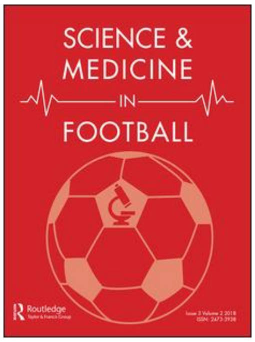

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*R*esearch in *A*nother un-*E*xamined (RAE) context. A Chronology of 35 Years of Relative Age Effect Research in Soccer: Is it time to move on?

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Abstract

It is approximately 35 years since the publication of the first relative age effect paper in sport and despite the volume of empirical studies, book chapters, conference presentations, and column inches dedicated to this topic we appear to be no further on in eliminating or attenuating this discriminatory practice. This commentary argues that the ongoing use of univariate methods, focusing on primary or secondary analyses of birth-date data, unearthed from previously un-examined contexts is not conducive to stimulating discussion or providing empirical *solutions* to relative age effects. This paper concludes by suggesting a departure from the traditionally narrow view of relative age inquiry and instead consider the role of transdisciplinary research.

Keywords: *Relative age effect, birth date, team sports, individual sports*

Introduction

The common practice of chronologically age grouping children and adolescents in sport is, generally speaking, designed to match children on their developmental milestones (i.e. experience, cognition, motor competence, social development and, to a lesser extent, physical development) (Malina, Bouchard & Bar-Or, 2004). This approach can often result in differences in age of up to 12-months, which might not be considered much across the life course, but during early childhood can represent a substantial proportion of a child's life (ibid.). For example, in England the cut-off date for participation in youth soccer begins on September 1st. Thus, players born in the later months of the selection year (*i.e.* June, July or August in England) are reportedly discriminated against via a biased view of current ability and future potential, when compared to players born earlier/closer to the cut-off point for selection. The reported asymmetric distribution of relatively older individuals' success in sports in comparison to relatively younger participants is commonly referred to as the relative age effect (RAE; Wattie, Cobley, & Baker, 2008).

It is approximately 35 years since the publication of the first RAE paper in sport (Barnsley, Thompson & Barnsley, 1985). Yet, despite numerous empirical studies, book chapters, conference presentations, and column inches dedicated to RAE, we appear to be no further on in eliminating or attenuating this discriminatory practice. We wish to be clear; this is not a slight against those early researchers. On the contrary, we stand on their shoulders, as it was their work that has enabled us to see further. It is not our intention to dismiss the robust work conducted thus far, nor is it our decree that research in this area comes to an immediate halt. Rather, as the title of this article suggests, it is our view that future RAE work would benefit from, *moving-on*. Our point being, that the ongoing use of univariate methods, focusing on primary or secondary analyses of birth-date data, unearthed from previously un-examined contexts is not conducive to stimulating discussion or providing empirical *solutions* to RAE. This dichotomy may be what Collins *et al*. (2019) were referring to when describing science *for* sport rather than science *of* or *through* sport in relation to methodological concerns in talent-related research; it is without doubt there are some similarities here. For example, both of these fields (*i.e.* talent identification and RAE) have suffered from atheoretical retrospective research designs that have encountered significant difficulties infiltrating, and then impacting upon applied sporting environments (Wattie, Schorer, & Baker, 2015). As such, we argue that future scientific endeavours should be directed towards longitudinal, hypothesis-driven studies, designed to reduce, eradicate or attenuate the prevalence of RAE.

We do not believe that we are alone in promoting our concerns surrounding the current position of RAE research. For example, Helson and colleagues (2012) speculated whether a decade's worth of RAE research had *made any difference* (emphasis added) in European professional soccer. In order to gain consensus on this position, however, we believe the sport science research community has some legitimate philosophical, methodological, and design-related questions to consider. In our view, future RAE studies should avoid replicating existing univariate selection methods and instead consider using experimental, multivariate, longitudinal, mixed method, qualitative, or translational interventions – essentially, research designs that have been largely overlooked, but are conducive to the production of applied solutions.

Like others (*i.e.* Cumming *et al*., 2017a; Cobley *et al*., 2019; Patel *et al*., 2020) we hope this commentary begins the process of re-positioning the RAE debate. If 'we' (i.e. the sports science research community) genuinely believe that talent identification and development are biased processes; and through no fault or wrong-doing young players experience a version of discrimination that, seemingly, has life-long and life-altering implications; then we need to move beyond a replication of cross-sectional, quantitative birth-date comparison studies conducted among youth and professional players and presenting exploratory results as confirmatory findings (Bergkamp, *et al*., 2019). The aim of this commentary therefore is to assess the chronology of RAE in performance sports (primarily soccer) and provide some pragmatic, research-informed solutions to help move future findings forward.

The 1980s

The first evidence of RAE in sport is generally attributed to the work of Barnsley, Thompson and Barnsley (1985), who reported the existence of skewed birth date distributions in Canadian minor hockey. Prior to 1985, evidence of RAE was predominantly located to the field of education and the earliest published paper we could find on this birth date phenomenon was published in the United Kingdom (UK) in 1966 (Armstrong, 1966).

As far back as 1985 Barnsley and colleagues described the prevalence of unequal birth date distributions in the composition of team rosters as a "recent phenomenon" and yet as we enter a new decade we are still describing RAE as a "phenomenon" that is seemingly parading itself across youth sport for the first time. The earliest proposition presented for the existence of RAE in team sports, especially in North America, was the international series with Soviet Union in 1972. Some researchers argued that the emergence of systematic methods of developing (hockey) talent, that was taking place across Europe, forced other sports to adopt the streaming of players via various levels of proficiency at an early age (Hurley, Lior & Tracze, 2001).

1990 – 2000

Throughout the 1990s correlational studies demonstrated the existence of RAE across multiple team sports (*e.g.* ice hockey, Barnsley & Thompson, 1998; American baseball, Thompson, Barnsley, & Stebelsky, 1991). The first soccer-related RAE study compared birthdate data against general population data in relation to an observed cut-off date for selection (Musch & Hay, 1999). This study reported a strong RAE across professional soccer in several countries (*e.g.* Germany, Brazil, Japan, and Australia); however, the most interesting statement was provided at the end of the article… "what remedies for the problem can be suggested?" (p. 61).

Despite our earlier claims regarding the absence of hypothesis-driven RAE studies, the 1990s actually provided several approaches that attempted to mitigate the effects of RAE. The first such effort was the Novem System (Boucher & Halliwell, 1991). Their solution proposed shortening the selection window to nine months, thus recycling the cut-off date throughout the year into three-month intervals. However, there is no evidence that this system has been operationalised, presumably due to the logistical issues (see our opening sentence) of creating a diminished period of competition. We considered the Relative Age Fair (RAF) Cycle System to be, perhaps, the most equitable methodology to mitigate bias associated with RAE (Hurley, Lior & Tracze, 2001). The RAF Cycle System operates on a calendar year principle and so creates contiguous birth date quarters. For example, a relatively younger player born in August in the year 2010 would be labelled P4 (*i.e.* player born in fourth quarter of the calendar year) in a team comprised of 2010(1)s, 2010(2)s, 2010(3)s, and 2010(4)s in an under 11 soccer team for the season 2020; in the next season (*i.e.* 2011) the composition of the team would include the following players: 2010(4)s (*i.e.* P4 moves from relative youngest to relative oldest), 2011(1)s, 2011(2)s and 2011(3)s. This approach, however, has not been well received by youth coaches as players would always be playing with different teammates, thus, changing the social and cultural dynamics of participation in soccer.

2000 – 2010

In 2005, the asymmetry of birth-date distributions of professional youth soccer teams across Europe was reported (Helsen, Van Winckel, & Williams, 2005). This cross-sectional study captured birthdates of national youth players across under-15 (U15), under-16 (U16), under-17 (U17) under-18 (U18) and under-21s (U21) in Belgium, Denmark, England, France, Germany, Italy, The Netherlands, Portugal, Spain and Sweden (n = 2175). Regression analyses revealed significant RAE across all of the age groups. A less pronounced effect was reported in the U21s and women's U18 team. The author's posited a number of solutions to eradicate RAE at the end of their paper, some of which are mentioned previously. However, their focus in overcoming the issue appeared to be adjusting the "mentality of youth team coaches" (p. 635). The argument presented was that youth coaches pay more attention to the technical and tactical attributes of players with less emphasis on physical characteristics such as height.

The juxtaposition between a team's philosophical view of winning verses the long-term development of the athletes can place unique pressure on coaches and young players (Reeves, Nicholls & McKenna, 2009). Indeed, the temptation for coaches (or heads of recruitment) to see physical ability (as a consequence of birth date and/or early maturation) rather than potential talent is one that permeates its way through both the RAE and talent literature (Hirose, 2009). Talent identification and development is a complex and multi-faceted process, especially when inter-individual variations in growth and maturation are prevalent during youth and adolescence (Malina, Bouchard, & Bar-Or, 2004). The advantageous physical requirements required for soccer (*i.e.* height, muscular strength, aerobic power, endurance and speed) and the advantages of biological maturity and a birthdate in the earliest part of the selection year is well evidenced (Vaeyens, Philippaerts & Malina, 2005). Vaeyens, Philippaerts and Malina's (2005) study was important for a number of reasons: First, the Royal Belgian Football Association moved the cut-off date for selection from 1st August to 1st January in 1997 to align with other European nations. Thus, this was one of the a few studies that explicitly sought to identify the existence of RAE (or not) in players before and after a change in cut-off for the selection year. Second, the study examined RAE in relation to two game-related variables (*i.e.* number of match selections and minutes played). With respect to the topic at hand, the results again confirmed the existence of skewed birth date distributions with a higher proportion of players born in the first quarter of the selection age, in both composition of squads and game involvement variables. Perhaps, more distinguishing was that this study demonstrated for the first time, that rotating cut-off dates, as proposed in through the Novem System, was not a viable method for reducing or eliminating RAE. The author's concluded that this would only "shift" the problem and again fell back on solutions of a more social and educational nature (*i.e.* greater awareness of sports federations, clubs, *etc*.). This study, however, opened the door for research opportunities designed to examine biological maturity that will be discussed later in the paper.

The strength of the argument for maturation-selection processes as the primary cause of RAE was gaining momentum, however, researchers were still focusing on obtaining relative age distributions rather than attempting to explain the nuances of *how* RAE operated and functioned on a historical or longitudinal basis. This call was answered in a study that tracked birthdate data across a 20-year period in the German Bundesliga (Cobley, Schorer, & Baker, 2008). Although the study reported the historical evidence for the existence of RAE for the first time, the analysis suffered from the well-known limitation of aggregate statistics. On the environmental side, however, this study reported the presence of secondary mechanisms of RAE, that when fully explored revealed implications for preventive RAE from a socio-cultural perspective. Of particular significance, here, was the emphasis on sports participation data and sports popularity. Though not insurmountable, this type of research would require accurate collection of sport withdrawal data which is fraught with logistical and ethical issues.

2010 – 2020

Models 'of' and 'for' RAE

In the two decades that followed the millennium, arguments to theorise and expand our understanding of RAE in sport were presented via various models (*e.g.* Hancock, Adler, & Côté, 2013; Pierson, Addona & Yates, 2014; Wattie, Schorer, and Baker, 2015). In Hancock *et al*. (2013) we once again read that: "Theories are required to guide research on *newer phenomena* (emphasis added), such as the relative age effect (RAE) in sport" (p.630).

The psychological genesis of the work of Hancock *et al.* (2013) was that physical maturity was often conflated with skill development and skill differences, a fair point that is echoed by others (Bailey & Collins, 2013), and mistakenly suggests that talent identification and development is a probabilistic endeavour (Vaeyens *et al*., 2008). By coagulating theories such as the *Matthew effect, Pygmalion effect,* and *Galatea effect* (see Hancock *et al*., 2013 for a full discussion) they proposed the foundations for what was termed the 'integrated social agent' model to explain RAE. Despite compelling arguments for the roles, both positive and negative, these social agents play in extenuating RAE, previous research has not been intuitive enough to determine the exact nature or impact of these social agents. The supposition, that by removing Matthew (difficult as someone will always be older), Pygmalion and Galatea effects would moderate, or at least mediate RAE – is still equivocal, in that it is at the moment empirically untested.

If we follow the arguments of others, this would probably be viewed as a model *for* RAE rather than a model *of* RAE (Cushion, Armour & Jones, 2006). For the purpose of this paper we view this as an idealistic representation of RAE at the moment and one that remains to be explicitly tested. The second RAE model we recorded in the literature was termed the 'behavioural dynamic model' (Pierson *et al*., 2014) and presented a solution to mitigate RAE in youth hockey. Based on the empirical nature of this system we would advocate this as a model *of* RAE. In considering some explicit statistical analyses and modelling, this is one of the few studies which does contain a hypothesis-driven approach to testing the magnitude of RAE. As the authors acknowledge, however, that the model is specific to a particular sport (*i.e.* hockey) and as yet, to our knowledge at least, it has not been examined in another sport.

The heuristic model of RAE (Wattie, Schorer, and Baker, 2015) followed, based on a constraint-based approach utilising developmental systems theory (DST) (Newell, 1986) which lends itself to a model *of* RAE. This, we would advocate, is worthy of further empirical investigation: The evidence for RAE strongly corroborates the existence of characteristics which interact between the individual and their environment. A good conceptualisation of this would be through Newell's (1986) framework that asserts, at both the intra- and inter-individual levels of analysis, movement behaviours emerge from the confluence of interacting constraints. These constraints have been categorised into three types individual (structural *i.e.* height, weight; and functional *i.e.* motivation); environmental (*i.e.* weather, playing surface, coach); and task (*i.e.* goal of activity, rules, equipment) and can be viewed as boundaries or features that constrain the possibilities (degrees of freedom) for action. At an individual level, the environment and tasks that players participate in on a daily basis will influence their playing style or preferred characteristics of play. At a higher scale of analysis, a team, when viewed through Newell's model, can be understood as complex deeply integrated systems that are made up of many individual component parts which are continuously interacting with one another. The potential for interactions between system parts can lead to rich patterns of behaviour but also some characteristics such as the soccer acting as an attractor state. Button *et al*. (2011) observed that young inexperienced soccer players tendency swarm around the ball and the strength of the swarming behaviour was influenced by constraints such as pitch size, technical ability and physical capacity. RAE may, therefore, be due to individual structural constraint, such as being tall or more physically developed; or by influencing the coach/talent scouts perceptions of 'talent' (environmental constraint) by manipulating play systems or tactics in a way that provides a short term advantage, such as winning a game, (task) but not within the considerations of long-term development.

Hypothesis driven "pragmatic" research designs to move the debate forward

Arguably the most pragmatic, hypothesis-driven, area-advancing study was conducted by Mann, Pleun, and van Ginneken (2017). The aim of their study was to establish whether selection bias associated with RAE could be reduced when talent identification staff were provided with the decimalised ages of the players during a game. The findings reported a significant selection bias when no-age group information was presented, however, the selection bias was eliminated when participants had access to the players' relative age, in the form of age-ordered shirt numbering. Evidence, that this pragmatic research is filtering its way into the performance domain was illustrated recently in a holistic ecological analysis of talent recruitment and development environments from eleven of the most successful elite soccer academies across Europe (Reeves & Roberts, 2019). Indeed, data indicated that the RAE was understood by all the clubs and pedagogical age group modification strategies similar to those reported by Mann and colleagues (2017) were employed during real-time scouting assignments. Integrated age-ordered shirt numbering was also reported as a pedagogic strategy promoted by academy coaches during age appropriate coaching, thus ensuring technical and tactical skills were provided in positive, supportive, and developmentally appropriate environments. However, no age group distribution data were reported so it is unclear whether RAE existed or not. Recently, no significant associations between birthdate distribution and selection processes were reported at an elite soccer academy in Spain (Castillo *et al*., 2019). Despite the modest sample size, strengths of this work include the tracking of *selected*, *non-selected*, *promoted*, and *non-promoted* players from 2013-2019. Data suggested the chances of promotion were not determined by date of birth or the physical characteristics of the player.

There have been recent efforts to adopt statistical modelling techniques and corrective adjustment procedures to effectively remove RAE for athletes participating in individual sports, such as sprinting (Romann & Cobley, 2015) and swimming (Cobley *et al*., 2019). However, there have been no attempts to apply the technique across team sports, as this may be problematic due to the variability of performance outcomes.

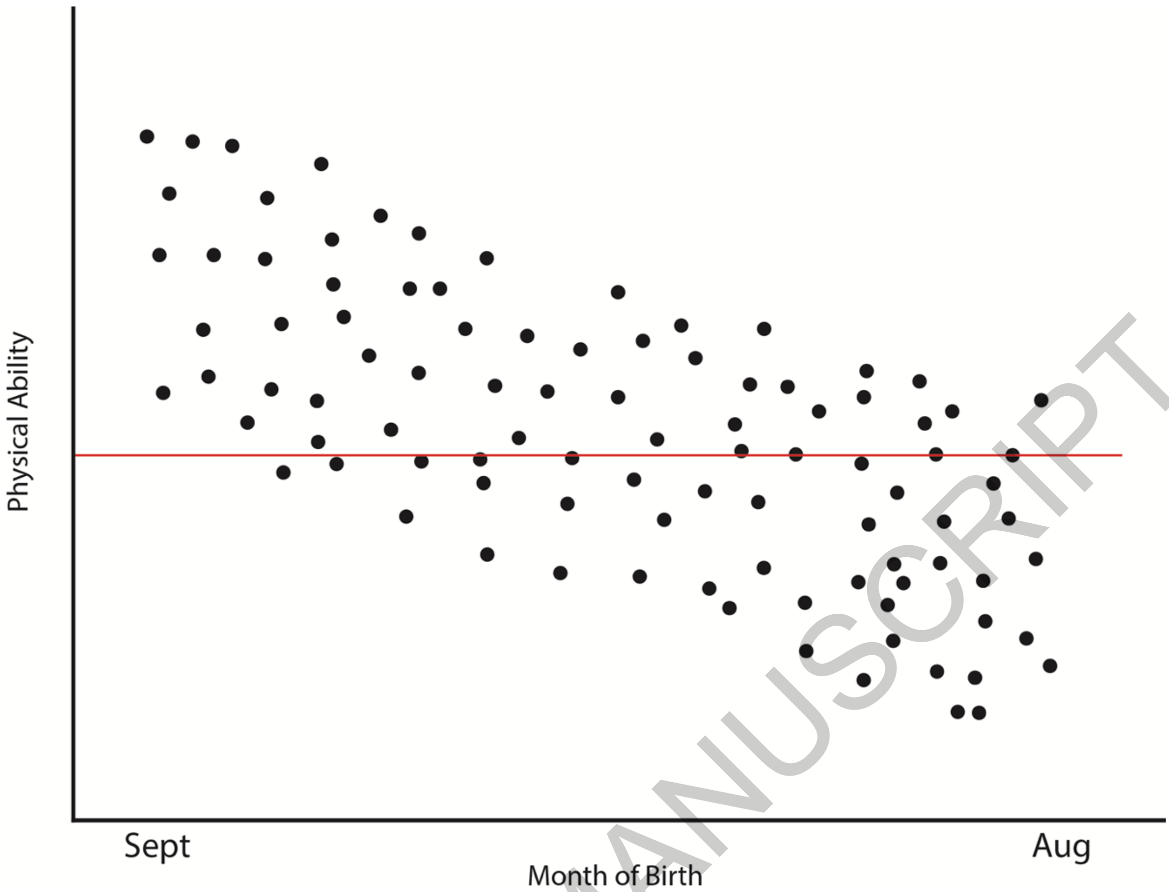
Relative age effect reversal/the under-dog hypothesis

Other approaches have reported how RAE may reduce when transitioning from youth-to-senior level (Cobley *et al*., 2009), or where serial-winning (male) players were more likely to be born in early in the selection year (Ford & Williams, 2012). Others have taken a step further, suggesting "…the RAE advantage apparent at selection and identification seems to be reversed by the end of the development process" (McCarthy & Collins, 2014: p.1607). In the following paragraph, however, this point is clarified in the context of the parameters of the study when the authors state "…what we demonstrate is *not* what the recent literature has labelled as a reversal of, or inverse RAE effect…(ibid, p.1607, emphasis in the original). This is further explained by the authors in their conclusion.

In a follow up study, using the same methods, McCarthy, Collins and Court (2015) reported similar findings in a UK sample of academy players from rugby union and cricket. Again, the findings identified a "reversal of RAE advantage" (p.1464) in relation to the birthdates of those players who progress to senior national representative level. Once more, we stress that we do not dispute these findings, and we are cognisant of the levels of caution and caveats provided by the researchers in this instance. What we propose, however, is that there may be another explanation for these findings; one that requires further methodological examination. For example, we speculate as to whether player samples were drawn from non-random populations and selected in many different ways, which makes it virtually impossible to tell whether the results measure a casual effect of relative age, or differences between groups of relatively old and young players that are dissimilar at baseline.

What we outline below may (or may not) explain some of the results in RAE reversal studies. These sampling issues include, *inter alia,* the following: First, to be selected into a soccer academy, players must be above a cut-off level of physical ability. Given that the relatively younger players may face a disadvantage in terms of physical, neural, motor, and psychosocial development (Wattie, Cobley, & Baker, 2008), to surpass the bar for admission into the academy, presumably the player must have a much higher ability in other skill performance attributes (*e.g.* speed, technique, decision making – in combination or isolation) to survive within the system (Ford & Williams, 2012). The sample of relatively younger players, therefore, likely consists of a group(s) of exceptional players, whereas the relatively older players probably do not have to be so exceptional to meet the academy standards (Voettler & Höner, 2014). This is illustrated in Figure 1, which plots physical/technical ability against month of birth, with the beginning of the competitive year (1st September in English soccer) located on the y-axis. The dots are purposefully drawn to show a negative relationship between physical/technical ability and the distance from the cut-off point. The red line indicates a cut-off point (based on a judgement) at which players enter the academy, and below the line where they do not. If only players above the cut-off "make it", then the relationship between ability and distance from the cut-off is, at least, made less negative; and depending on how it is drawn, could be shown to slope upward. In this case, there is no actual "reversal" of the RAE, but rather it is an artefact of imposing a lower bound on technical/physical ability and choosing only the best players from the wider sample.

!INSERT FIGURE 1 ABOUT HERE!



This is, potentially, what we believe is the strongest driver of the observed difference between relatively old and young players. The second sample issue is a well-known issue with RAE research in soccer and that it only includes players that are "likely to make it". It is well documented that relatively younger players are more likely to be rejected from and/or may take longer to be accepted into an academy system; thus, by the time these players enter the academy (if they are still involved in playing soccer) the sample of relatively young players, more likely has higher technical ability than the larger sample. Even with the absence of a causal effect of relative age outcomes, this would bias the results toward finding an advantage for the relatively young.

As a final note on this issue, even without a selected sample, analysing the effect of relative age on academy performance outcomes is difficult, if not impossible. The biggest issue being that not all talented youth players progress into an academy environment, and so any appropriate methodology must first estimate the relationship between relative age and being admitted into an academy and hold that relationship constant when analysing how RAE impact on player or performance outcomes. This information is not always possible, especially when samples do not include specific information (*i.e.* starting age of players in academy systems) or track those players who did not make it into the academy system or were rejected at various development stages and no discernible reason for their deselection is available. The question is – are we actually observing a reversal of the age effect or as some have stated the *underdog effect?*

Relative age effect and biological maturation

Bio-banding

We have decided to include a section on bio-banding, not because it will address the issues of RAE, *per se*, but to help illustrate how bio-banding may help youth coaches understand the differences between biological maturation and relative age (Cumming *et al*., 2017). First, however it is important to note that maturity and relative age are not equivalent and result from different factors (*i.e.* cut off dates *vs* gene by environmental interactions). Indeed, intra-individual variations in the timing and tempo of biological maturation can have a significant impact upon a child's involvement in sport (Malina *et al*., 2015). Between the ages of 10 to 15 years old, children's maximal strength and subsequent performance in tasks associated with physical capacity and sports performance (*e.g.* jump height, sprint speed, acceleration) can vary dramatically (Lloyd *et al*., 2014). As the rate of improvement differs between individuals, those who mature in advance of their peers (*i.e.* 'early maturation') are said to be more likely to be represented in sports that demand greater size, strength, and power. In soccer this has resulted in specific anthropometrical attributes influencing positional roles in youth soccer academies (Towlson *et al*., 2016). It is important to state however, that a relatively older chronological age does not necessarily imply advanced maturity status (Hill *et al*., 2019). Conversely, those who develop at a slower rate, relative to their counterparts (*i.e.* 'late maturation'), are more likely to drop out of sport (*i.e.* self-selection and/or success-related selection) (Rees *et al*., 2016). The non-linear nature of a child's growth can mean biases emerge at different ages (e.g., early childhood *v*s pubertal onset) as a result the implementation of chronological grouping of young athletes for competition can compound selection and development issues. As such, a child born in the first quarter of the year can have a 'head-start' on a peer born in the last quarter of the year. As a result, children born early in the competitive year who are also 'early' in their maturation have a significant chance of success (Ostojic *et al*., 2014).

Despite its earliest use in soccer being reported by Bilton (1999), before the turn of the millennium, the bio-banding literature is still in its relative infancy and it must be acknowledged that a validated bio-banding methodology does not exist. There are, however, two possible approaches to group the players into their respective groups: 1) *Percentage of predicted adult stature*: Children's predicted adult stature can be estimated using equations (*e.g.* Khamis & Roche, 1994) which incorporate the child's anthropometric measurements and the child's biological parents' stature. The percentage of each child's predicted adult stature can then be used as an estimate of their 'maturity status'. 'Banding' players from 80-85%; 86-90% and 91-95% PHV has typically been used to categorise youth soccer players aged between 11-to-14 years old. 2) *Mirwald* (2002) *equation:* seated and standing height can be used to calculate trunk and leg length, which are then incorporated into a sex-specific calculation to estimate the amount of time the child is from reaching PHV and if the child is either an 'early', 'average' or 'late' maturing child (Malina *et al*., 2015).

Within the literature, there are three equations to estimate maturity off-set which have been developed using longitudinal data by Mirwald *et al.*, (2002), Moore *et al.*, (2014) and more recently by Fransen *et al.*, (2017). A band of −1 to +1 year around the event of estimated PHV can identify youth who are in the period of their growth spurt (during) and has been recommended as a way to group the players (Cumming, 2017). From a biological perspective, variations between chronological age and biological maturation (*i.e.* relatively older *vs* late maturing) are reported to be understood by a number of Europe's leading academies and, in some cases, estimates of skeletal maturity are in place to measure and monitor players classified as late, average or early maturity according to birth date quarter (Reeves & Roberts, 2019). One club was employing bio-banding strategies (Cumming *et al*., 2017) where players were grouped by estimated biological maturity status (Kharmis & Roche, 1994) for specific competitions and training once maturity variances were observed. Together these findings suggest the academies are perhaps better 'educated' regarding the nuances of RAE than has been suggested previously, however, further research is required to test whether RAE was eradicated in these environments.

Recently, bio-banding has also been used to group junior-elite soccer players during tournament competitions (Cumming *et al*., 2018). Here, the researchers studied the experiences of players competing in three 11-v-11 games. In this project players were categorised using the percentage of predicted adult stature method (Cumming *et al*., 2018). The investigators found that, in general the players showed support for bio-banding. Chronologically younger players classified as 'early maturing' who were asked to play at an older age category, cited the games as a more challenging environment (both physically and technically) which overall was a positive experience. Whereas, late maturing, but chronologically older boys described their experiences as an opportunity to demonstrate leadership skills and/or exhibit physical/technical skills. Similar findings have been reported by Bradley and colleagues (2019) in a cohort of 115 academy players competing in a small sided game formatted tournament. Although, in a study exploring the perceptions of bio-banding in coaches, parents and players across the pre-season training phase, the authors note there was confusion surrounding both the definition of and aims of bio-banding, which questions the reliability of earlier studies (Reeves *et al*., 2018). Reeves and colleagues also note other important implications of bio-banding: 1) implications for the social dynamic of each team; 2) additional planning is needed by each coach to meet individual learning objectives for players they might not typically have responsibility for; and 3) bio-banding can have additional logistical and organisational issues.

Whilst studies investigating the perceptions of bio-banding in professional soccer offer some unique insights, the long-term effect during training and competition is not known and requires further work. At present, we do not know the impact of bio-banding on the acute physical and physiological intensity and subsequent technical demands imposed upon the players during training and match-play. Understanding physiological intensity and subsequent technical demands, might allow coaches and practitioners to plan more effective training sessions in-line with macro training plans and players' individual learning objectives. Secondly, the impact of bio-banding on group dynamics, social skills and psychological factors relating to performance and player wellbeing is not well understood, although what preliminary evidence we have access to suggests that its impact could be meaningful.

Sport, and particularly soccer, does not occur in a social vacuum – talent emerges through constantly changing physical, biological, and behavioural environments. As such, understanding how bio-banding impacts physical, psychological, and social development might improve our understanding of how young players develop. It is likely that bio-banding could operate as part of a multifaceted and holistic program of player development. Considering that training technical competence is more effective when the performer is exposed to stimuli that complement their maturity status (Wattie *et al*., 2015), it could be argued that bio-banding could complement the 'constraints-based model', offering an alternative method to challenging players at pre-planned phases of their development. As

Cumming and colleagues (2017) suggest, bio-banding should not be a substitute for age group training or competitions but an adjunct activity that has the potential to challenge the athlete in a unique manner and to create a more diverse and developmentally appropriate learning environment.

Moving the RAE debate forward: The potential for transdisciplinary research?

Having shared our concerns regarding some of the methodological challenges surrounding RAE research, it is only appropriate that we offer some of our own translational, pragmatic research ideas, to move the RAE debate forward. The evidence cited, thus far, suggest the problem(s) of RAE are embodied, multi-dimensional, dynamic, and culturally mediated that incorporate, rather than isolate, interactions between the player, coach and their environment (Vaughan *et al*., 2019). Studies across the *majority* of RAE studies are characterised by a quantitative, reductionist, and mono-disciplinary approach (*e.g.* anthropometry, physiology, psychology, *etc*.) and this reliance on positivist assumptions *may* be what has contributed to what others have described as the cyclical (re)production of fragmented knowledge and further specialisation (Alhadeff-Jones, 2009; Hristovski *et al*., 2016). This is what we consider to be one of the design-related issues holding back the evolution of innovative RAE solutions. This is not an attack on mono-discipline work or, as stated earlier, a call for researchers to abandon quantitative, reductionist ontologies. Rather, we present a potential integrative solution to what has become depicted in other sport science literature as a "wicked" problem (Vaughan *et al*., 2019). We, therefore, suggest a departure from the traditionally narrow view of RAE inquiry and instead consider the role of transdisciplinary (TD) research.

Due to the constraints placed on word count, it is outside the scope of this paper to discuss TD research in depth (see Vaughan *et al*., 2019 for a review), however, due to the scarcity of TD research in soccer, we offer a brief summary. Transdisciplinary research attempts to answer questions to complex problems that cannot be sufficiently addressed via mono-discipline approaches and uniform theoretical approaches. Thus, it requires researchers and practitioners spanning diverse groups to create partnerships and cross-disciplinary and sub-disciplinary boundaries. Rather than constrained by epistemological and ontological assumptions, transdisciplinary researchers strive for "integration" across both the biological and social sciences. This form of integration combines not only methodologies and data capture techniques, but also theories and conceptual frameworks (Balagué *et al.*, 2017). The current weakness as we see it with RAE research could *potentially* be remedied by researchers adopting a TD framework while working alongside *in-situ* practitioners to help provide integrative, practical solutions.

Closing the gap between science and practice: The researching professional

Despite our optimism in proposing an alternative way forward we are also mindful that theoretical frameworks and concepts and the sharing or "unification" of ideas in sport science is considered problematic (Balagué *et al.*, 2017). To mitigate this potential risk, we propose academics work closely with researching professionals (*e.g.* Professional Doctorate/PhD students) working in applied soccer environments. For instance, researching professionals are generally required to investigate complex "real world", or "wicked" (Vaughn *et al.*, 2019) problems and provide transformative solutions and applied impact to the organisation or the environment where they are situated. They function in environments where the landscape is dynamic, permeable and lithe; continually emerging, changing and transforming. These researching professionals often function in organisations where they are required to adapt and change and contemplate embedding new modes of knowledge (Balagué *et al.*, 2017). Thus, compelling the 'doing of research' and providing the practitioner with opportunities to engage with practice-informed research and research-informed practice (Eubank & Forshaw, 2019). This TD view of working, which requires both *in-situ* practitioner and academic to consider the relationship across different research disciplines could provide some solutions to the methodological issues which have typically affected traditional forms of RAE enquiry (*e.g.* longitudinal research and tracking of players at baseline).

There is also notable absence of cohort studies in the RAE literature (Romann *et al*., 2018). A large TD cohort study may provide the most appropriate study design to capture the nuances of the RAE problem. For example, the participant sample can be uniform (*i.e.* time of entry into academy) and tracked prospectively, objective and subjective outcomes can be measured, and more than one outcome variable can be investigated (Webdale *et al*., 2019). These study designs are, however, expensive and time-consuming and it may take several follow up years for any results to emerge.

Concluding thoughts

The conclusions drawn from our assessment and understanding of the RAE literature include the following: 1) RAE continue to be prevalent in team sports such as soccer despite 35 years of empirical sport science research; 2) cut-off dates associated with inter-maturational differences (especially around puberty) are a factor, but professional soccer clubs are reluctant to consider elite soccer pathways until the late teens to mitigate the influence of chronological age and biological maturation; 3) rotating cut-off dates for selection only shifts the problem; 4) maximising provision may be persuasive but only shows association and not cause and effect; 5) providing player withdrawal/rejection data would be useful, albeit potentially difficult, to capture; 6) developing more sensitive measures of relative age (*e.g.* Cumming *et al*., 2018) is important, simply aggregating players into different quartiles (*e.g.* Q1 and Q4) for analysis purposes is problematic as it does not account for the individual differences, and assumes quartile groupings are homogenous; and 7) there remains a dearth of research providing applied, pragmatic solutions to mitigate RAE.

In our view, editors in chief, associate editors, and journal reviewers should reflect and consider, very strongly, how much more of this atheoretical work they are willing to accept. As stated at the beginning of this commentary, unless we are more robust and critical with our research questions and hypothesis where will it all end? Unless we open the door to innovative integrated research designs and methodologies then the answer, we suspect, will be more of the same: exploratory, cross-sectional studies, and secondary analyses unearthed from previously un-examined contexts - sports such as pool, snooker or darts - RAE in Formula 1 or equine sports, perhaps? We understand the realities, complexities, and challenges of RAE. We understand any potential solution(s) will be problematic and time consuming, but surely there has to be a line in the sand and an acceptance that any future questions, hypotheses, methodologies, and methods must attempt to provide strategies to eradicate RAE once and for all.

Approaching four decades of debate and research the search for a solution to the RAE phenomenon is proving to be elusive. This commentary points to a possible way of moving this debate forward. Ultimately, it will be the sport science community that will determine whether future research designs in this area are "good enough" and whether researchers are serious about eradicating the discriminatory practice once and for all. If not – then perhaps it is time to move on.

Disclosure of interest

The authors report no conflict of interest.

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Figure 1. Physical/technical ability plotted against date of birth