for that activity, were such that players and observers perceived that a football match was being played. These insights suggest a role for non-deliberate practice (or play) in expertise development, since these practices socially emerge and their purpose is not performance improvement per se, but intrinsic motivation and achievement (Araújo & Davids, 2009, Baker et al., 2009). As can be seen, Brazilian cultural constraints provide a rich and stimulating context for illuminating evidence on acquiring expertise in football (see Table 1). In this respect, an important activity practiced by all Brazilian footballers is pelada.

In the Brazilian football context pelada provides variable practice experiences (“nude” is a direct translation, perhaps alluding to the “naked” environments where these football games occur). It is the cultural term used to describe football played with adapted norms and rules in a variety of locations – such as streets, beaches, town squares, yards, courts and dirt fields (Fonseca, 2007). Pelé said of pelada that: “It is necessary to grasp these opportunities with one’s fingernails. All those experiences, and that conviviality, helped me a lot in my preparation” (Manual do Atleta Inteligente, 2008, p. 48, our translation).

Table 1. Quotes From World Class Brazilian Football Players Identifying the Value of Their Early Specialization in Football by Means of Unstructured, Non-Coached and Enjoyable Practice (Our Translation)

| Sócrates n/d | We started playing football on the street with an avocado seed (...) the fact that I had learned this way was excellent. When you play in orchard, with irregular surfaces and surrounded by trees, there is a need for developing a bunch of abilities in order to prevent injuries. To not get hurt, and to you’re your eye on the look to the ball and on the game, we also needed to keep an eye out for the mango trees and their roots on the ground. |
| Zico in Assaf & Garcia, 2003, pp. 28 | I used to spend my whole day with the ball. Sometimes I made little sock-balls and sometimes I played with those rubber balls. I threw it at the wall and then I tried to master the ball alone in my room. Sometimes, I played as a goalkeeper and all those things gave us reflexes. Maybe, a portion of my ability is a result of all these practices. |
| Castro, 1995, pp. 38, Castro wrote Garrincha’s biography | Dribbling the ball barefoot, without twisting or damaging your ankle on uneven surfaces is a considerable feat in itself. Dribbling on the border of a slope and not allowing the ball to drop down was another great challenge. Garrincha performed both of these tasks in a very easy way. After losing control of the ball on the uneven surface so often he learned how to dribble on uneven surfaces and against the opponents. Garrinha really hated to go down a slope to retrieve the ball – so he tried not to let it drop out of control down there. |

Garrincha was a Brazilian right winger and forward who helped the Brazilian national team win the World Cups of 1958 and 1962. FIFA considers him the best Brazilian player ever after Pelé. He is also widely regarded as the best dribbler in football history.
In a sample of 93 Brazilian woman elite players, Rosa, Costa, and Navarro (2009) identified the surfaces for football practices before and after players had reached 14 years of age. Findings are described in Figure 2.

In Figure 2 it is clear that all the contexts involved high levels of practice until 14 years of age. Moreover, the highest levels were associated with practice on streets and courts (i.e., futsal). The only surface more prominent in practice after 14 years of age is grass. Importantly, even after 14 years of age, players continue to be engaged in futsal, playing on cement and wooden surfaces, continuing their early diversification. However, this is not a diversification achieved by practicing a range of different sports (Baker et al., 2009; Côté, 1999). This experience exemplifies a ‘diversification within specialization’ in football.

Futsal is a 5 vs. 5 version of football that is played officially on indoor courts (FIFA official area is 40 m x 20 m). However, it is also played in unofficial ways outdoors on courts of different sizes. Its roots are associated with the scarcity of available football fields in the 1930s, with games taking place on empty basketball courts and other small-sized areas (Fonseca 2007; Tolussi, 1982). Futsal has been seen as another major contributor to the development of Brazilian football players, particularly in football schools. In 2002 (i.e., the last time Brazil won a World Cup) at least eight of the eleven players on the pitch, of the Brazil National Team, practiced Futsal (Fonseca, 2007). In a sample of 186 young male football players, Marques and Samulski (2009) found that 80.6% had played futsal. Rosa, et al. (2009) reported that, in a sample of 93 elite woman football players, 97.85% had played futsal. Thus, pelada is a broad description for the diversification of football practice task constraints. To better illustrate the pelada’s context, Table 2 summarizes the descriptions found in Freire (2006), Scaglia (1999, 2005), Silva and Chaveiro (2007), as well as Cabral and Neves (2007).

As observed in Table 2, pelada contrasts with traditional practice through unique constraints like: (i) its irregular surfaces (e.g., changing size, changing type, changing slopes), (ii) its competitive balance where players change from one team to another independent of the number of players in each team, their gender and their age to provide equitable competitive conditions, and (iii) its unplanned time schedule, and unpredictable
Table 2. Environmental and Task Constraints That Characterize Brazilian Pelada (See Text for References)

<table>
<thead>
<tr>
<th>Constraint</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local of practice</td>
<td>Street, beach, court, dirt-fields, formal fields, backyards or any available space. Different surfaces and conditions can generate different variations of football games.</td>
</tr>
<tr>
<td>Field dimension</td>
<td>Tacit, undefined and variable. The pitch can be constantly adjusted through implicit agreement amongst players, based on player's suggestions or to adjust to the particularities of the task, or of the local (e.g., before the building).</td>
</tr>
<tr>
<td>Facilities</td>
<td>Stones, shoes or bags are used as posts, and goal sizes can be modified according to the game. Game can be played with any kind of ball or something able to be kicked. Uniform can be t-shirts versus shirtless. Players also often are playing barefoot.</td>
</tr>
<tr>
<td>Team conditions</td>
<td>Adaptive and versatile. The number of players is adjusted to keep ongoing challenge, fun and well-balanced levels of competition. It can happen with different age-groups and gender playing together, with numerical disparity and different levels of ability.</td>
</tr>
<tr>
<td>Intervention</td>
<td>No coach or instructors intervention. Learning happens among players, who usually try to replicate skills performed by elite players or skilful friends.</td>
</tr>
<tr>
<td>Functions and tactical positions</td>
<td>There are no fixed positions or tactical arrangements. A player can change position or function many times during the game. And the actual game might help players arrange themselves in defensive and attack movements and positions.</td>
</tr>
<tr>
<td>Targets</td>
<td>Replicate the same technical movement or skill performed by a famous player. Try to execute something new or in a new way. Have fun with friends. Maintaining high levels of competition and challenges as criteria for the continuity of the game, besides winning.</td>
</tr>
<tr>
<td>Training sessions</td>
<td>The game happens until a number of goals have been scored, reach a set time or even players get tired or lose fun and enjoyment. During a whole day, the game might be stopped many times and restarted in an old or new configuration.</td>
</tr>
</tbody>
</table>

Break times. From these findings it can be noted that Brazilian football players experience a range of games, contexts, surfaces, and cultural situations. Also it is evident that, when compared with experiences of higher social classes in other developed countries, the development of expertise occurs in apparently aversive contexts and follows different "norms" in local contexts. In Brazilian culture, it is clear that early specialization in football, developed through unstructured practice, without coaching interventions and full of fun and enjoyment, is possible.

At Bronfenbrenner's microsystem level, some of the secondary influences on behaviour (Baker & Horton, 2004) should also be considered at this level, such as coaching (Davids & Baker, 2007), interaction with peers and relative age effects (Musch & Grondin, 2001).

**Bronfenbrenner's Mesosystem**

Beyond the microsystem, the mesosystem is defined as comprising the relationships existing between two or more settings (i.e., microsystems). This level constitutes the family environment, or activities in the wider sport club beyond just training. (e.g., social and community activities). Importantly, parents play a critical role in promoting the athletic development of their children. Côté (1999) noted that athletes undergo stages of development and that resources provided by parents shift as athletes mature. Pelé, considered the best footballer ever, once observed that:

> My first experiences with the ball were promoted by my father. Since I was a boy he taught me some tricks and motivated me to perfect my natural talent. It was him who encouraged me to improve the heading skills and to kick with the left leg. If you don't work hard you will get nothing, said my father. (Manual do Atleta Inteligente, 2008, p. 46, our translation)

**Bronfenbrenner's Exosystem**

The next level of Bronfenbrenner's framework is the exosystem which comprises the linkages and processes between two or more settings. In these settings events occur that indirectly influence processes within the immediate setting (i.e., the microsystem) of the developing individual. A good example in sport involves certain aspects of the
demographics of expertise, such as birth location of the athlete. Consider the existence of locations without available places for practice. This may happen due to urban and geographical constraints. In these cases, if children want to practice they either have to travel to other locations with appropriate facilities or they have to use local unconventional facilities/surfaces to acquire skill, for example, when playing football on the slope of a hill, or in a middle of a street where cars and people are constantly passing. Locally, learners can engage in this type of practice whenever they want. In other regions, the saturation of practice locations, such as the fields of the local professional team, promotes the discovery of other surfaces for other players to practice (e.g., a tennis court or a small garden). In fact, evidence suggests that the size of the city in which an athlete develops may influence their likelihood of attaining elite level performance (Carlson, 1988). Individuals growing up in rural areas and smaller towns and cities have a higher probability of becoming professional athletes than those growing up in large cities, even though the latter may have access to superior sport facilities and more highly organized junior sport competitions. Côté, MacDonald, Baker, and Abernethy (2006) found that the optimal city size for athletic development appears to be between 1,000 and 500,000 people. This effect may be due to the possibility of developing athletes in smaller communities receiving more social support, and having available a greater amount of safe recreational space (Davids & Baker, 2007).

**Bronfenbrenner’s Macrosystem**

This is the highest level in Bronfenbrenner’s systemic approach and can be described as the broad socio-cultural context for the developing individual (e.g., national sport culture). The bioecological model indicates that the analysis of expertise acquisition is based on an intricate network of influences, which is somehow missed if we simply assume them as primary and secondary influences on sport expertise (Baker & Horton, 2004).

Contrasting with data from studies conducted in the US, Canada, Australia, and parts of Europe, Salmela and Moraes (2003) suggested different roles of coaching, families and cultural contexts for the development of expertise in countries with emergent economies and extensive lower socioeconomic classes, such as Brazil. Despite attempts to identify and organize the constraints for adequate long-term expertise development in young athletes, we know little about the role of macro environmental constraints. In a series of papers, Salmela and colleagues (e.g., Marques & Salmulska, 2009; Salmela, Marques, Machado, & Durand-Bush, 2006; Moraes, Rabelo, & Salmela, 2004; Moraes, Salmela, Rabelo, & Vianna, 2004; Salmela & Moraes, 2003) analysed experiences of Brazilian football players showing that, at junior level, the developmental pathways of squad Brazilian footballers (U18) differed from those of National squad footballers of other countries (Visscher, Eiferink-Gemser, & Lemmink, 2009). The main differences were the more typical absence of familial support, specialized coaching, and adequate facilities in Brazil. Moreover, these players dedicated childhood time practicing football to the detriment of other activities, and they saw sport rewards as a possible path to improve their social standing and support their families. According to the Brazilian footballer Didi, one of the best midfielders of the world, “the boy who has an easy life doesn’t have a chance in football because he doesn’t know the value of a plate of food” (Manual do Atleta Inteligente, 2008, p. 47, our translation). Pelé also commented:

> My father was a football champion in 1946, but three, four years later he broke his knee and we started to have difficulties at home. My father was always my great idol, and I was observing his decline. At 13 years of age I had to work to help my family. I went to sell newspapers, to polish shoes and I thought that I wanted to be the same as my father; therefore, I was too much devoted to this work. When I worked in a boot factory I thought about abandoning the dream of being a player but all those difficulties helped me a lot to understand life and to value it. We were “hungry for playing”; I always put my heart into my football boots. (Manual do Atleta Inteligente, 2008, p. 47, our translation)

The narratives of Brazilian sportswriter Rodrigues Filho (2003) have highlighted that, since the introduction of football in the 1930s, Brazil has experienced two antagonistic
contexts of learning and practice. He described the experiences of higher social classes who played on manicured grass fields with many facilities and specialized instruction involving British coaches and Brazilian students recently graduated in Europe. Rodrigues Filho (2003) contrasted those experiences with that of the lower social classes, without access to football academies, coach education, and adequate material facilities. Consequently, they were compelled to produce their own footballs (e.g., sock balls) and play on the streets or fields of mud and stone, trying to express what they had seen at the professional games, changing the movements into new movement forms. Players from these lower social classes began to be accepted at small football clubs of higher classes, performing more skilfully than players from the football academies.

Bronfenbrenner's Interactive Dimensions

For Bronfenbrenner (2005), the power of developmental forces operating at any one system level of the environment depends on the nature of structures existing at the same or higher levels of the system. Bronfenbrenner (e.g., Bronfenbrenner & Morris, 2006) considers the joint interaction (i.e., the process) of the person with the environment over different timescales. This aspect helps, not only in organizing extant knowledge about sport expertise, but also in the search for environmental variables at different levels of analysis (micro, meso, exo and macrosystem). It considers different time scales (micro, meso and macrotime, both from a personal and from a broader historical perspective), the characteristics of the person, and the interactive nature of development (i.e., the process, Bronfenbrenner & Morris, 2006). Importantly, this model is more a framework for organizing knowledge than a theory of sport expertise. To this end, a joint perspective of Gibsonian ecological psychology and dynamical systems theory, the ecological dynamics perspective, is promising with respect to explaining the interaction of constraints at an ecological scale (Araújo, Davids, & Serpa, 2005; Araújo, Davids, & Hristovski, 2006; Davids & Baker, 2007, Phillips et al., 2010).

The influence of environmental constraints on non-experts’ development is not clear. This is a critical issue, since it is not clear whether there are some athletes experiencing similar environmental population constraints who may not achieve expertise. It may be possible that athletes from very different cultural backgrounds may achieve expertise in different sports and physical activities (Salmela & Moraes, 2003). An implication of Davids and Baker’s (2007) review for understanding individual variations in sport performance is that there may be diverse pathways to achieve the same performance outcome levels (see also Phillips et al., 2010).

Conclusion

Recent research has begun to highlight the role of environmental constraints on the development of sport expertise. The importance of putative secondary influences is being investigated, by considering the influence of cultural importance, instructional resources, familial support, sport maturity, and depth of competition (Baker & Horton, 2004). However, more than intuitively exploring the environmental constraints that may have an influence on the development of expertise, Bronfenbrenner’s bioecological model (e.g. Bronfenbrenner & Morris, 2006) guides and organizes this search for influences. In this case, we can observe evidence for the influence of not so intuitive constraints, such as those environmental constraints found in Brazilian football. This finding means that Brazilian football is not an exception that contradicts past findings, but that a broader theoretical view should be taken in order to contextualize past findings in their ecology. Intercultural programs of research are much needed in order to further address this issue, and it is firmly argued that without situating research findings in their ecology, an over-generalization of what “appropriate” training environments are may occur. In this paper, experiential knowledge of world-class footballers was examined showing how expertise can be achieved with little formal coaching, without material facilities, and with little parental support. Early specialization involving football type experiences and activities,
without a coach to structure training, played an important role in skill acquisition. In this paper we argued that a different kind of early specialization exists, not based on precise repetition of movement drills in structured practice tasks, but rather on a huge variability of constraints encountered during self-generated, non-guided discovery learning during play. In these practice environments, skill acquisition emerged from the athlete's continuous adaptation to uncertain constraints. In this way, a broad range of early specialization is developed. These findings contrast with perspectives on the development of expertise through deliberate practice by Ericsson and colleagues (Ericsson et al., 1993). In pelada, Brazilian players undertake a variety of different activities with the ball and feet, not just official, structured football. These observations cannot be considered deliberate play, either. They are not activities that resemble sports, they are real football experiences under changing ecological constraints. However, the qualitative data fit with findings from the studies of Côté and colleagues (e.g., Côté et al., 2007), who noted that players can specialize very early in 'feet-ball activities', but in the Brazilian case, the activities have a direct correspondence to organized football.

Finally, the important, constraining characteristics of learning environments like the pelada provide ideas on the design of practice constraints in modern sport development programs. Some key characteristics of learning design include: (i) not relying on formalised games and training drills all the time; (ii) designing fun and enjoyment (rather than work as in deliberate practice) into programmes; (iii) creating learning environments that encourage search, discovery and exploration in movements; (iv) enhancing adaptive behaviours by creating opportunities for learners to satisfy different constraints (playing in different weathers, against different age groups, gender, number of players, etc); (v) varying equipment and facilities for practice, sometimes keeping the environment very simple and uncluttered, varying surfaces, footwear, ball types; (vi) not conceptualising an idealised target movement pattern as 'the' way to perform a skill; (vii) making sure that skill practice is 'repetition without repetition'. But can talent development programs change their practice to harness principles of unstructured play to ensure that learners are open to the influence of informal environmental constraints? Family support, facilities access and other environmental constraints need to be considered as integral constraints on expert performance and development of expertise. An important part of exhibiting expert performance involves understanding how to act in a manner that reflects the sociocultural context (Araújo, 2007). The performance of an expert should be conceived as being influenced by an interaction of individual, environmental and task constraints (Davids, Button, & Bennett, 2008). Ecological constraints such as quantity and quality of practice, significant others' influence, coaching, available facilities and so on, may exert a deliberate or an implicit influence, and both types of influences have a nonlinear impact on the development of expertise. Only through acknowledgement of the ecological nature of expertise development, guided by a theoretical framework such as Bronfenbrenner's bioecological model (e.g., Bronfenbrenner & Morris, 2006), can meaningful practice contexts be designed.

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Relative Age and Birthplace Effects in Division 1 Players – Do They Exist in a Small Country?

Ronnie Lidor¹,²*, Jean Côté³, Michal Arnon¹, Aviva Zeev¹ and Sara Cohen-Maoz¹

Abstract: This study examined the existence of two factors associated with achieving a high level of proficiency in sport – the relative age effect (RAE) and the birthplace effect. Information on these effects was collected from 521 male players playing for various Division 1 ball clubs in Israel (the highest division in the country): 68 basketball players, 161 handball players, 209 soccer players, and 83 volleyball players. Three main findings emerged from the data analyses: (a) RAE did not exist in the studied ball games, (b) a birthplace effect was observed in soccer, handball, and volleyball, but not in basketball, and (c) the birthplace effect was not found to be associated with cities of a similar size. It is proposed that a sport- and culture-specific approach be adopted when examining environmental factors associated with sport expertise in countries with a small population such as Israel.

Keywords: sport development, elite athletes, relative age effect, birthplace effect, ball-game activities

A number of genetic and environmental factors associated with achieving a high level of proficiency in the domain of sport have been reported in the literature on talent development and expertise (for reviews see Baker & Horton, 2004; and Davids & Baker, 2007). Among the genetic factors are psychological traits (e.g., the motivation to excel or the ability to cope with failure), the structure of the skeletal muscles, and the skeletal muscle energy system. Among the environmental factors are the quality of the training program, the coaching, and family support. It is assumed that each factor, as well as the interactions among the factors, influence the chances of an athlete to achieve a high level of excellence in sport.

Two factors that have recently been studied and were found to influence the likelihood of achieving a high level of sport performance are (a) relative age (the Relative Age Effect, RAE) of the prospect (when the prospect was born), and (b) place of birth (the birthplace effect; where the prospect was born or where he or she grew up during their developmental years, namely up to about 14 years of age; see Baker & Logan, 2007; Baker, Schorer, Cobley, Schimmer, & Wattie, 2009; Côté, MacDonald, Baker, & Abernethy, 2006; MacDonald, Cheung, Côté, & Abernethy, 2009).

The RAE implies that individuals who are relatively older than their peers in a given cohort/year, or that their birthdate is closer to the cutoff date for their age group classification, are more likely to have better achievements (Musch & Grondin, 2001; Wattie, Cobley, & Baker, 2008). Studies on elite athletes in baseball (Grondin & Koren, 2000), junior ice hockey (Baker & Logan, 2007), soccer (Musch & Hay, 1999), and youth handball (Schorer, Baker, Lotz, & Büsch, 2010) provide support for the RAE by showing that those athletes who were born early in the competition year had a greater representation than those who were born late in that year.

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http://www.iratde.org
Two arguments have been suggested to account for the RAE (see Baker & Logan, 2007; MacDonald, Cheung et al., 2009). First, older athletes are probably more experienced than younger athletes in various motor-physical abilities such as balance, coordination, speed, and strength, and therefore they perform better in these sport skills. Second, the older athletes in a cohort/year are more likely to be selected to better teams, and therefore are provided with guidance and training superior to that of the younger athletes, who practice with the lower-skill level athletes and might be exposed to lower-quality training conditions. This more advanced training, as well as an enhanced supportive environment, probably enable the older athletes to improve their motor-physical abilities and sport skills to a greater extent than the younger athletes.

The second factor – the place where the athlete was born – has been investigated in a number of studies on male players in professional baseball, basketball, golf, and hockey (Côté et al., 2006), football (MacDonald, Cheung et al., 2009), and junior ice hockey (Baker & Logan, 2007), as well as on female elite performers in soccer and golf (MacDonald, King, Côté, & Abernethy, 2009). Findings from these studies showed that male athletes who were born in cities of less than 500,000 people, and female athletes who were born in cities of less than 1,000,000 people (for soccer) and 250,000 (for golfers), were more likely to play for professional leagues and attain a high level of sport competition than athletes who were born in larger cities. Although these studies suggested that elite athletes are less likely to come from very small or extremely large cities, it was reported in one study that exceptions may occur both within and across sport contexts (Baker et al., 2009). When comparing the distribution of Olympians from Canada, the USA, the United Kingdom, and Germany according to region size, Baker and his colleagues (Study 1) found distinct differences between countries. For example, compared with US Olympians, Canadian Olympians were about four times and two times more likely to have been born in regions with a population of 500,000 to 999,999 and 1,000,000 to 2,499,999, respectively. In another case in Study 1, compared with US Olympians, UK Olympians were approximately six and three times more likely to have been born in region sizes of 100,000 to 249,999 and 250,000 to 499,999 persons, respectively. The authors of this study suggested that socio-cultural factors influenced the results obtained from their comparisons.

Although large cities can provide children with enhanced conditions such as well-designed and equipped sporting facilities (e.g., arenas, fields, and swimming pools) and more experienced coaches, it appears that athletes who are in their developmental years can benefit much more from living in a smaller place. MacDonald, King, and their colleagues (2009) suggested that "... the developmental opportunities for nurturing sporting talent offered by small towns and cities may be somehow superior to the development opportunities of larger cities" (p. 234). Among the developmental opportunities that may be superior in smaller cities are (a) a greater amount of independent mobility and physical safety, (b) an integrative approach to sport participation involving schools, families, and the community at large, and (c) a more personal relationship between athletes and coaches.

The abovementioned conditions, which are found in cities of small size, may be the most favorable for young athletes to develop their abilities and skills. However, living in a small city may be also a disadvantage for some children who have an interest in sport activities. For example, children who live in a small city that offers only a limited number of sport programs, due to sport policy or budgets constraints, may not be able to find their preferred sport activity and could decide not to be involved in any sport activity.

Based on studies on the RAE and the birthplace effect, two main observations can be made. First, data were mainly collected on athletes who practiced and competed in places like Canada (e.g., Baker & Logan, 2007; Côté et al., 2006), Germany (Schorer et al., 2010), the USA (e.g., Côté et al., 2006), and the United Kingdom (e.g., Musch & Hay, 1999), where sport is perceived as one of the major foundations of the national culture. That is, youngsters in these countries are encouraged to participate in sport, and in turn this participation is reinforced by their families and the community at large (Baker, 1988;
Coakley, 2004). Second, data were obtained on individuals who were born in countries with a large population (e.g., Germany, the United Kingdom, and the USA) or a large geographical area (e.g., Canada).

So far the RAE and the birthplace effect have not been examined extensively in elite athletes who practice and compete in small countries with characteristics such as a small population and/or a limited geographical area. Smaller countries in terms of population or geographical area present unique environmental conditions, such as the relatively small distances between the living areas and the sporting facilities, for the development of talent in sport, but have received little attention from researchers. Therefore, examining the existence of the RAE and the birthplace effect in small countries may increase our understanding of their transferability across countries of different characteristics, sport cultures, and sport development systems. In this respect, a number of points associated with talent development in small countries should be taken into consideration, among them (a) the low number of children involved in sport activities – Since the number of children is relatively low in countries with a small population, and not all of them show interest in sport activities, coaches are required to be more flexible in their selection process, at least in its initial phases, and may not rely only on the strongest and fastest individuals born in a given year; (b) the lack of competition for the number of places in a given sport – Since the number of children who show interest in sport activities may be low, there is a lack of competition for the number of available places in the sport activity. This lack of competition compels the coach to also make his or her selection from among children who are not necessarily advanced in their physical development. In addition, the lack of competition can serve as a moderator for the RAE in small countries (Musch & Grondin, 2001; Schorer, Cobley, Büsch, Bräutigam, & Baker, 2009); (c) the short distances between small cities and large cities – geographical distances are less significant in small countries compared with those in large countries, so that talent may be effectively developed not only in small- to medium-sized cities, as found in the studies on the birthplace effect, but also in large cities. Athletes can live in a large city and practice in a small place, and vice versa.

The purpose of this study was to examine the RAE and the birthplace effect in professional and elite players in basketball and soccer, and semi-professional players in volleyball and handball, in Israel – a small country in terms of the size of its population (less than 7,000,000 people; State of Israel – Central Bureau of Statistics, 2009a) and limited geographical area. Data were collected on all players who were on the rosters of these professional and semi-professional teams during one season.

The different status of the players – professional (basketball and soccer) and semi-professional (handball and volleyball) – reflected their status only as elite adult players. At the beginning of their sport involvement, all players in each of the ball games went through similar developmental pathways. Supervised sport activities for children and youth are offered and organized by structured clubs, located in every city around the country. This means that sport in Israel is not organized by the school system but by these clubs, which are financially supported by the Ministry of Sport (Lidor & Bar-Eli, 1998). The clubs offer their activities only after school hours and during holidays.

Players are required to go through three phases until they reach the professional level (for basketball and soccer) or the semi-professional level (for volleyball and handball). These developmental phases were determined by the national federations of basketball, soccer, volleyball, and handball in order to provide children and youth in Israel with the optimal instructional settings to develop their talent. In general, there are three phases of sport development. In Phase 1 (recreational and fun activities for about two years) children aged 6–8 typically are engaged in recreational sport activities, focusing on playing games for fun as well as on acquiring basic fundamental motor skills (e.g., passing, catching, and kicking). No competitive events are scheduled in Phase 1.

In Phase 2 (competitive leagues for children for about five years) children are encouraged to participate in competitive teams which typically practice three to four times per week
and play one league game each week. Phase 2 is composed of separate leagues for children at the ages of 9–10, 11–12, and 13–14 years. The children who took part in Phase 1 are encouraged to join the 9–10 year-old teams. In fact, they are not necessarily selected but rather assigned to teams in order to motivate them to continue their sport participation and development. However, a selection process starts after the children reach the age of 10, namely that only the best players progress from the young league (for the 9–10 year-old players) to the older leagues (for the 11–12 year-old players and then for the 13–14 year-old players). The most talented in the league for the 13–14 year-old children move on to Phase 3.

Phase 3 (competitive leagues for youth for about three years) is composed of two separate leagues: one for 15–16 year-old players and one for 17–18 year-old players. In both leagues, players practice four to five times per week and play one league game each week. In Phase 3, the most talented players also play for the Israeli youth national teams – the 15–16 year-old team and the 17–18 year-old team. Both teams participate in European Championships. The most talented players in the 17–18 year-old league move on to play on the professional level in basketball and soccer or the semi-professional level in volleyball and handball. The less-talented players, who cannot reach these levels of sport competition, play for lower divisions in each sport (i.e., semi-professional divisions in basketball and soccer or recreational leagues in volleyball and handball), play on a recreational basis, or quit the sport activity.

Method

Participants

The RAE and the birthplace effect were assessed in 521 male Israeli-born players who played for clubs that were part of Division 1 in basketball (the league was composed of 12 teams; total number of players $N=144$, among them 68 Israeli-born players), handball (12 teams; total number of players $N=168$, among them 161 Israeli-born players), soccer (14 teams; total number of players $N=308$, among them 209 Israeli-born players), and volleyball (10 teams; total number of players $N=120$, among them 83 Israeli-born players) in Israel. Data were collected on all the Israeli-born players who were on the rosters of the clubs during the 2007–2008 season. The rest of the players on the rosters of the teams were either foreign players (i.e., players who were not Israeli citizens) or players who were Israeli citizens, but were born and grew up out of the country. On average, the basketball players had 15.22 ($SD=2.94$) years of experience playing competitive basketball, among them six years of playing in Division 1 clubs. The soccer players had 17.43 ($SD=3.87$) years of experience playing competitive soccer, among them eight years in Division 1 clubs. The volleyball players had 14.26 ($SD=3.54$) years of experience playing competitive volleyball, including five years of playing for Division 1 clubs. The handball players had 12.72 ($SD=3.32$) years of experience playing competitive handball, including six years of playing in Division 1 clubs.

The games of basketball, handball, soccer, and volleyball are considered to be the most popular sports in Israel. For a description of the sport structure in Israel, see Lidor and Blumenstein (2009). Division 1 is the highest division in each of these sports. The players who play for the basketball and soccer clubs in Divisions 1 are professionals. However, those who play handball and volleyball in Divisions 1 are semi-professional; they do not earn enough from their sport career to support themselves, and therefore are required to work in other jobs. The national teams in Israel are typically composed of players playing at the Division 1 level.

Procedure

Information on the RAE and birthplace effect was obtained from a 5-minute interview conducted with each player by one of four trained graduate students. The interviews took
place either immediately before or after a practice session. Prior to the conduction of the interviews, the managers of each Division 1 club in basketball, handball, soccer, and volleyball received a letter providing the background and objectives of the current study. In addition, the letter requested official permission for the graduate students to attend practices, so that the interviews with the players could take place as planned. All of the club managers approved the study. At the beginning of each interview, the player signed a letter of agreement approving his participation in the research project, after being presented with the objectives of the study. The players were then asked about their birthdate and the place they were born. This process of data collection was performed because the information could not be obtained from the official websites of the relevant sports federations or of the professional and semi-professional clubs.

To examine the birthplace effect, similar procedures to the ones performed in previous studies (e.g., Baker & Logan, 2007; Côté et al., 2006; MacDonald, King et al., 2009) were used in the current study. The city size of the birthplace of each player from each of the four games was based on Israel census data obtained from a demographics website (State of Israel – Central Bureau of Statistics, 2009b). Four categories of city size were used. Two categories of residential size were selected directly from the Israel census data: small villages (population less than 2,000) and large cities (population of above 200,000). The two other selected categories reflected five different categories for small and medium city sizes as they appeared in the Israel census data. Instead of having five different categories for small and medium cities (e.g., cities of 2,000–10,000 people or cities of 50,000–100,000 people), as can be found in the Israel census data, we decided on two categories: small cities (population size of 2,000–50,000) and medium cities (population size of 50,000–200,000). Therefore, the selection of the four categories allowed us to examine the birthplace effect in four sizes of cities – very small (i.e., villages), small, medium, and large.

Since the mean age of the basketball, handball, soccer, and volleyball players was 25.10, 27.21, 25.04, and 26.71 years, respectively (overall mean age $M$=26.31 years, $SD$=5.82), census and demographic data from the year 1987 were used to provide the number of males under the age of 14 who lived in each of the residential size categories. This methodology was used in previous studies on the birthplace effect (e.g., Côté et al., 2006). In the current study, we used the census data presented in 1987 since it was the most appropriate year reflecting the years the players were born. Information was unavailable on the migration between large cities and small cities or between small cities and large cities; however it was assumed that the net movements between large cities and small cities, or between small cities and large cities were likely to be equal.

### Data Analysis

To test the RAE, a Chi-square ($\chi^2$) procedure was performed to determine the significance of deviations for the expected number of birthdates in each quartile of the selected annual season. The birthdate of each player in each sport was recorded to represent his birth quartile (Q). The calendar year for all ball games in Israel is from September 1st to August 31st. The cut-off day of September 1st is unique for ball-game programs available for children and youth in the country; it differs from the cut-off day for the national teams activities, which is January 1st. Therefore, four birth quartiles were designated: Q1=September, October, November; Q2=December, January, February; Q3=March, April, May; Q4=June, July, August. Players who were born in Q1 were considered to be relatively older than those who were born in Q4. The comparison among quartiles was based on the assumption that there is an equal distribution of birthdates across the months of a year (Baker & Logan, 2007; Côté et al., 2006). For the RAE data, effect sizes and the power of the tests were also calculated.

In order to test the birthplace effect, odds ratio (OR) was calculated to determine the likelihood of playing in Division 1 for each city size, and 95% confidence intervals (CI) were calculated around each OR. An OR greater than one (with upper and lower CI-limits
higher than 1) implied that a player born in the given city size was more likely to become a Division 1 player in the given sport than if he were born in any other city size. An OR of less than 1 (with upper and lower CI-limits less than 1) implied that a player born in the given city size was less likely to become a Division 1 player than if he were born in a city of a different size. ORs including the value of 1 within their CI range were not considered to be statistically significant.

**Results**

**RAE**

The frequency and percentage distribution of the players' birth months and the results of the $\chi^2$ analysis are presented in Table 1. The $\chi^2$ showed no significant deviations across quartiles, namely that the frequency and percentage distribution of the players' birthdates in each of the four quartiles were similar. An additional analysis on the RAE across months revealed similar results: no significant differences in the frequency and percentage distribution of the players' birthdates were observed.

**Birthplace Effect**

The representations of the Israeli population, Division 1 ball-game players, and ORs and CIs across cities of different sizes are presented in Table 2. Mixed results were found for the birthplace effect across the sports. For the basketball players, no effect was found across cities of different size. The likelihood to play in Division 1 was similar for players who were born in small or large cities.

For the soccer players, cities with a population of less than 50,000 yielded an OR significantly lower than 1, whereas cities with a population of between 50,000–200,000 yielded an OR significantly more than 1. This means that the likelihood for players who were born in a very small village (i.e., less than 2,000 people) or a small city (i.e., between 2,000–50,000 people) to play Division 1 soccer was lower than for players who were born in a city of a different size. In addition, the likelihood for players who were born in a medium city (i.e., between 50,000–200,000) to play in Division 1 was higher than for players who were born in a city of a different size.

For the handball players, only cities with a population between 50,000–200,000 produced an OR significantly higher than 1. That is to say, the likelihood of playing in Division 1 was higher for players who were born in medium cities than for players who were born in a city of a different size. Different results were indicated for the volleyball players. Cities with a population between 2,000–50,000 showed an OR significantly lower than 1, while places with a population of less than 2,000 people showed an OR significantly higher than 1. The likelihood to play in Division 1 in volleyball for players who were born in a small size city was lower than for those who were born in a city of a different size. Also, the likelihood to play in Division 1 for players who were born in a very small place was higher than for those who were born in cities of various sizes.

**Discussion**

There were three prominent findings in the current study. First, the RAE was not observed in the data collected on Division 1 players in basketball, handball, soccer, or volleyball in Israel. A similar number of individuals from each quartile were selected to the teams; the number of athletes who were born in Q1 (the physically strongest children in the given year) was not significantly higher than that of those who were born in Q4 (considered to be the least physically strong children in the given year). Second, a birthplace effect was found in soccer, handball, and volleyball, but not in basketball. Third, the birthplace effect was found to exist for cities of different sizes, namely that growing up in a medium city was found to be an advantage for the soccer and handball players; growing up in a very small village or a small city was found to be a disadvantage for the soccer players; and for
Table 1. The Frequency and Percentage Distribution of the Players’ Birth Months and the Results of the $\chi^2$ Analysis

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Basketball</th>
<th>Soccer</th>
<th>Handball</th>
<th>Volleyball</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>22 (32.41%)</td>
<td>59 (28.21%)</td>
<td>40 (24.83%)</td>
<td>18 (21.72%)</td>
</tr>
<tr>
<td>Q2</td>
<td>17 (25.04%)</td>
<td>49 (23.44%)</td>
<td>39 (24.27%)</td>
<td>21 (25.35%)</td>
</tr>
<tr>
<td>Q3</td>
<td>16 (23.52%)</td>
<td>56 (26.84%)</td>
<td>36 (22.76%)</td>
<td>22 (26.51%)</td>
</tr>
<tr>
<td>Q4</td>
<td>13 (19.13%)</td>
<td>45 (21.53%)</td>
<td>46 (28.64%)</td>
<td>22 (26.52%)</td>
</tr>
</tbody>
</table>

| Total   | 68         | 209     | 161      | 83         |
| $\chi^2$ | 2.47      | 2.35    | 1.31     | 0.52       |
| $p$     | .48       | .50     | .73      | .92        |
| $\omega$ | .19      | .11     | .09      | .08        |
| Power   | .75       | .77     | .83      | .94        |

Note. Q1: September–November, Q2: December–February, Q3: March–May, Q4: June–August.

Table 2. Representations of the Israeli Population, Division 1 Ball-Game Players, and ORs and CIs across Cities of Different Size

<table>
<thead>
<tr>
<th>City size</th>
<th>Israel population (%)$^a$</th>
<th>Basketball</th>
<th>Soccer</th>
<th>Handball</th>
<th>Volleyball</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>%</td>
<td>OR</td>
<td>CI</td>
<td>%</td>
</tr>
<tr>
<td>&gt; 200,000</td>
<td>19.38</td>
<td>19.12</td>
<td>0.98</td>
<td>[0.44, 2.21]</td>
<td>25.84</td>
</tr>
<tr>
<td>50,000–200,000</td>
<td>34.93</td>
<td>35.29</td>
<td>1.02</td>
<td>[0.48, 2.17]</td>
<td>54.07</td>
</tr>
<tr>
<td>2,000–50,000</td>
<td>33.77</td>
<td>30.88</td>
<td>0.88</td>
<td>[0.41, 1.89]</td>
<td>17.22</td>
</tr>
<tr>
<td>&lt; 2,000</td>
<td>11.92</td>
<td>14.71</td>
<td>1.27</td>
<td>[0.55, 2.97]</td>
<td>2.87</td>
</tr>
</tbody>
</table>

Note. $^a$ Percentage of males under the age of 14 in each of the subdivisions of the 1987 Israeli census. $^b$ Percentage of Division 1 players in 2007–2008 who were born or grew up in each of subdivisions of the 1987 Israeli census. OR: Odds Ratio. CI: Confidence Interval. $^*$ Significant difference.
the volleyball players, growing up in a very small place (i.e., a small village) was found to be an advantage, while growing up in a city of a small size was found to be a disadvantage.

Although the findings from our study on the RAE are in line with data from some previous studies (e.g., Baker et al., 2009; MacDonald, Cheung et al., 2009), most studies conducted on elite sport performers provide support for the RAE (e.g., Baker & Logan, 2007; Côté et al., 2006; Musch & Grondin, 2001; Schorer et al., 2010; Thompson, Barnsley, & Steblelsky, 1991; Wattie et al., 2008), finding that athletes who are relatively older than their counterparts in a given cohort/year enjoy a developmental advantage. Two explanations can be proposed for the lack of support for the RAE in our study. The first one is the small size of the population in Israel, and consequently the relatively low number of children interested in participating in sport activities. Although no information is available on the number of children under the age of 14 engaged in sport activities in Israel, this number would obviously be lower than that in countries with higher populations (e.g., Canada, Germany, the USA, or the United Kingdom). Because only a relatively small number of children in Israel select sports as their preferred activity, the selection process of the coaches is probably more flexible than that conducted by coaches in other countries. This is to say that not only the most mature children in the given year are selected to be on the teams, but also those who may be less mature but are still considered as possessing a potential for future attainments. We suggest that because of its small population and limited opportunities for participation in sport, children in Israel do not get selected or "de-selected" for participating in sport according to their physical maturity.

From another perspective, coaches are able to select children who are not necessarily advanced in their development, since only a small number of children are competing for the available number of places in the sport activity. It has already been suggested that the lack of competition can serve as a moderator for the RAE (Musch & Grondin, 2001; Schorer et al., 2009).

The second explanation is the "open door" policy adopted by most of the clubs in the country. Ball games are considered to be the most popular sports at both the youth and adult levels in Israel (Lidor & Bar-Eli, 1998; Lidor & Lavyan, 2002). Since relatively few children participate in sport activities, clubs in each ball game struggle to recruit children for their specific sport. In essence, each club is competing with the other clubs to recruit more children. In general, the policy of the clubs is to enable a child who shows an interest in a particular ball game to join the team. The assumption of the sport policy makers is that those who are talented and motivated to excel will remain in the program for a longer period of time, and thus their abilities and skills will improve. In contrast, those who have less talent and are not highly motivated to achieve will eventually drop out.

This "open-door" policy also reflects the educational foundation of the policies of the sport development system as adopted by the sport clubs in Israel, at least in the first two phases of the system – Phase 1 (recreational and fun activities) and Phase 2 (competitive leagues for children). Children involved in these phases are encouraged to continue their sport experience, even though some of them do not demonstrate the physical attributes required to achieve in sport. It is assumed that this policy enables those who are considered to be "late bloomers" to continue their sport participation, and be part of an effective training environment with highly qualified coaches. Indeed, dropping out often occurs in the period from Phase 1 to Phase 2, however this is mainly the result of a decision made by the child and his or her family, and not by the coach:

When examining the number of years those players who reached the Division 1 level in basketball, soccer, volleyball, and handball played in this division, it can be observed that they had been playing at this level for a number of years – six years for the basketball players, eight years for the soccer players, five years for the volleyball players, and six
years for the handball players. Taking into account the mean age of these players (i.e., mid-twenties), it is assumed that they can continue playing in this level for at least several more years. It is also speculated that the "open-door" approach adopted by the ball clubs in the country, particularly in Phase 1 and Phase 2 of the system, may have helped some of the players reach the professional and semi-professional levels, and consequently maintain their activity at this level of performance for a number of years.

The cut-off date for ball-game programs available to children and youth in Israel (i.e., September 1\textsuperscript{st}) is different than the one for national teams (i.e., January 1\textsuperscript{st}). This mixture of cut-off dates is probably one of the reasons for the absence of the RAE in the elite ball players examined in our study. It is assumed that coaches who worked with players who reached Phase 3 of the three-phase developmental programs also considered the needs of the national teams.

Our data on the birthplace effect in soccer and handball are consistent with the data presented in previous studies. For example, it was found by Côté and colleagues (2006) that the optimal city size for the development of young athletes was between 1,000 and 500,000 people. An optimal city size of less than 500,000 people for talent development in sport was also found by MacDonald, Cheung et al. (2009). In our study, the likelihood of the soccer and handball players who were born in cities of 50,000–200,000 to reach the level of Division 1 was higher than those who were born in a city of different size. In addition, as indicated by Côté et al., growing up in too small a place (less than 10,000 people in Côté et al.'s study and less than 2,000 people in our study) could be a disadvantage, at least for the soccer players in the current study.

However, our data on the basketball and volleyball players are not consistent with previous data on the birthplace effect. While Côté and colleagues (2006) found that the likelihood of playing professional basketball was higher in those who were born in small cities, we did not find any advantage/disadvantage in the Israeli basketball players who were born in either small or large cities. For the volleyball players, we found a birthplace effect; growing up in a very small village (less than 2,000 people) was found to be an advantage, while growing up in cities of 2,000–50,000 was found to be disadvantage. These data are also in contrast to our own data on the handball players, and partially for the soccer players. In this respect, it was found by Baker et al. (2009, Study 1), examining the birthplace effect in Olympic athletes from Canada, Germany, the United Kingdom, and the USA, that there was some consistency suggesting that Olympic athletes are less likely to come from very small or excessively large cities, but exceptions could occur both within and across sport contexts. The data obtained in our study primarily showed that the birthplace effect was found to be inconsistent among sports. This inconsistency was probably moderated by cultural factors.

A number of explanations on the contribution of places of small and medium sizes to the development of talent in sport have already been proposed. Among these explanations are (a) athletes who grow up in small and medium places are provided with social support by their counterparts, families, schools, and the community at large, enabling them to develop their skills and focus on their sport activities, and (b) safe environments are available for children to be active in open-space areas. In addition, it has been found that children experience fewer conflicts with others (see Côté et al., 2006; Davids & Baker, 2007; MacDonald, Cheung et al., 2009). These explanations also apply to our data on the soccer and handball players.

It has been argued that it would be difficult for children who grew up in very small places to develop their talent due to a number of environmental constraints, such as the small number of children of the same age to play and practice with, the lack of skilled and experienced coaches, or the limited number of sport activities (Côté et al., 2006; Davids & Baker, 2007). These arguments can be used to explain our data on the soccer players, and particularly that of the small number of children of the same age to play and practice with.
In very small villages and in small cities it may be difficult to maintain organized and supervised activities in soccer, since a large group of children at the same age is required.

However, our data on the volleyball players indicate an over-representation of players who grew up in a place with a size of less than 2,000 people (i.e., a small village), in contrast to the findings that emerged from previous studies (e.g., Côté et al., 2006). The explanation for our results is associated with the historic fact that in Israel the game of volleyball was originally played in very small places, such as Kibbutzes (cooperative farming settlements) and villages (Lidor & Bar-Eli, 1998). In fact, only during the last 10 years have volleyball programs been developed and offered to children and youth in the country's cities.

It is difficult to explain the lack of the birthplace effect among the basketball players. We collected information on the RAE and the birthplace effect on only 68 basketball players, compared to 209 soccer players, 161 handball players, and 83 volleyball players. The low number of basketball players can explain the lack of RAE in these players (see the frequency and percentage distribution of the basketball players' birth months in Table 1). Unfortunately, not many Israeli-born players play for professional clubs in Division 1, since the clubs are allowed to draft players who do not carry Israeli citizenship (Galily & Sheard, 2002). Presently, five to six international players (most of them from the USA) are playing for each club, a phenomenon that dramatically minimizes the number of players on the teams who were born in Israel.

Based on the data from this study, we can conclude that between the two investigated effects – the RAE and the birthplace effect – only the latter was found to be associated with playing on a Division 1 level. However, the birthplace effect was not found to be consistent across the ball games, as found also in previous studies (see Baker et al., 2009, Study 1). It is suggested that a sport- and culture-specific approach be adopted when examining environmental effects that contribute to sport proficiency in small countries such as Israel, where coaches have to make great efforts to increase the number of young people involved in sports, and where the traditional structure of the local sports system has to be overcome. In places such as Canada and the USA, which share similar cultures and consequently similar sport cultures, a cultural generality may exist (see data on the American and Canadian athletes in the study by Côté et al., 2006). However, this cultural generality may not be observed in countries of different sizes and different sport systems, as shown in the current study.

It has been already proposed by Baker and colleagues (2009) that research on the birthplace effect "should consider the unique developmental systems of each country, but also different sports within a country..." (p. 338). This suggestion is also true for the RAE. The three-phase sport development system that exists in Israel and the policies adopted by the sport clubs in the country make an essential contribution to the lack of the existence of the RAE. The influence of the social-cultural climate on the establishment of each ball game activity in the country, for example in volleyball, is considered as an important factor for the existence of the birthplace effect.

To provide support for the observation that a sport- and culture-specific approach should be adopted when examining environmental effects that contribute to sport proficiency in small countries such as Israel, additional research is needed. Data should be collected on athletes playing other ball games or involved in other sport activities (e.g., golf, tennis), as well as on athletes of both genders practicing and competing in a small country. Future research should also focus on the existence of the RAE in professional and semi-professional players playing for teams of different skill levels in Division 1, such as the most successful teams versus the less successful teams, to determine if there is an association between the RAE and teams of different skill levels.
References


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Anthropometric, Physiological and Selection Characteristics in High Performance UK Junior Rugby League Players

Kevin Till1*, Steve Cobley1, John O’Hara1, Chris Chapman2 and Carlton Cooke1

Abstract: The present study examined relationships between anthropometric, physiological and selection characteristics of junior (N=683; aged 13–16) representative Rugby League players who underwent a battery of tests (e.g., height; VO2max) as part of a national talent development program. Considerate of playing position (categorised as ‘Outside-Backs’, ‘Pivots’, ‘Props’, ‘Backrow’), ‘Props’ were more likely to be the relatively oldest and most mature. However, MANCOVA — with chronological age and maturation controlled — also identified that ‘Props’ were the worst performing on physiological tests. To add, physiological characteristics did not differ according to relative age. Findings suggest that relationships between anthropometric and physiological characteristics are not consistent with biases in selection, which raises issues regarding identification for immediate and long-term player selection and development.

Keywords: performance, talent identification, relative age effects, maturation

In the pursuit of sporting excellence, the emphasis on identifying and developing talented youth athletes within respective contexts has increased dramatically in recent years (Stratton, Reilly, Williams, & Richardson, 2004; Williams & Reilly, 2000). For instance, in the UK, Rugby League’s sports governing body the Rugby Football League (RFL) employed a player development system between 2004 and 2008, whereby participating juniors (aged 12–16 years) were identified and selected to a Player Performance Pathway program (see Till, Cobley, Wattie, O’Hara, Cooke, & Chapman, 2010; for a more detailed explanation). This program was similar to talent identification processes used in other sports (e.g. soccer), where governing bodies and professional clubs invest resources to identify outstanding youngsters at an early age in order to accelerate their development (Reilly, Williams, Nevill, & Franks, 2000). While these intentions may seem appropriate, recent research-based discussions (e.g. Vaeyens, Lenoir, Williams, & Philippaerts, 2008) have raised concerns regarding the effectiveness of such programs. For example, Vaeyens et al. (2008) highlight that applied and theoretical talent identification models have a low predictive value as well as emphasising how selection and cross-sectional assessment within junior annual-age groups can inaccurately identify talent. In such developmental systems, it is often the early maturing individual (Malina, Eisenmann, Cumming, Ribeiro, & Aroso, 2004; Sherar, Baxter-Jones, Faulkner, & Russell, 2007) and the relatively older player (Cobley, Baker, Wattie, & McKenna 2009) who is identified, excluding those who may be equally talented but at present lack the physical characteristics which correlate with performance at this developmental stage.

One clear consequence of such programmes has been Relative Age Effects (RAEs). RAEs in sport refer to participation, selection and attainment inequalities which occur as a result of an individual’s chronological age relative to peers within the same annual-age group.
(Musch & Grondin, 2001; Coblery et al., 2009). A recent study in Rugby League (Till et al., 2010) identified RAEs across stages of player development with heightened effects in representative selected junior players (e.g. Under 14s Regional players – Q1=44.6%, Q4=7.9%, $\chi^2=42.52, p<0.001$). It is also apparent that within one year, there is considerable variation in the growth and biological maturity of individuals, which can also lead to the misclassification of children in relation to biological maturity (Baxter-Jones, 1995). Research in youth soccer (Malina, Pena Reyes, Eisenmann, Horta, Rodrigues, & Miller, 2000; Malina et al., 2004) and ice hockey (Sherar et al. 2007) has already associated earlier maturing boys as being more likely to be selected for representative squads, based on their advanced physical capacities. Also, if maturation impacts performance on standard measurements used to assess and monitor physical capacities relevant to particular sports (see Malina, Bouchard, & Bar-Or, 2004), less mature (and likely to be relatively younger) juniors may be especially disadvantaged on performance tests which compare data across age-group norms (Armstrong, Welsby, & Kirby, 1998; Beunen, Malina, Lefevre, Claessens, Kanden Eynde, Vanreusel, & Simons, 1997).

Rugby League is a high intensity, intermittent, collision sport requiring players to have well developed physiological capacities for strength, power, speed, agility and aerobic power (Baker, 2001, 2002). To date, a number of Australian studies (Gabbett, 2002; 2005; 2006; Gabbett & Herzig, 2004; Gabbett, Kelly, Ralph, & Driscoll, 2007) have provided anthropometric and physiological characteristics of youth Rugby League players, showing how such characteristics increase between age categories. However, no study has provided data in relation to a complete cohort of high performance junior Rugby League players from the UK or examined maturation status in junior Rugby League players, unlike research in soccer (Malina et al., 2000; 2004) and ice hockey (Sherar et al., 2007).

In summary, recent research has examined anthropometric, physiological characteristics (e.g. Gabbett, 2005), maturational status (Malina, Eisenmann, Cumming, Ribero, & Aroso, 2004; Sherar, Baxter-Jones, Faulkner, & Russell, 2007) and selection issues such as RAEs (Till et al., 2010) in youth sport. However, only one recent study (Carling, le Gall, Reilly, & Williams, 2009) has examined anthropometric and fitness characteristics alongside RAEs in a talent identified group of elite academy soccer players. Results found a significant difference in height according to relative age quartiles, yet no significant differences were found in any fitness measures. This demonstrated that a similar group of players existed in terms of physical ability (Carling et al., 2009) and that RAEs may not be associated with any further advantages beyond initial selection into the talented group. Further research examining the relationships between selection issues and physical characteristics is necessary if the interactions between player selection, growth/maturation and physical performance in youth athletes are to be better understood.

Since 2004, the RFL has undertaken anthropometric and physiological testing of junior players selected for their Player Performance Pathway. The original rationale behind this methodological procedure and data collection was to provide: (i) an assessment of junior Rugby League players, (ii) individual feedback to clubs, coaches and players in the development of training programmes, and (iii) monitor player development. However, upon subsequent examination of the data we became interested in several selection and development based issues (e.g., RAEs; see Till et al., 2010). The initial purpose of the present study was to examine the anthropometric and physiological characteristics of high performance UK junior (Under 13–15) Rugby League players, with respect to annual-age grouping and playing position. However, a secondary (and emerging) purpose was to evaluate and discuss the consequences of selection and physiological assessment for a talent identification model, such as the RFL Player Performance Pathway. Finally and closely aligned to the secondary purpose, the third purpose was to examine the relationships between selection (maturation and relative age), anthropometric and physiological characteristics, in an effort to determine whether interactions existed and thus, consider their implications for long term player selection and development.
Methods

Participants

Fitness testing results from the 2005 to 2007 RFL Regional representative squads were collected and analysed. Data on 683 male junior players (age \( M = 14.58 \) years old; \( SD = 0.84 \), range 12.95–15.89 years) were obtained. Regional representative selection resulted in players attending a week long training camp in July to undertake specialised training. Within the week, players completed a battery of anthropometric and physiological tests. All participants were instructed to refrain from strenuous activity 48 hours prior to testing and to consume their normal pre-training diet. The protocols for all assessments received both institutional ethics approval and RFL approval. Further, informed assent and consent was obtained from players and parents respectively.

Procedures

Anthropometry. Height and sitting height were measured using a Seca Alpha stand, with measurements taken to the nearest 0.1 cm. Body mass was measured using calibrated Seca alpha (mode 770) scales, with measurements to the nearest 0.1 kg. A Harpenden skinfold calliper (British Indicators, UK) was used to assess body composition, with the sum of four skinfolds at the sites of the biceps, triceps, subscapular and suprailliac recorded. These procedures were in accordance with Hawes and Martin (2001). Intraclass correlation coefficients for reliability of skinfold measurements were \( r = 0.994 \) (Bicep, \( p < 0.001 \)), \( r = 0.996 \) (Triceps, \( p < 0.001 \)), \( r = 0.902 \) (Subscapular, \( p < 0.001 \)) and \( r = 0.875 \) (Suprailiac, \( p < 0.001 \)) respectively, indicating appropriate reliability.

Physiological Characteristics. All players performed field tests to determine the physiological characteristics of lower and upper body power, speed, change of direction speed as well as estimated aerobic power (\( VO_{2max} \)).

Lower body power was assessed using the vertical jump test measured using a Takei vertical jump metre (Takei Scientific Instruments Co. Ltd, Japan). A countermovement jump with hands positioned on the hips was used with jump height measured to the nearest centimetres. Each participant performed one practice jump followed by three testing jumps with the highest of the three trials used as the vertical jump score. The intraclass correlation coefficient for the vertical jump was \( r = 0.903 \) (\( p < 0.001 \)), indicating acceptable reliability based on established criteria (i.e., >.80; Hopkins, 2000).

Upper body power was measured using a 2 kg Medicine Ball (Max Grip, China) chest throw. Participants were seated with their back against a wall and instructed to throw the ball horizontally as far as possible. Each participant performed one practice throw followed by three testing throws, with the highest of the three trials used as the score. Distance was measured to the nearest 0.1 cm from the wall to where the ball landed. The intraclass correlation coefficient for the medicine ball chest throw was \( r = 0.965 \) (\( p < 0.001 \)).

Sprint speed was assessed at 10 m, 20 m, 30 m and 60 m using Brower Timing System speed gates (Brower Timing Systems, IR Emit, USA). Speed gates were positioned at each distance with participants starting 0.5 m behind the initial timing gate. Participants were instructed to set off in their own time from a standing start and run as fast as possible along the 60 m distance. Times were recorded to the nearest 0.01 s with each participant performing three trials. The quickest of the three trials at each distance was used as the sprint score. The intraclass correlation coefficients for the 10 m, 20 m, 30 m and 60 m sprints were \( r = 0.788 \) (\( p < 0.001 \)), \( r = 0.852 \) (\( p < 0.001 \)), \( r = 0.899 \) (\( p < 0.001 \)) and \( r = 0.924 \) (\( p < 0.001 \)).

Change of direction speed was assessed using the agility 505 test (Ellis et al., 2000), again using Brower Timing System speed gates. Participants assumed a starting position 15 m from a turning point with timing gates positioned 10 m from the start point. Players were instructed to accelerate as fast as possible from the starting point, turn on the 15 m line and run as quickly as possible back through the timing gates (Gabbett & Herzig, 2004).
Players turned off both left and right feet and performed three alternate attempts on each foot. Change of direction speed was measured to the nearest 0.01 s, with the quickest of the trials on the left and right foot used as the change of direction speed result. The intraclass correlation coefficients for the agility 505 left and right foot were $r=0.823$ and $r=0.844$ ($p<0.001$) respectively.

The Multi Stage fitness test (MSFT) was used to estimate $\dot{V}O_{2\text{max}}$ (Ramsbottom, Brewer, & Williams, 1988). Players ran back and forth along a 20 m track, keeping in time to a series of signals played from a CD player. As the test progressed, the time between signals decreased (i.e., requiring running speed to increase) until subjects reached volitional exhaustion. Regression equations were used to estimate $\dot{V}O_{2\text{max}}$ from the stage reached during the multistage fitness test (Ramsbottom et al., 1988). Ramsbottom et al. (1988) reported a correlation of $r=0.92$ between the multistage fitness test and $\dot{V}O_{2\text{max}}$.

**Playing Position.** Playing position was classified into four sub-groups, similar to that described in previous research (Gabbett, 2005; Sykes et al., 2008). These were 'Outside-Backs' (Fullback, Wing, Centre), 'Pivots' (Stand-Off, Scrum-Half, Hooker), 'Props', and 'Backrow' (Second-Row, Loose-Forward).

**Relative Age Within Annual Age Group.** In Rugby League annual age groups are defined on a yearly basis (e.g. Under 13s, 14s, etc.) with September 1st used as the date to divide annual age-groups. Players’ month of birth with respect to the first of September was used to calculate relative age compared to peers. On this basis Quartile (Q) relative age categories were then generated, so that Q1 reflected the relatively oldest players (i.e., born between September–November); Q2=December–February; Q3=March–May; and Q4=June–August (i.e., relatively youngest).

**Maturation (Age at Peak Height Velocity).** Age at peak height velocity (PHV) is the most common somatic measurement of maturity status, and a prediction equation to estimate age at PHV was used (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). This prediction method used a gender specific multiple regression equation including stature, sitting height, leg length, body mass, chronological age and their interactions to estimate age at PHV (Sherar et al., 2007). The 95% confidence interval associated with this equation for boys is ±1.18 years (Mirwald et al., 2002). Years from PHV was calculated by subtracting age at PHV from chronological age to determine how far players were from PHV.

**Data Analysis**

**Part 1.** Using SPSS Version 15.0 for Windows, mean scores and standard deviations (SD) were calculated for each annual-age group and playing position on each anthropometric and physiological variable. Multivariate analysis of variance (MANOVA) tests with Scheffe’s post hoc analyses were then carried out to determine the influence of age category and playing position upon anthropometric and physiological characteristics. Full effect sizes ($\eta^2$) were also calculated with significance levels set at $p<0.05$.

**Part 2.** To detect biases in selection, relative age data were assessed using both Chi-square and odds ratio (risk) analyses. Chi-square analysis assessed quartile asymmetry against national (UK) birth populations (Till et al., 2010) with effect sizes calculated using G-Power version 3.1.2. Basic Odds Ratio (ORs) calculations and 95% confidence intervals (CI) determined the risk size of RAEs, comparing quartiles (i.e., Q1 v Q4; Q2 v Q4; Q3 v Q4) and half year distributions (H1 v H2). Cross sectional stature and weight reference curves for the UK, (1990; Freeman et al., 1995) were used for comparisons of aged matched height and body mass with the normal population.

**Part 3.** To examine relationships between maturation, anthropometric and physiological characteristics a multivariate analysis of covariance (MANCOVA) with Bonferroni adjustment was applied with playing position as the fixed factor and chronological age and maturity (Years from PHV) entered as covariates to adjust for variations in age and maturation status. A similar MANCOVA was also used to examine differences between anthropometric and physiological characteristics according to relative age. This analysis
Table 1. Annual-Age Group Characteristics of UK Junior Rugby League Players

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Under 13s (1)</th>
<th>Under 14s (2)</th>
<th>Under 15s (3)</th>
<th>MANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>M (SD)</td>
<td>N</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>221</td>
<td>13.6 ± 0.27</td>
<td>240</td>
<td>14.58 ± 0.28</td>
</tr>
<tr>
<td>Age at PHV (years)</td>
<td>221</td>
<td>13.54 ± 0.62</td>
<td>240</td>
<td>13.58 ± 0.54</td>
</tr>
<tr>
<td>Years from PHV</td>
<td>221</td>
<td>0.06 ± 0.64</td>
<td>240</td>
<td>1.00 ± 0.58</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>221</td>
<td>169.56 ± 7.65</td>
<td>239</td>
<td>174.68 ± 6.44</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>221</td>
<td>62.17 ± 10.39</td>
<td>239</td>
<td>70.04 ± 11.05</td>
</tr>
<tr>
<td>Sum of skinfolds (mm)</td>
<td>221</td>
<td>36.56 ± 14.89</td>
<td>239</td>
<td>39.07 ± 16.76</td>
</tr>
<tr>
<td>Vertical jump (cm)</td>
<td>209</td>
<td>37.94 ± 5.16</td>
<td>227</td>
<td>40.78 ± 5.02</td>
</tr>
<tr>
<td>MB chest throw (metres)</td>
<td>209</td>
<td>5.22 ± 0.67</td>
<td>226</td>
<td>5.83 ± 0.63</td>
</tr>
<tr>
<td>10 m (seconds)</td>
<td>194</td>
<td>1.94 ± 0.12</td>
<td>227</td>
<td>1.89 ± 0.10</td>
</tr>
<tr>
<td>20 m (seconds)</td>
<td>194</td>
<td>3.36 ± 0.17</td>
<td>227</td>
<td>3.27 ± 0.18</td>
</tr>
<tr>
<td>30 m (seconds)</td>
<td>194</td>
<td>4.73 ± 0.26</td>
<td>227</td>
<td>4.56 ± 0.22</td>
</tr>
<tr>
<td>60 m (seconds)</td>
<td>194</td>
<td>8.86 ± 0.56</td>
<td>227</td>
<td>8.48 ± 0.47</td>
</tr>
<tr>
<td>Agility 505 L (seconds)</td>
<td>207</td>
<td>2.57 ± 0.15</td>
<td>226</td>
<td>2.48 ± 0.14</td>
</tr>
<tr>
<td>Agility 505 R (seconds)</td>
<td>207</td>
<td>2.57 ± 0.15</td>
<td>226</td>
<td>2.50 ± 0.16</td>
</tr>
<tr>
<td>VO2max (ml.kg⁻¹.min⁻¹)</td>
<td>207</td>
<td>47.19 ± 4.76</td>
<td>223</td>
<td>48.72 ± 5.40</td>
</tr>
</tbody>
</table>

Note. The numbers in parentheses in column headings relate to the numbers used for illustrating significant (p<0.05) differences in the post-hoc analysis. The N values differ between tests as not all players undertook every test.

Part 1: Anthropometric and Physiological Characteristics

Results

Table 2 presents the anthropometric and physiological characteristics and agility 505 tests. Pairwise comparison analyses identified significant main effects for age at PHV, sum of four skinfolds, and agility 505 tests according to playing position. Significant differences in the post-hoc analyses showing all performance variables as significantly improving across the three age groups, except for chronological age and maturation (age at PHV and years from PHV), height and body mass. 'Props' and 'Back' and 'Pivot' positions showed different from other positions except chronological age. MANOVA analyses identified significant main effects for all variables as significantly improving across the three age groups, except for the anthropometric and physiological characteristics. Again, chronological age and maturation (years from PHV) was controlled. Significance levels were set at p<0.05 for main effects and adjusted for number of comparisons when applying Bonferroni adjustment.
Table 2. Playing Position Characteristics of UK Junior Rugby League Players

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Outside-Backs (1)</th>
<th>Pivots (2)</th>
<th>Props (3)</th>
<th>Backrow (4)</th>
<th>MANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( N )</td>
<td>( M (SD) )</td>
<td>( N )</td>
<td>( M (SD) )</td>
<td>( N )</td>
</tr>
<tr>
<td>Age (years)</td>
<td>220</td>
<td>14.52 ± 0.83</td>
<td>157</td>
<td>14.84 ± 0.87</td>
<td>118</td>
</tr>
<tr>
<td>Age at PHV (years)</td>
<td>220</td>
<td>13.66 ± 0.54</td>
<td>157</td>
<td>14.00 ± 0.96</td>
<td>118</td>
</tr>
<tr>
<td>Years from PHV</td>
<td>220</td>
<td>0.86 ± 0.95</td>
<td>157</td>
<td>0.54 ± 0.96</td>
<td>118</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>220</td>
<td>172.85 ± 7.70</td>
<td>157</td>
<td>169.42 ± 7.96</td>
<td>118</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>220</td>
<td>65.93 ± 10.64</td>
<td>157</td>
<td>62.32 ± 9.53</td>
<td>118</td>
</tr>
<tr>
<td>Sum of skinfolds (mm)</td>
<td>220</td>
<td>33.57 ± 12.00</td>
<td>157</td>
<td>33.82 ± 12.35</td>
<td>118</td>
</tr>
<tr>
<td>Vertical Jump (cm)</td>
<td>204</td>
<td>42.19 ± 5.65</td>
<td>148</td>
<td>39.47 ± 5.27</td>
<td>110</td>
</tr>
<tr>
<td>MB chest throw (m)</td>
<td>205</td>
<td>5.79 ± 0.84</td>
<td>148</td>
<td>5.51 ± 0.78</td>
<td>110</td>
</tr>
<tr>
<td>10 m (seconds)</td>
<td>199</td>
<td>1.88 ± 0.14</td>
<td>145</td>
<td>1.88 ± 0.13</td>
<td>109</td>
</tr>
<tr>
<td>20 m (seconds)</td>
<td>199</td>
<td>3.23 ± 0.18</td>
<td>145</td>
<td>3.26 ± 0.18</td>
<td>109</td>
</tr>
<tr>
<td>30 m (seconds)</td>
<td>192</td>
<td>4.52 ± 0.25</td>
<td>140</td>
<td>4.58 ± 0.28</td>
<td>104</td>
</tr>
<tr>
<td>60 m (seconds)</td>
<td>192</td>
<td>8.39 ± 0.51</td>
<td>140</td>
<td>8.55 ± 0.59</td>
<td>104</td>
</tr>
<tr>
<td>Agility 505 L (s)</td>
<td>202</td>
<td>2.48 ± 0.14</td>
<td>147</td>
<td>2.49 ± 0.14</td>
<td>108</td>
</tr>
<tr>
<td>Agility 505 R (s)</td>
<td>202</td>
<td>2.50 ± 0.14</td>
<td>147</td>
<td>2.50 ± 0.13</td>
<td>108</td>
</tr>
<tr>
<td>( \dot{VO}_{2\text{max}} ) (ml.kg(^{-1}.\text{min}^{-1}) )</td>
<td>202</td>
<td>49.07 ± 4.90</td>
<td>145</td>
<td>49.88 ± 4.60</td>
<td>109</td>
</tr>
</tbody>
</table>

**Note.** The numbers in parentheses in column headings relate to the numbers used for illustrating significant \((p<0.05)\) differences in the pairwise comparisons analysis. The \(N\) values differ between tests as not all players undertook every test.

Table 3. Relative Age Effects of Regional Representative Players According to Playing Position

<table>
<thead>
<tr>
<th>Position</th>
<th>( N )</th>
<th>( % Q_1 )</th>
<th>( % Q_2 )</th>
<th>( % Q_3 )</th>
<th>( % Q_4 )</th>
<th>( \chi^2 )</th>
<th>( \omega )</th>
<th>( p )</th>
<th>(OR (CI)) Q1vQ4</th>
<th>(OR (CI)) Q2vQ4</th>
<th>(OR (CI)) Q3vQ4</th>
<th>(OR (CI)) H1vH2</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>683</td>
<td>48.02</td>
<td>25.33</td>
<td>17.86</td>
<td>8.79</td>
<td>236.4</td>
<td>0.581</td>
<td>&lt;0.001</td>
<td>5.47 (2.21 - 13.56)</td>
<td>2.89 (1.12 - 7.44)</td>
<td>2.03 (0.76 - 5.42)</td>
<td>2.75 (1.52 - 4.97)</td>
</tr>
<tr>
<td>OB</td>
<td>219</td>
<td>46.58</td>
<td>21.46</td>
<td>22.83</td>
<td>9.13</td>
<td>64.34</td>
<td>0.542</td>
<td>&lt;0.001</td>
<td>5.11 (2.07 - 12.55)</td>
<td>2.35 (0.91 - 6.01)</td>
<td>2.50 (0.97 - 6.44)</td>
<td>2.12 (1.20 - 3.78)</td>
</tr>
<tr>
<td>PV</td>
<td>158</td>
<td>44.94</td>
<td>27.22</td>
<td>16.46</td>
<td>11.38</td>
<td>45.85</td>
<td>0.514</td>
<td>&lt;0.001</td>
<td>3.95 (1.68 - 9.27)</td>
<td>2.39 (0.98 - 8.80)</td>
<td>1.45 (0.57 - 3.69)</td>
<td>2.59 (1.44 - 4.66)</td>
</tr>
<tr>
<td>PR</td>
<td>118</td>
<td>56.78</td>
<td>26.27</td>
<td>12.71</td>
<td>4.24</td>
<td>75.22</td>
<td>0.798</td>
<td>&lt;0.001</td>
<td>13.39 (4.32 - 41.53)</td>
<td>6.20 (1.93 - 19.88)</td>
<td>3.00 (0.88 - 10.27)</td>
<td>4.90 (2.55 - 9.41)</td>
</tr>
<tr>
<td>BR</td>
<td>188</td>
<td>46.81</td>
<td>27.66</td>
<td>16.49</td>
<td>9.04</td>
<td>62.85</td>
<td>0.569</td>
<td>&lt;0.001</td>
<td>5.18 (2.10 - 12.77)</td>
<td>3.06 (1.20 - 7.78)</td>
<td>1.82 (0.68 - 4.87)</td>
<td>2.98 (1.61 - 5.30)</td>
</tr>
</tbody>
</table>

**Note.** All=All Players; OB='Outside-Backs'; PV='Pivots'; PR='Props'; BR='Backrow'. \( N \)=Total in sample; \( Q \)=Quartile; OR=Odd Ratio calculation; CI=95% Confidence Interval calculation; H=Half-year (i.e., 6 months).
status and height, however ‘Props’ were significantly heavier with a greater skinfold thickness. ‘Outside-Backs’ also had a significantly greater vertical jump than any other playing position, with ‘Props’ and ‘Backrow’ scoring significantly higher in the 2 kg medicine ball chest throw. ‘Props’ were significantly slower than ‘Outside-Backs’ and ‘Pivots’ over 10 m and 20 m sprint distances, while ‘Props’ performed significantly worse on the 30 m and 60 m sprint, change of direction speed, and estimated tests.

Part 2: Selection

Relative Age Effects (RAEs). Table 3 shows the quartile distributions, Chi-square ($\chi^2$), ORs and 95% CIs for all players according to playing position. Results revealed that a general selection inequality exists in Regional representative selections. Odds ratio risk analyses identified that ‘Props’ had the highest risk of selection bias (Q1vQ4 OR: 13.39, CI95%: 4.32–41.53). ‘Outside-Back’ (Q1vQ4 OR: 5.11, CI95%: 2.07–12.55) and ‘Backrow’ (Q1vQ4 OR: 5.18, CI95%: 2.10–12.77) positions also reported strong, but reduced, levels of selection bias. Meanwhile the ‘Pivots’ position reported a still significant, but reduced risk (Q1vQ4 OR: 3.95, CI95%: 1.68–9.27) of selection inequality.

Height, Body Mass and Maturation (Age at PHV). Height and body mass of all players were compared against UK 50th and 97th reference values (Freeman et al., 1995). For height, 92.4% of players were taller than the aged match 50th percentile with 33.3% being above the 97th percentile. For body mass, 96.0% of players were heavier than the 50th percentile with 30.3% of players also above the 97th percentile. The mean age at PHV for all junior Rugby League players was 13.61±0.58 years.

Part 3: Relationships Between Selection, Anthropometric and Physiological Characteristics

Maturation and Performance. Figure 1 and 2 provide a summary of the maturational, anthropometric and physiological results between playing positions. The figures demonstrate that ‘Props’ have the earliest maturation and largest anthropometric characteristics. When compared to the physiological characteristics of the other players, ‘Props’ underperformed on all tests except the 2 kg medicine ball chest throw. Based on these initial observations, and to control for chronological age and maturation (Years from PHV), further MANCOVA analyses were undertaken examining playing position variability. Table 4 presents the MANCOVA and pairwise comparisons analysis between positions. Results identify that the ‘Props’ position were the worst performing playing position on all tests except medicine ball chest throw, where no significant difference was found between playing positions.

Table 4. MANCOVA Between Playing Positions Controlling for Age and Maturation

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>$F$</th>
<th>df</th>
<th>$p$</th>
<th>$\eta^2$</th>
<th>Pairwise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>4.875</td>
<td>3.678</td>
<td>0.002</td>
<td>0.025</td>
<td>4, 3&gt;1, 2</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>36.283</td>
<td>3.678</td>
<td>&lt;0.001</td>
<td>0.158</td>
<td>3&gt;4&gt;1, 2</td>
</tr>
<tr>
<td>Sum of skinfolds (mm)</td>
<td>25.547</td>
<td>3.678</td>
<td>&lt;0.001</td>
<td>0.117</td>
<td>3&gt;4&gt;1, 2</td>
</tr>
<tr>
<td>Vertical jump (cm)</td>
<td>15.985</td>
<td>3.639</td>
<td>&lt;0.001</td>
<td>0.076</td>
<td>1&gt;2, 4&gt;3</td>
</tr>
<tr>
<td>MB chest throw (m)</td>
<td>0.351</td>
<td>3.640</td>
<td>0.788</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>10 m (seconds)</td>
<td>4.846</td>
<td>3.625</td>
<td>&lt;0.001</td>
<td>0.024</td>
<td>1, 2&lt;3, 4</td>
</tr>
<tr>
<td>20 m (seconds)</td>
<td>10.993</td>
<td>3.625</td>
<td>&lt;0.001</td>
<td>0.084</td>
<td>1, 2&lt;3, 2, 4&lt;3</td>
</tr>
<tr>
<td>30 m (seconds)</td>
<td>15.947</td>
<td>3.596</td>
<td>&lt;0.001</td>
<td>0.074</td>
<td>1, 2&lt;3, 2, 4&lt;3</td>
</tr>
<tr>
<td>60 m (seconds)</td>
<td>17.750</td>
<td>3.596</td>
<td>&lt;0.001</td>
<td>0.084</td>
<td>1&lt;2, 4&lt;3</td>
</tr>
<tr>
<td>Agility 50 S (s)</td>
<td>10.160</td>
<td>3.633</td>
<td>&lt;0.001</td>
<td>0.080</td>
<td>1, 2, 4&lt;3</td>
</tr>
<tr>
<td>Agility 50 R (s)</td>
<td>9.225</td>
<td>3.634</td>
<td>&lt;0.001</td>
<td>0.049</td>
<td>1, 2, 4&lt;3</td>
</tr>
<tr>
<td>$VO_{max}$ (ml.kg$^{-1}$.min$^{-1}$)</td>
<td>7.038</td>
<td>3.651</td>
<td>&lt;0.001</td>
<td>0.038</td>
<td>1, 2&lt;4&lt;3</td>
</tr>
</tbody>
</table>

Note. The numbers in the pairwise comparisons analysis are 1=’Outside-Backs’, 2=’Pivots’, 3=’Props’, 4=’Backrow’.
Figure 1. Summary of the maturational and anthropometric characteristics by playing position.

Figure 2. Summary of the physiological results by playing position.
Relative Age and Anthropometric and Physiological Characteristics. Table 5 shows the MANCOVA between the anthropometric and physiological characteristics of players according to relative age (i.e., Quartile 1–4). No significant main effects for relative age were found, with pairwise comparisons only showing Q2 players as having a greater body mass and sum of skinfolds compared to Q3 players; while Q4 players outperformed Q1 players for the medicine ball chest throw. MANOVA for maturation showed Q4 (13.39±0.59 years) as having an earlier age at PHV than Q1 (13.65±0.57 years) and Q2 (13.65±0.55 years). However, Q1 (1.12±0.88 years) were more mature than Q4 (0.71±1.02 years) players.

Anthropometric vs. Physiological Characteristics. Table 6 shows the correlations between anthropometric and physiological characteristics when controlling for chronological age and maturation. Height was positively related to medicine ball chest throw, 30 m sprint and estimated VO2max with body mass also positively related to all physiological characteristics. However, sum of four skinfolds were negatively related to all variables except the medicine ball chest throw.

Discussion

The primary aim of the current study was to examine the anthropometric and physiological characteristics of high performance UK junior (Under 13–15) Rugby League players, with respect to annual-age grouping and playing position. Secondary purposes were (a) to evaluate the consequences of selection and physiological assessment for the RFL Player Performance Pathway; and (b) to examine the relationships between selection (maturation and relative age), anthropometric and physiological characteristics. To date, research combining talent selection issues (e.g. RAEs and maturation) with anthropometric and fitness characteristics has been limited (for one exception see Carling et al., 2009). These study purposes are important if we are to better understand the interaction of anthropometric, physiological and selection characteristics, and therefore be able to resolve some of the problems surrounding player identification, selection and development in present day youth sport.

Overall, findings demonstrated that each annual-age group resulted in significant changes of anthropometric and physiological characteristics. Advancing chronological age (i.e., from one annual year to the next) was associated with increases in characteristics. This is consistent with previous research (Gabbett, 2002; Gabbett & Herzig, 2004) and occurs due to the normal adaptations related to growth, maturation and development in children (Malina, Bouchard, & Bar-Or, 2004). More specifically, analyses of playing position revealed clear differences on anthropometric and physiological characteristics. These observations are also consistent with findings in previous samples (Gabbett, 2002; 2005; Gabbett et al., 2007) with the ‘Props’ and ‘Backrow’ positions taller, heavier with more body fat than ‘Outside-Backs’ and ‘Pivots’. These results emphasize the importance of larger physical attributes in forwards whose game demands predominantly require physical collisions, tackles and ruck domination (Gabbett, 2002). Physiological differences were also identified between playing positions with ‘Outside-Backs’ outperforming other positions on the vertical jump and ‘Props’ and ‘Backrow’ performing better on the medicine ball chest throw. On measures of speed, change of direction speed and estimated VO2max the ‘Props’ performed significantly worse than any other position; a finding contrasting previous observations (Gabbett, 2002; 2005) where no significant differences were found. Nonetheless, present results and the correlational analysis provide evidence that a higher sum of four skinfolds (i.e., higher body fat) is negatively associated with performance measures (e.g., vertical jump, sprint, change of direction speed and aerobic power); an assertion previously stated, but not directly evaluated (Meir et al., 2001; Gabbett, 2005).
Table 5. Relative Age Characteristics of UK Junior Rugby League Players

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Quartile 1 (1)</th>
<th>Quartile 2 (2)</th>
<th>Quartile 3 (3)</th>
<th>Quartile 4 (4)</th>
<th>MANCOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>M (SD)</td>
<td>N</td>
<td>M (SD)</td>
<td>N</td>
</tr>
<tr>
<td>Age (years)</td>
<td>329</td>
<td>14.77 ± 0.80</td>
<td>176</td>
<td>14.53 ± 0.81</td>
<td>120</td>
</tr>
<tr>
<td>Age at PHV (years)</td>
<td>329</td>
<td>13.65 ± 0.87</td>
<td>176</td>
<td>13.65 ± 0.85</td>
<td>120</td>
</tr>
<tr>
<td>Years from PHV</td>
<td>329</td>
<td>1.12 ± 0.88</td>
<td>176</td>
<td>0.88 ± 0.96</td>
<td>120</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>329</td>
<td>17.41 ± 6.72</td>
<td>176</td>
<td>17.51 ± 8.33</td>
<td>120</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>329</td>
<td>70.26 ± 11.83</td>
<td>176</td>
<td>69.03 ± 12.00</td>
<td>120</td>
</tr>
<tr>
<td>Sum of skinfolds (mm)</td>
<td>329</td>
<td>38.97 ± 16.69</td>
<td>176</td>
<td>39.51 ± 16.60</td>
<td>120</td>
</tr>
<tr>
<td>Vertical jump (cm)</td>
<td>307</td>
<td>40.52 ± 5.43</td>
<td>166</td>
<td>40.04 ± 5.50</td>
<td>116</td>
</tr>
<tr>
<td>MB chest throw (m)</td>
<td>307</td>
<td>5.78 ± 0.87</td>
<td>166</td>
<td>5.81 ± 0.82</td>
<td>116</td>
</tr>
<tr>
<td>10 m (seconds)</td>
<td>302</td>
<td>1.90 ± 0.14</td>
<td>162</td>
<td>1.90 ± 0.14</td>
<td>113</td>
</tr>
<tr>
<td>20 m (seconds)</td>
<td>302</td>
<td>3.27 ± 0.18</td>
<td>162</td>
<td>3.28 ± 0.19</td>
<td>113</td>
</tr>
<tr>
<td>30 m (seconds)</td>
<td>289</td>
<td>4.57 ± 0.25</td>
<td>154</td>
<td>4.60 ± 0.26</td>
<td>109</td>
</tr>
<tr>
<td>60 m (seconds)</td>
<td>289</td>
<td>8.50 ± 0.49</td>
<td>154</td>
<td>8.58 ± 0.54</td>
<td>109</td>
</tr>
<tr>
<td>Agility 505 L (s)</td>
<td>306</td>
<td>2.50 ± 0.15</td>
<td>164</td>
<td>2.52 ± 0.16</td>
<td>114</td>
</tr>
<tr>
<td>Agility 505 R (s)</td>
<td>306</td>
<td>2.53 ± 0.15</td>
<td>163</td>
<td>2.53 ± 0.16</td>
<td>114</td>
</tr>
<tr>
<td>(\bar{V}O_{2\text{max}}) (ml.kg(^{-1}).min(^{-1}))</td>
<td>303</td>
<td>49.26 ± 5.29</td>
<td>162</td>
<td>49.26 ± 4.47</td>
<td>115</td>
</tr>
</tbody>
</table>

Note. The numbers in parentheses in column headings relate to the numbers used for illustrating significant (p<0.05) differences in the post-hoc analysis. The N values differ between tests as not all players undertook every test.

Table 6. Correlations Between Anthropometric and Physiological Characteristics

<table>
<thead>
<tr>
<th>Anthropometric characteristics</th>
<th>Vertical jump</th>
<th>Med ball chest throw</th>
<th>30 m sprint</th>
<th>Agility 505</th>
<th>(\bar{V}O_{2\text{max}})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>p</td>
<td>r</td>
<td>p</td>
<td>r</td>
</tr>
<tr>
<td>Height</td>
<td>0.20</td>
<td>ns</td>
<td>0.148</td>
<td>&lt;0.001</td>
<td>-0.106</td>
</tr>
<tr>
<td>Body mass</td>
<td>-0.213</td>
<td>&lt;0.001</td>
<td>0.298</td>
<td>&lt;0.001</td>
<td>0.204</td>
</tr>
<tr>
<td>Sum 4 skinfolds</td>
<td>-0.348</td>
<td>&lt;0.001</td>
<td>-0.003</td>
<td>ns</td>
<td>0.417</td>
</tr>
</tbody>
</table>

Note. ns=non significant.
Within talent identification programmes in youth sport, problems with selection in annual-age groups and cross-sectional assessment have been emphasised (Vaeyens et al., 2008). Consistent with previous research in Rugby League (Till et al., 2010) the current investigation substantiates these findings, identifying a selection discrepancy based on relative age across the whole sample. Such results are consistent with findings in other team sports (e.g. soccer; Simmons & Paul, 2001). However, similar to other studies where RAES were evident (e.g., ice hockey: Grondin & Trudeau, 1991; German Handball: Schorer, Cobley, Busch, Brautigam, & Baker, 2008) effect sizes did vary as a function of playing position. For instance, RAE risk was inflated for ‘Props’ and decreased in the ‘Pivots’ when positions were contrasted. Based on their data, Grondin and Trudeau (1991) explained that high RAES in ice hockey were associated with playing positions requiring the greatest physical demands. The anthropometric characteristics of ‘Props’ in the present sample lend support to this explanation, with a more pronounced selection bias in ‘Props’ compared to the ‘Pivot’ positions.

In their review, Musch and Grondin (2001) suggested that maturation status was a primary cause of RAES in youth sport, explaining that relatively older juniors would be more likely to possess desirable physical characteristics, compared to their relatively younger peers. The current study suggests an orientation toward the selection of players who are taller, heavier and more mature than the age-matched UK normal population, using reference values for height and body mass (Freeman et al., 1995). Players in the present sample had an age at PHV of 13.61 (±0.58) years, indicating earlier rates of maturation, when considering that the average age of PHV in European boys occurs between 13.8–14.2 years (Malina, Bouchard, & Bar-Or, 2004). Such selection of early maturing players is similar to patterns reported in other popular youth sports contexts (e.g., soccer: Malina et al., 2004; ice hockey: Sherar et al., 2007). This leads us to conclude that boys advanced in maturity are likely to have greater representation in such youth contexts, and are more likely to be selected within talent development systems, on the proviso that such sports require particular physical demands, and the sport system values immediate performance success.

Physical performance is related to biological maturation during adolescence (Philippaerts et al., 2006), with greater indices of maturation generally regarded as beneficial to performance (Malina, Bouchard, & Bar-Or, 2004). However, when analysing the present results by playing position, ‘Props’ and ‘Backrow’ (i.e., the most mature) do not outperform ‘Outside-Backs’ and ‘Pivots’ on the battery of physiological tests. Interestingly, MANCOVA analysis (controlling for chronological and maturational age) identified that the ‘Props’ position performed significantly worse on all measures, except medicine ball chest throw (where no significant difference occurred). This raises further considerations for talent identification and selection processes. In the RFL Player Performance Pathway, selection was made before physiological assessment is undertaken, suggesting that physical size was an important contributor toward selection, however, coaches, in making their selections, appear not to consider the potential constraining or detrimental effect that particular aspects of size (e.g., body fat) have upon physiological performance. To add, present results suggest that some later maturing players actually outperformed the more mature ‘Prop’ players, especially where body mass and fat impeded their performance. Therefore, if some later maturing players were already in advance of some early maturing players on selected performance tests, then it is likely that further differences would develop as maturity into adulthood occurred, as there is more potential for further development in the later maturing players.

When examined collectively, the impact of relative age upon anthropometric and physiological characteristics was negligible for the current high performance sample; a finding similar to the talented group of soccer players examined by Carling and colleagues (2009). This lack of difference according to relative age exemplifies some key points. First, that the group of selected players within annual age-groups were physically and anthropometrically homogenous. Second, that a similar archetypal athlete was being
selected into the RFL pathway by coaches. For example, if a Quartile 4 individual was to be selected, they were likely to require physical and anthropometric characteristics similar to the relatively older player (i.e., Q1). A rare outcome, due to the odds of such an individual being early maturing compared to the national population, and more specifically the sample of players. To remain clear though, coaches did not consider maturation (or relative age) as part of selection for Regional representative players; instead selection was based on a range of criteria, including actual game performance.

This study, while examining a large sample of representative junior Rugby League players over three consecutive years, is not without limitations. Due to the large sample obtained over a number of years anthropometric measurements were taken by several individuals, which may have led to some intra and inter examiner errors. Still, examiners were fully trained and adhered to the standardised procedures recommended. Errors in anthropometric measures may have lead to errors in estimation of maturation status (age at PHV), which is also a prediction equation with a 95% confidence interval associated with this equation for boys being ±1.18 years (Mirwald et al., 2002). While accepting potential error, such an assessment of maturation remains beneficial, as it is a simple, non-intrusive and non-expensive way of calculating maturation, as applied in other research (e.g. Sherar et al., 2007). Due to the field based nature of all tests applied, and the high sample size, the multistage fitness test was used to estimate $V_{O_{2\text{max}}}$ instead of a direct assessment. The original research (Ramsbottom, Brewer, & Williams, 1988) identified a 0.92 correlation between the multistage fitness test and $V_{O_{2\text{max}}}$ suggesting the test is a valid and reliable measure for estimating $V_{O_{2\text{max}}}$.

Problems with Talent Identification in Youth Sport: Results of the current study suggest that some current practices in talent identification and the application of development models may be problematic. One of the major problems is the process of player selection from annual-age groups, using standardised fixed time periods of coaching assessment, trials and performance measurement, at a notoriously variable phase of growth and development. Here it is suggested that talent, or outstanding performance relative to peers, is confounded by advanced maturation and developmental variation. These occur at a time where individual differences in skill, as a result of practice and/or training may not be differentiated from advanced maturation. Consequently, such developmental systems may be detrimentally impacting upon participation and selection during early and representative stages of youth sport (Till et al., 2010). Applied talent identification models may be based on false assumptions differentiating and treating young sport athletes, where pre-adult physical disposition is clouding coach’s ability to identify and select truly outstanding and skilful youngsters. Enhanced training, coaching and playing opportunities occur for those selected, but it is important to consider whether there is an immediate or long lasting effect to those not included, likely to be the relatively youngest and late maturing individuals, who may dropout even though they could be as good (if not better) at the same level of maturation (Sherar et al., 2007).

As maturation status impacts upon performance in sport related tasks or tests, it is critical that talent identification and testing protocols conducted within annual age groups, consider age and maturity related indicators. Cross-sectional testing, without considering the longitudinal nature and complexity of growth and maturation, will only achieve the outcome of capturing performance at the present moment, remaining blind to the numerous physical changes which occur over time. Player assessment needs to consider the numerous other factors (e.g., technical, tactical and psychological skills) which are, or will become associated with performance beyond maturation. Although data in the current study were not considered longitudinally, they identify that early maturing selected ‘Props’, were outperformed on a selection of performance tests by later maturing ‘Outside-Backs’ and ‘Pivots’. If weight and other related variables are not regulated within future recommended training, it is unlikely that such players would continue to be
considered as ‘talented’ as players progress through the developmental stages of the game, where pace, strength and aerobic power demands of the game are likely to increase. This raises the question as to whether the earlier maturing, relatively older player can maintain and develop the physiological and performance characteristics required to perform in older (e.g., Under 16–18) more advanced levels, and where other aspects of the game have to be developed, understood and assessed. For what appears to be talent right now may not be the characteristics of talent in the longer-term.

Conclusion

The current investigation highlights that anthropometric and physiological characteristics differ between annual-age groups and playing positions in high performance UK junior Rugby League players. Selection into the RFL Player Performance Pathway generates RAEs and the selection of earlier maturing players, with selection opportunities limited for the relatively younger or later maturing player. When analysing performance data and controlling for chronological age and maturity status, it was found that the earlier maturing ‘Props’ were outperformed by later maturing ‘Pivots’ and ‘Outside-Backs’ players on a range of physiological tests, highlighting issues related to immediate player selection and long-term development. When examining anthropometric and physiological characteristics across relative age no differences were apparent, highlighting the selection of a very homogenous group of players within annual age groups. Future research and talent identification models in sport need to consider and evaluate strategies for long term development, instead of early (de)selection. Other performance components (e.g., technical and psychological skills) also need to be considered in addition to these physical measures in a longitudinal manner if we are to better understand the process of talent development, as well as improve the predictive value and utility of applied models.

References


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Canadian Women's Ice Hockey – Evidence of a Relative Age Effect

Patricia L. Weir1*, Kristy L. Smith1, Chelsea Paterson1 and Sean Horton1

Abstract: The relative age effect (RAE) suggests that athletes born earlier in a sport's selection year have an advantage in terms of team selection and playing opportunities. While this is highly prevalent in men's sports, little work has been directed at examining the RAE in women's sports. The studies to date present an equivocal pattern of findings across a variety of women's sports. The purpose of the present study was to examine the prevalence of the RAE in Canadian women's ice hockey. Relative age and player position information on 660 female hockey players registered with Hockey Canada were gathered from the Hockey Canada website. From the chi-square analyses, there was a higher proportion of female players born in Q2 (32.88%) than in Q4 (16.82%), and a higher proportion born in the first half of the year (60.00%) as compared to the second (40.00%). These data suggest that similar to previous research on men's hockey, opportunities for females to participate at an elite level are concentrated primarily among relatively older players. We anticipate that the increasing growth and popularity of women's ice hockey will result in the RAE becoming even more pronounced at all levels of participation.

Keywords: relative age effects, female hockey, birth distribution, player position

Virtually all organized sports operate on the basis of annual age groupings for athletes. This is done to promote fair play, to facilitate instruction, to ensure that each and every athlete has an equal likelihood of participation and success, and to promote safety in the playing environment (Barrow & McGee, 1971; Barnsley & Thompson, 1988; Vincent & Glamser, 2006). Even in this system designed to promote equity, inequities exist. One inequity, described by the relative age effect (RAE) refers to the differences in ages between athletes in the same age group (Barnsley, Thompson, & Legault, 1992). For example, Canadian and U.S. ice hockey players are grouped according to the calendar year, beginning on January 1st and ending on December 31st. Thus, children born in early January can be up to 12 months older than those born at the end of December. Across a variety of sporting contexts, both at the youth and professional levels, relatively older athletes are over-represented on teams compared to their younger counterparts. This pattern has been found in minor hockey (Grondin, Deshaies, & Nault, 1984), professional hockey (Barnsley, Thompson, & Barnsley, 1985), professional soccer (Dudink, 1994); and tennis (Edgar & O'Donoghue, 2005; for a complete review see Cobley, Baker, Wattie, & McKenna, 2009).

Several mechanisms have been proposed to explain the RAE (see Musch & Grondin, 2001 for an excellent review), including competition, physical development, psychological development, and experience. Overall, these ideas fall into two complementary hypotheses (Cobley et al., 2009). First, relatively older athletes tend to be physically taller, heavier, and stronger than relatively younger athletes (Malina, 1994). This increased physicality tends to lead to greater success in athletic performance, particularly in sports in which these attributes are advantageous, such as hockey and football. Early success often promotes further physical and psychological investment by the athlete resulting in a greater likelihood of staying in the sport. Second, relatively older athletes are more likely

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to be identified by coaches as ‘talented’ and get selected for all-star or representative teams (Helsen, Starkes, & Van Winckel, 1998). Such selection often has a number of positive ramifications, including more opportunity to play and practice, access to better coaching, exposure to better competition, and superior technical knowledge. In addition to this broad generalization of mechanisms underlying the RAE, other psychological variables positively related to being relatively older are increased self-esteem (Fenzel, 1992), and perceptions of competence (Musch & Grondin, 2001; Vincent & Glamser, 2006).

As a consequence, the RAE is intimately linked to talent development, and the early selection and streamlining of young athletes in certain sports has been identified as a potential key contributor to this effect. While relative age is positively linked to higher levels of performance due to early selection to teams and greater opportunities to play (Helsen, Van Winckel, & Williams, 2005), it is also associated with early dropout (Helsen, Starkes, & Hodges, 1998), and ultimately missed opportunities for long term skill development for those who are relatively younger (Côté & Hay, 2002). Thus, as long as early selection and streamlining remains in place, coaches and administrators of sport will need to accept the associated positive and negative consequences.

While the RAE has been researched extensively in male sports, little work has been done identifying the prevalence of RAE in women's sports. As advocated by both Musch and Grondin (2001), and Wattie, Cobley, and Baker (2008) it is important to address this imbalance. To date only 2% of the work done on the RAE has looked at women's sports (Cobley et al., 2009). It is unclear whether the lack of research addressing the RAE is related to the lower value placed on women’s sport in society as evidenced by the lack of opportunity to play at a professional level and in professional leagues compared to men, or whether the early work done by Baxter-Jones and colleagues (Baxter-Jones, 1995; Baxter-Jones, Helms, Maffull, Baines-Preece, & Preece, 1995) that identified the presence of RAE in women’s elite junior tennis, adequately addressed the issue.

Since the work of Baxter-Jones and colleagues, only a handful of studies have examined relative age effects in women's sports, and the published work focussed primarily on adolescent age groups has produced equivocal findings with respect to the presence of the RAE (Cobley et al., 2009). Edgar and O'Donoghue (2005) examined RAEs with a sample of junior (<18 years) and senior elite tennis players who participated in Grand Slam tennis events. Senior players participated in singles tennis in each of the four Grand Slam tournaments in 2002 or 2003, while the junior players were those who had amassed 120 ranking points on the junior circuit by the end of 2003. With a cut-off date of January 1st, they classified dates of birth into four seasons of three months each. For both senior and junior players, they reported more relatively older than younger female tennis players at both junior and elite levels of competition, and across the entire sample, more players were born in the first six months of the year as compared to the last six months.

Vincent and Glamser (2006) examined 1344 male and female soccer players identified by the US Olympic Development Program (ODP) as being the most talented players born in 1984. Male and female ODP players were gathered from regional and state programs as well as the women's U-19 National team and the men's U-17 National team. Male soccer players exhibited strong relative age effects across all levels of competition. While a traditional RAE did not emerge for the females, more female regional players were born in the first half of the year (60.6%) compared to the second half of the year (39.4%), a finding not supported by Helsen, Van Winckel, and Williams (2005) for European Federation U-18 women's soccer.

Delorme and Raspaud (2009) examined all female basketball players in France participating in licensed youth categories, between 7 and 18 years of age. Across all age groups, a consistent RAE emerged with a higher percentage of players born in the first two quartiles and a smaller percentage born in the last two quartiles, suggesting that the RAE emerges as early as 7 years of age. In one of the only studies on adult female athletes, Delorme, Boiché, and Raspaud (2010) examined all female soccer players associated with the French Soccer Federation. In contrast to youth and adolescent soccer players where
relatively more players are born in the first quartile and relatively fewer born in the fourth quartile, the adult players were overrepresented in the second and third quartiles and underrepresented in the first and fourth quartiles. The authors suggest that part of the reason that a less traditional finding emerged was due to the competition level of the athletes. As the sample was not restricted to elite level players, the playing level dropped to “average” which may have accounted for the different distribution (Delorme et al., 2010).

Specific to women’s hockey, Wattie, Baker, Cobley, and Montelpare (2007) reported no RAE among birth quartiles for elite Canadian Women’s National Championship ice hockey players, which was in stark contrast to the comparative sample of male NHL hockey players. This strong RAE has been reported repeatedly in men’s hockey (Barnsley et al., 1985; Grondin & Trudeau, 1991). These gender differences may arise as a result of the disparities in the level of competition, and the fact that there are fewer developmental programs for women. For many years, young girls who wanted to play hockey often had to play on boys’ teams, as there were so few competitive opportunities for females. In a celebrated case in the mid 1980s that went all the way to Canada’s Supreme Court, 13 year-old Justine Blainey eventually won permission to play on a boys’ elite squad (Andiappan, Cresthol, & Singh, 1989). Blainey’s case exemplified the dearth of developmental opportunities for female hockey players that persisted for many years.

Elite female hockey is a relatively new phenomenon, with the first World Championships held in 1990, and women’s hockey becoming a full medal sport in the Olympics in 1998. In contrast, men’s professional ice hockey has a long and established history. While women playing in the Canadian Championships and Olympics represent the best female players in the country, they are drawn from a relatively small pool of players compared to the men. Despite the fact that participation in girls’ hockey leagues increased 300% in the decade following the first World Championship (Canadian Association for the Advancement of Women and Sport and Physical Activity) the level of participation for women is still far short of the men. For example, in the 2006–2007 minor hockey season in Canada, there were only 73,791 female hockey players registered out of the 500,000 athletes enrolled (Hockey Canada, n.d.-a).

While the presence of a RAE in men’s ice hockey is well documented and represents some of the first work on age biases, it has been suggested that the RAES in elite level ice hockey are magnified when player position is taken into account. Grondin and Trudeau (1991) observed that the RAE was strongest among goalies – a position characterized by high physical demands – with two-thirds of them born in the first quartile. With the additional equipment that goalies need to wear, the authors speculated that they have greater physical strength requirements than forwards or defensemen. These data support a maturational mechanism as contributing to the presence of an RAE. A recent study by Schorer, Cobley, Büsch, Bräutigam, & Baker (2009) also examined player position within the sport of handball. Data on German first league adult handball players were gathered and coded according to birthdate and player position. For the backcourt positions, where players are advantaged by a larger, more physical body type, the data revealed an over-representation of players born in the first two quartiles relative to the last two quartiles. More importantly, the data were clear in demonstrating that player position and level of competition affect the strength of RAES. Similarly, Baker, Schorer, Cobley, Bräutigam, and Büsch (2009) examined U.S. national level youth and adult female soccer players. RAES were observed for all player positions in youth athletes (goaltending, midfield, forward, and defense), but RAES emerged only for the defense and goaltending positions in adults, with a striking over-representation in the second quartile for the goaltenders.

Although few studies have examined these positional relationships, it remains an intriguing area of inquiry and is worth investigating in female ice hockey. In support of the differences in physicality required in women’s hockey, Geithner, Lee and Bracko (2006) examined the physical and performance differences among a sample of University level, female hockey players. When examined by player position, forwards tended to have the
leanest body type, and goalies the most robust, with the highest percentage of body fat. Defensemen fell between these two groups, displaying a tendency for larger lower leg circumference and a larger trunk. The forward and defensive players displayed greater aerobic and anaerobic capacity than the goalies, and they were more agile in their skating performance. Geithner et al. (2006) concluded that these physical and performance characteristics were position specific, and reflect the greater work requirements of a forward compared to a defenseman or goalie. Intriguing questions persist as to whether these characteristics existed prior to, or are the result of, their hockey training.

Considering the paucity of research that has examined RAEs in women’s sport and the equivocal nature of the existing findings, further investigation of this topic is warranted. Considering the cultural importance of ice hockey in Canada, and the explosion of the women’s game in the last two decades since its inclusion in the Olympics, the sport provides an ideal vehicle to examine RAE. Women's hockey may be ideally suited for witnessing changes in the emerging patterns of a RAE, particularly since the first study on Canadian women's hockey by Wattie et al. (2007) did not reveal the presence of any effects. Thus, the purpose of the current study was to examine: (1) the prevalence of the RAEs in elite women’s ice hockey in Canada and, (2) the dependency of RAEs on player position.

Methods

Data Collection

The birthdates of Canadian women hockey players were collected from the Hockey Canada website (Hockey Canada, n.d.-b). Participant data were taken from the World Championship rosters (1999–2009), the Team Canada Under-22 rosters (1998–2009), Team Canada Under-18 rosters (2007–2009; Hockey Canada, n.d.-c), and Team Canada’s All Time roster (Hockey Canada, n.d.-d). These players were combined into a single sample representing all players who had represented Canada in an international tournament (International sample: n=291). Data were also gathered for women who played in the, National Championship Under-18 tournaments (2005–2009; Hockey Canada, n.d.-e). These players represented their province in the national championship (National sample: n=369). Players who competed in more than one year, or at both national and international levels were only included once, at their highest level of playing competition. Team Canada’s official rosters varied in format; with birthdates being recorded in month/day/year format or day/month/year format. The variability in presentation was used as a method of verification for the recorded dates of birth (DOB). Any birthdates in question were confirmed with a representative from Hockey Canada. Information for each individual player was coded for position (goalies=1; defence=2; forwards=3), and DOB quartile (Jan–Mar=Q1; Apr–June=Q2; July–Sept=Q3; Oct–Dec=Q4). Where available, additional data were collected on player height and weight to examine physical differences among players.

Data Analyses

Chi-square goodness of fit tests were used to compare the distribution of players across the birth quartiles, and analyses were evaluated at the p<.05 level of significance. As with previous studies, comparisons were based on the assumption of equal distributions of births across the months of the year. Thus, the expected frequency in each quartile was 25.0%. Analyses were conducted based on the level of competition, and further analyses were conducted by player position, namely goalies, forwards, and defense. Effect sizes were calculated using Cramer’s phi.
Results

Level of Competition

The data for both the national and international players are presented in Figure 1 and Table 1. Across both levels of competition, there was an over-representation of players born in Q1 and Q2, as compared to Q3 and Q4. However, in contrast to the more traditional pattern of RAE across quartiles, the largest over-representation was in Q2. Given the similarity in the distribution of players in the national and international samples, they were collapsed into a single sample that represented all elite women hockey players in Canada between 1998–2009 (n=660).

Table 1. Birth Date Distribution for Female Hockey Players in Both the National and International Samples

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| National   | 100| 115| 89 | 65 | $\chi^2(3)=14.43, p=.002, \phi=.20$
| International | 79 | 102| 64 | 46 | $\chi^2(3)=23.19, p=.000, \phi=.28$

Table 2. Birth Date Distributions for All Women Hockey Players by Playing Position

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| All        | 179| 217| 153| 118| $\chi^2(3)=36.12, p=.00, \phi=.23$
| Goalies    | 19 | 24 | 19 | 19 | $\chi^2(3)=0.93, p=.82, \phi=.11$
| Defense    | 51 | 70 | 43 | 29 | $\chi^2(3)=18.21, p=.00, \phi=.31$
| Forwards   | 109| 123| 91 | 63 | $\chi^2(3)=20.84, p=.00, \phi=.23$
| Skaters    | 160| 193| 134| 92 | $\chi^2(3)=37.71, p=.00, \phi=.25$
All Players

For the entire women's sample there were significant differences in the distribution of births across the four quartiles (see Table 2). Similar to the analysis presented above, there was an over-representation of births in Q2.

When examined by position, the forwards (n=386) and defense (n=193) revealed a virtually identical pattern of RAE with an over-representation in Q2 and an under-representation in Q3 and Q4 (see Table 2). In contrast, the goalies did not reveal an RAE, although the small sample for the goalies (n=81) is undoubtedly a limiting factor. Due to the similarity in representation of players across the quartiles, the forwards and defense were combined to represent player positions dominated by skating (n=579).

Discussion

The purpose of this study was to examine the prevalence of the RAE in elite Canadian women's ice hockey. Results indicate that the RAE exists in Canadian women's hockey at both the national and international level. These findings expand upon the work of Wattie et al. (2007) to include more players in multiple age divisions. It is important to note that the players represented in the Wattie et al. (2007) study represent a subset of the national level players included in the current sample. Thus, with a larger, more robust sample of elite female players, a pattern of RAE emerges.

While there is clear evidence of more players born in the first half of the year, the overrepresentation of Q2 compared to Q1 differs from what has been reported previously in men's hockey where the highest percentage of players are born in Q1, and then the number progressively decreases from Q2 to Q4. While the overrepresentation of players born in Q2 does not follow the classical pattern of RAEs, this same overrepresentation in Q2 was also reported by Delorme et al. (2010) and Baker et al. (2009) for adult female soccer players. Importantly, the work by Delorme and colleagues showed no variation in birthrates of females by month across the population as a whole. Thus, one potential reason for a different relative age distribution among male and female athletes is that there is less competition among girls to gain a position on an elite team (Delorme, Boiché, & Raspaud, 2009). This parallels Musch and Grondin (2001) who proposed that the popularity of a sport increases the competition for available spots on teams, thereby fostering the development of the RAE. With 85% of youth hockey players in 2006–2007 in Canada being male, and just 15% female (Hockey Canada, n.d.-a), the greater number of male players might significantly affect the competition for membership on a developmental or elite level hockey team.

There is evidence from the women's data that the presence of the RAE may in part be position dependent. Positions requiring skating show a relative age effect, whereas the goalies do not, although it is again important to note that the non-significant findings for goalies may be a function of the smaller sample size. The evidence of a RAE among our skaters, but not the goalies, is of particular interest considering Grondin and Trudeau's (1991) findings of a stronger RAE in male goaltenders than in other positions. They attributed this finding to the more physically demanding job of having to wear extra equipment, which might require a larger, stronger player. A similar argument could be adopted in terms of the anaerobic and aerobic demands required of skating positions in women's hockey (Geithner et al., 2006). Skaters born earlier in the year may be physically stronger than players born later in the year. To determine whether players born earlier in the year were physically different in stature, an analysis of variance was done on the height and weight of the skaters. Results showed no significant differences in height or weight based on birth quartile. Given that selection to elite teams within the Hockey Canada system generally occurs in players' late teens, this finding might not be surprising, as developmentally the maturation of young females is often complete by 14 years of age (Malina, 1994). More importantly, it underscores the idea that physical differences present in younger minor league players may diminish after puberty leaving
other, more organizationally based, factors responsible for the relative age effects. While current physical attributes of players are not different based on their birth quartile, it may be that at a younger age, a player’s height or weight did constitute an advantage, and is an issue for future studies to investigate.

While the pattern of RAEs in the current women’s sample does not follow the more traditional pattern of RAEs found in men’s hockey, when collapsed into the first and second halves of the year the percentage of women born in the first six months approaches 60%, a value similar to that reported in earlier studies on men’s hockey (e.g., Barnsley et al., 1985). This may speak to the development of women’s hockey over the last 20 years; in a relatively short period of time, the relative age distribution of the women is starting to look similar to the men, in spite of the fact that far fewer women play the sport. It is possible that, if female hockey grows in popularity and becomes increasingly structured, the RAE trends may be exacerbated, eventually mirroring what we see in the male game. Considering the success of Team Canada in international women’s competition (including three successive Olympic Gold medals), it raises the intriguing possibility that the presence of an emerging RAE may either predict or coincide with a country’s success in that particular sport. Whether this is the best, or most efficient, method of developing talent is debatable (e.g., Gladwell, 2008). It is evident, however, that the majority of opportunities to play at an elite level in Canada are going to women born early in the year, a trend that may well strengthen if participation in women’s hockey continues to grow. As of now, Team Canada Women’s U-18 program has only been in existence for three years and Team Canada Women’s U-22 for 12 years. As these programs continue to develop they will provide a fascinating test case for talent development research.

Overall, the current results display that the RAE does exist in women’s elite hockey in Canada. While the relationship differs somewhat between women’s and men’s teams, it is evident that the developmental programs now in place for female players tend to identify players born earlier in the year as having the most potential. Future work in this area should continue to examine the existence and patterning of the RAE in women’s sports, with particular emphasis on player position for team sports. Finally, the reasons for the overrepresentation of female athletes born in the second quarter of the year, both in our results and in previous studies, remain unclear. Future studies examining the RAE across different domains may be able to shed light on this somewhat unconventional finding in the relative age literature.

Acknowledgements

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Notes

1 This data set includes all hockey players listed on the Hockey Canada website for all levels of National team play (Team Canada, Team Canada U-22, Team Canada U-18) from 1998–2009, and the women’s U-18 National Championship teams dating from 2005 when this tournament was held on a consistent basis.

2 Team Canada’s All Time Alphabetical Roster includes a listing of all women who have played for Team Canada since 1990. This listing includes 117 players. This list was used to identify additional players for the database. Birthdates were then obtained from additional resources.
The data were analyzed on the assumption of equal birth rate distributions across the four quartiles. To justify this assumption, Canadian birthrates across each quartile of the year were analyzed using single-sample t-tests for 1965, 1975, and 1985. For all three years there were no significant differences for any birth quartile (p > .05). Given the strong support for no birthrate differences across the quartiles, we feel justified in using an equal birthrate distribution in the chi-square analyses.

References


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