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Relative age and physical maturity status of elite Scottish youth soccer players: Effects on physical performance

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<u>Declaration of Originality</u>

The material contained within this thesis is my own work, except where stated. This material has not been submitted for the fulfillment of any other degree.

Signature:...

Date:...

Abbreviations List

APHV, age at peak height velocity; IE1, intermittent endurance 1; PHV, peak height velocity; RAE, relative age effect; RBFA, Royal Belgian Football Association; SA, skeletal age; talent ID, talent identification.

Literature Review

Introduction

Youth soccer in Scotland is structured according to chronological age with the intention of creating fair competition. Eligibility for a squad is a date of birth between 1st January and 31st December of the relevant year, which allows for an almost one-year difference in chronological age between players in the same squad. 'Relative age' refers to the differences in chronological age between players in the same age category (Wattie *et al.* 2008). The 'relative age effect' (RAE) is the widely reported finding that athletes born at the start of a selection year are over-represented and those born at the end are under-represented compared with the birth date distribution in the general population (Musch & Grondin, 2001; Boucher & Mutimer, 1994). To establish the presence of a RAE it must be demonstrated that the birth month distribution of the sample is significantly different from that of the general population and an assumption that births are evenly spread across all months of the year should not be made.

The presence of a RAE in soccer indicates a bias in favour of relatively older children while discriminating against younger children. Helsen *et al.* (2000b) reported that children born early in a selection year were more likely to be assessed as talented compared to those born late in the selection year. This finding is apparent regardless of the cut-off dates for a selection year (Helsen *et al*. 2000b). These results suggest that advanced relative age is mistaken for talent by coaches. This highlights the potential for potentially talented individuals to be deselected at an early age simply because they are born late in the selection year. The RAE is not present in all sports. Baker *et al*. (2012) reported no RAE among junior and senior figure skaters. The presence of a RAE is dependent on the nature of the sport in question and it may be the case that 'aesthetic' sports such as figure skating are not susceptible to such bias while contact sports such as soccer are. However, a RAE has been reported within the sports of tennis, cross country skiing, curling and snowboarding showing the phenomenon is not unique to contact sports (Raschner *et al*. 2012; Loffing *et al*. 2010). It may be that physicality, whether this manifests itself as direct contact between players or not, may be an underlying contributor to the RAE in sport.

The following review will explore the research surrounding the prevalence of the RAE in sport, with an emphasis on soccer. In addition, the relationship between the RAE and physical maturity – the extent to which the skeletal, sexual and neuroendocrine systems have developed fully (Malina *et al*. 2004) - will be considered as will the influence of physical maturity on key performance indicators. Explanations for the RAE outwith differences in physical development are explored and finally, potential solutions to the RAE in soccer are discussed.

The relative age effect; prevalence and implications

The RAE is not a phenomenon unique to sport as it also exists in the sphere of education. In the context of education, the RAE refers to the superior academic attainment of older compared to younger children. Relatively older children tend to perform better in school during the early years while relatively younger children are disproportionately classified as learning disabled (Diamond, 1983). DiPasquale *et al.* (1980) stated that relatively younger children subject to academic referrals eventually 'caught up' with their older peers over a number of years. It should be noted that Gredler (1980) disputes the existence of a RAE in education, citing other potential factors for the finding such as socio-economic status. While some debate may exist within the realm of education as to whether a RAE is present, the evidence is unequivocal in sport. A key difference between the RAE in education compared to sport is that within sport there is no requirement for an athlete to remain in the system, whereas a child must continue to go to school even if they struggle academically. There is no such obligation for an elite sports club to retain an individual in the absence of sporting success. In this fashion, it is possible that potentially talented individuals can be lost from the talent pool if they suffer biased selection policies early in life and therefore miss out on the opportunity to catch up.

The RAE phenomenon exists in many sports including soccer (Musch & Grondin, 2001; Boucher & Mutimer, 1994) and it is also apparent in many countries (Helsen *et al.* 2012; Helsen *et al.* 2005). Jiménez & Pain (2008) reported that the RAE was stronger in youth compared to adult professional soccer. It was suggested that large inter-individual differences in physical maturity between youth players that are not present in adulthood explained this finding. They also showed that within senior professional squads in Spain, the RAE was strongest amongst the youngest players. Again, this was likely because of the previously mentioned differences in physical maturity between younger players. The severity of the skewed birth month distribution dwindled with increasing age. Birth month distribution of players aged 30 years and older mirrored that of the general population (indicating no RAE among players who were aged 30 years or older). This finding among players aged 30 years and older shows that making selection decisions based on the physical maturity status of youth players is unproductive since by adulthood relatively older players hold no advantage over relatively younger ones. Van Den Honert (2012) also revealed the RAE to be strongest in youth compared to adult soccer in Australia. They showed the RAE was strongest amongst 14 year-old male soccer players. A possible reason being that transient differences in physical maturation between adolescent boys will be greatest around age 13-14 since this is typically when boys experience their growth spurt (Malina *et al*. 2004). Coaches and scouts may appraise physically mature players as more talented than their less mature peers when in reality they are actually mistaking physical precocity for talent (Helsen *et al*. 2000a).

The level of competition also appears to have a bearing on the severity of the effect. Youth international squads have been reported as demonstrating the most bias in player birth month distributions (Jiménez & Pain, 2008). Williams (2010) reported a RAE in most international youth teams at six world cup competitions between 1997 and 2007. Interestingly, Africa was the only continent not to enter teams with a strong RAE. The authors concluded this was likely due to erroneous reporting of birth dates by the countries in question. Equally, it may well have been the case that African teams placed more emphasis on technical skill than physicality. This explanation is under the proviso that excellence in technical skill is not dependent on physical maturation, a hypothesis supported by Vandendriessche *et al*. (2012). The over-representation of early born players in youth international competitions possibly reinforces the RAE by providing additional development opportunities for those selected and excluding those born later in the year so not allowing them to catch up.

A RAE has been reported to appear within ice hockey amongst children as young as 9 years old (Hancock *et al.* 2011). More worrying, a RAE was observed by Helsen *et al.* (1998) in youth soccer among children as young as 6 years old. Such a pattern of participation among children so young can only be viewed as undesirable. Helsen *et al.* (1998) highlighted a consequence of the RAE when they showed that the dropout rate of late-born players was greater than early-born players by age 12. This reflects player discouragement and demonstrates the loss to the talent pool the RAE causes.

The ultimate goal of youth soccer academies is to produce elite adult performers. If by age 30 there are just as many late-born as early-born players in professional teams then it would seem unnecessary for such an age bias to exist in youth teams. The equal numbers of early and late born players in the 'over 30 years old' category hint at the theory that only the very best late born youth players are selected to elite youth academies and are more likely than early born players to make it into elite adult squads once they are 'in the system'. It is conceivable that the high turnover of players within elite youth teams involves mostly early born players who were perhaps selected primarily on physical attributes while the late born players are retained year on year due to their exceptional technical ability (possibly enhanced by having to compensate for their lesser physical maturity status). The implications of the RAE in soccer are not fully understood, however, it is conceivable given the current situation that talented players are lost from the sport due to the existing selection bias. In Scotland, due to the financial limitations experienced by most professional clubs, a greater requirement for academy players to graduate to the elite adult first team is emerging. As such, these clubs should be concerned about any inefficiency in their talent identification (talent ID) systems.

Why does a RAE exist in soccer?

The precise reasons behind the RAE are nebulous and a number of factors likely contribute. The question now is what are the contributing factors? Talent ID is the practice of selecting performers with the potential to reach the elite level within a particular discipline. Within youth soccer this commonly takes the form of 'scouting' whereby scouts/coaches subjectively appraise the performance of an individual (Wolstencroft *et al.* 2002; Williams & Reilly, 2000). While the idea of scouting is to select players with the potential to play as an adult professional, it is likely the case that scouts' attention will be drawn to the best performers in any given game. The player with the most potential to improve and develop as an adult professional may not be the best performer at a young age and hence may be overlooked by scouts. This is because important attributes such as intrinsic motivation, tactical awareness, technical ability and a willingness to learn are not easily quantifiable and possibly get overshadowed at youth level by domineering players who are advanced in their physical maturation. This difficulty in separating indicators of current performance and potential is central to the RAE phenomenon.

Talent is a complex construct that is ill defined. Howe *et al.* (1998) attempted to define talent and suggested it to have five key aspects: it likely originates from DNA, is domain specific (only relevant in a narrow field of expertise), rare, is at least partially apparent during youth and those early indicators can be used to predict future success. Current evidence is lacking to support the idea that future performance can be predicted by any objective measure of talent (Helsen *et al.* 2000a). However, Helsen *et al.* (2000a) stated that they have never met a coach who felt they were not able to 'see' talent. Reilly *et al.* (2000b) reported that of the objective talent ID programmes that do exist in soccer, none have a strong scientific rationale. Current approaches comprise a mixture of anthropometric, physiological, psychological and soccer-specific skill assessments (Vandendriessche *et al.* 2012; Reilly *et al.* 2000b). It is conceivable that a talent ID process based primarily on subjective evaluation of young players may not be the most efficient in identifying future adult performers.

In addition to potentially rudimentary talent ID practices, another simple explanation for the RAE may be a positive correlation between relative age and success. Augste & Lames (2011) revealed that such a correlation did exist in German youth soccer. Final league placing of teams was related to the relative age of the squad. The nearer to the start of the selection year the median birth date of the squad, the higher their league placing. Short-term success may well be related to relative age in junior teams. However, the goal of an academy is to produce adult performers for the senior side, not necessarily to win youth league titles. Jiménez & Pain (2008) stated that if immediate success at the youth level is the desired outcome of youth academies, then the RAE serves that purpose well. The issue is that a RAE is not necessarily conducive to identifying and developing young players for the senior team.

The mechanisms behind the RAE are not clearly understood with the most commonly cited explanation being that relatively older children are more physically mature than their younger peers inferring a competitive advantage. Augste & Lames (2011) proposed that advanced physical maturity amongst older players was the reason for their finding – that relatively older teams achieved a higher league placing than younger ones – although they did not actually record any measure of it. Musch & Grondin (2001) described the likely contribution of physical demands of sport on the presence of a RAE. They also stated, however, that the current evidence base is not sufficient to support maturational differences as the sole reason behind a RAE. Other explanations suggested in the scientific literature relate to differences in psychological development between relatively older and younger players, the presence of competition and psycho-social theories e.g. Pygmalion effect (Hancock *et al*. 2013; Musch & Grondin, 2001).

Measures of maturity

Measuring physical maturity is a challenging objective to achieve with a number of different methods identified in the literature. Skeletal, sexual and somatic maturity are all candidates for measurement and each has advantages and disadvantages in the establishment of an individuals' maturity status as discussed below. The primary difficulty in the assessment of maturity status is that the timing and tempo of growth varies between individuals. This means that a child who is classified as delayed in maturity status at age six may not still be classified as such at age 12. One-off assessment of maturity status is vulnerable to misinterpretation over time because of these differences in timing and tempo of growth. Longitudinal monitoring is useful in the applied setting as it allows regular updating of an individual's maturity status.

Skeletal maturity is arguably the best method in terms of quantifying physical development since skeletal maturation spans the full spectrum of growth from childhood through to adulthood (Malina *et al*. 2004). Assessment of skeletal maturity is possible because the start and end point in skeletal development is the same in each individual, namely, the skeleton is made up of cartilage prenatally and transitions to fully developed bone in adulthood (Malina *et al.* 2004). Radiographs of the hand and wrist are used when assessing skeletal maturity and numerous methods of interpreting these radiographs exist and are based on the concept of comparing them to reference examples as discussed below.

The Greulich-Pyle method involves the matching of an individual's hand-wrist X-ray with various reference slides to attain the closest match (Greulich & Pyle, 1959). The reference slides correspond to typical radiographs of the hand-wrist at a certain chronological age. An individual's skeletal age (SA) refers to the chronological age associated to the reference slide that most closely coincides with his or her own radiograph. For example, it is possible for a child with a chronological age of 12 years to have a SA of 14 years. In such an example, the child possesses a SA in advance of their chronological age and may be described as advanced in maturity status. The

Tanner-Whitehouse method involves the evaluation of various individual bones that are present on the hand-wrist radiograph (Tanner *et al.* 1962). A score is assigned using specific criteria to assess what stage each bone is at in its development. The sum of each bone's score produces a maturity score ranging from zero (immaturity) to 1000 (maturity). A number of variants from the original method now exist and these are based on different reference populations. The issue of reference population specificity is a pertinent one as the comparison of an athletic population's radiographs to that of a sedentary population may not give relevant results. The Fels method is based on the process of matching specific bones of the hand-wrist to specific criteria and assigning them grades (Roche *et al.* 1988). The Fels method also provides a standard error of estimate for each assessment. Radiographs of the hand-wrist provide a snapshot of maturity status, however, due to the expense, exposure to radiation (in the case of X-ray) and time commitment, this method is not practically useful in the longitudinal tracking of maturation. It is now possible to use MRI scans as oppose to X-rays to attain an image of the bones that make up the hand and wrist. This removes the issue of repeated exposure to radiation. However, MRI scanning is still not practical for the longitudinal tracking of maturation in youth soccer players due to the high cost of the equipment (Dvorak *et al.* 2007). The results of each method are not necessarily equivalent as the Greulich-Pyle, Tanner-Whitehouse and Fels methods each produce a different SA for the same radiograph (Malina *et al.* 2004). The reference values that each method is based on are different and this may partly explain the discrepancy in results. The samples used in the formation of each method are from different countries and even different generations. Recent samples of children have demonstrated a consistently greater SA than the reference values indicating a possible shift in anthropometric norms over the last 50 years (Malina *et al.* 2004).

Sexual maturation, as measured by assessment of secondary sex characteristics provides another avenue for quantifying maturity status. The most widely used criteria for categorizing different stages of secondary sex characteristics were established by Tanner (1962). The indicators considered when assessing maturity status are generally breast (in girls), genital (in boys) and pubic hair (boys and girls) development. Classification of different stages of development is challenging because the criteria that define the discrete stages of breast, genital and pubic hair development, excluding the earliest and latest stages, are somewhat arbitrary (Malina *et al.* 2004). For example, using a five-point scale the differences between stages one and five may be clear. The difference between the end of stage three and beginning of stage four is ambiguous. Classification can thus become subjective and equivocal (Malina *et al*. 2004). Assessment of stage of development is usually achieved by direct observation by a practitioner. Self-assessment is possible albeit, considered less accurate, with individuals either under- or over-estimating what stage they are at (Schlossberger *et al*. 1992). Such an assessment is most often performed in the clinical setting (Malina *et al.* 2004) and has limited practicality in the sports setting as the invasion of privacy is a legitimate concern of adolescents and parents. The rating of secondary sex characteristics as a measure of maturity status is only useful during puberty and hence not the full spectrum of growth. This limits its use as a tool to a window during adolescence that does not encompass early childhood and young adulthood.

Measurement of secondary sex characteristics provides a less expensive and slightly more practical option for the assessment of maturity status than the calculation of SA.

A third option is the use of somatic measurements such as stature and mass for calculating maturity status, however, these are not indicators of maturity in isolation (Malina *et al.* 2004). If longitudinal data are collected then somatic measurements can be used to identify certain events that relate to maturation. Age at peak height velocity (APHV) is the chronological age that corresponds to the most rapid rate of growth during adolescence. APHV can be identified and predicted using somatic measurements including stature, seated stature, mass and chronological age with various prediction equations. The use of prediction equations and somatic measurements provide a practical way to monitor maturation of young soccer players in an applied setting. Mirwald *et al.* (2002) developed an equation using regression analysis to predict APHV, reporting that APHV could be predicted ±1 year. They suggested that the maturity-offset value the equation produces only be used to categorize adolescents as pre or post peak height velocity (PHV) rather than as a continuous measurement. However, the authors also stated that with more frequent observations the equations become more robust. This suggests that using the equation as a continuous monitoring tool in the sport setting is a viable option for measuring maturation.

A positive correlation exists between maturity status as calculated from hand-wrist X-rays and predictive equations (Mirwald *et al.* 2002). However, the strength of the relationship is tenuous. Malina *et al.* (2012) demonstrated that a relatively poor correlation existed between maturity status calculated via the Fels method and Mirwald's equation. The relationship between other methods of skeletal assessment (Greulich-Pyle, Tanner-Whitehouse) and the predictive equation are not clear. Differences in the timing of skeletal and somatic maturation may account for the weak relationship. Malina *et al.* (2012) suggested that Mirwald's equation was not sensitive enough to classify players into maturity groups. Very different classifications arose when maturity status was calculated using the Fels method or Mirwald's predictive equation. SA calculated from a radiograph of the hand-wrist is currently considered the gold standard in assessing maturity status because skeletal maturation spans the entire spectrum of physical development (Malina *et al*. 2004). Logistically this is a difficult method to use in an applied setting. Predictive equations are useful in the applied setting though may not provide as accurate an estimation of maturity status in young soccer players.

Monitoring of physical maturity is important within academies as it allows the maturity status of individual players to be taken into account when interpreting both subjective and objective performance assessments. If advanced physical maturity is associated with improved sprinting speed and agility, it would be unfair to compare two players differing in maturity status at age 14 since this is when transient maturational differences are likely to be at their greatest. Being born near the start of the selection year means it is likely that an individual will be more physically mature than someone born near the end and this is why many studies have presumed physical differences between older and younger players explain the presence of the RAE. This explanation is based on the proviso that advanced physical maturity is associated with superior physical performance.

Physical maturity and the RAE

Many studies presume the RAE is a result of physical maturation advantages to early born players yet this is not always supported by the scientific literature. Figueiredo *et al.* (2009) reported that late maturing soccer players – indicated by skeletal age – were under represented in various age group squads but that players who differed in maturity status did not differ in chronological age. This demonstrates that physical maturity may play a role in player selection but it is in contrast to the idea that relatively older children are more mature. Physiological capacities have been shown to be reasonable predictors of progression from academy level to professional status in soccer (Gonaus & Müller, 2012) hence; if advanced maturity is associated with improved physiological capacities then this may explain the lack of late maturing players in youth soccer academies. Yet, this finding would still not reveal whether the relatively older players in an age category are also the most physically mature.

Children's physiological capacities increase year on year and this continues into adolescence (Borms, 1986). PHV is a particularly important stage in this physiological development. Ford *et al.* (2011) stated that the largest gains in sprinting speed are seen just after PHV. Similarly, Philippaerts *et al.* (2006) observed the greatest rate of improvement in balance, speed, agility, strength and power in young soccer players during PHV. The earlier an individual reaches PHV and consequently begins to increase their speed, strength and endurance the more likely they are to stand out within a squad of players and enhance their chance of progression. It is conceivable that late maturing players may be appraised as inferior compared to early maturing players based on transient differences in physiological development. This would suggest that advanced maturity status should be particularly advantageous around the chronological age of 13-14 years when boys typically experience PHV (Malina *et al.* 2004). Thus the two key issues surrounding this research area are; firstly, within the context of a one-year age band are chronologically older players more physically mature compared to their chronologically younger counterparts and secondly, is advanced physical maturity associated with superior physical performance?

Matthys *et al.* (2012) described no correlation between chronological age and predicted APHV in handball players aged 14 years. Matthys *et al.* (2012) classified participants as early, on time or late maturing depending on their predicted APHV. Early maturing individuals were classified as having a predicted APHV > 1 year prior to a normative value while late maturing individuals; > 1 year-post the normative value. Early maturing players were significantly taller, heavier, faster and more powerful than late maturing players in the same age group. Greater maturity certainly appears to confer an anthropometric advantage but whether it is linked to relative age is less clear. Advanced maturity status appears to be advantageous in terms of selection in Portuguese youth soccer players (Malina *et al.* 2000). A marked bias existed in favour of early maturing players aged 13-16 years. This reinforces the advantage of advanced maturity but the study did not report the relationship between relative age and maturity making it difficult to determine if the relatively older players were more mature than their younger peers.

The Royal Belgian Football Association (RBFA) set up national 'futures' teams at both U16 and U17 levels to run parallel to their standard youth international teams to try and reduce dropout rates amongst late maturing players. In concurrence with Matthys *et al*. (2012), Vandendriessche *et al.* (2012) reported no difference in chronological age between Belgian youth international and futures youth teams. The futures teams were less physically mature (assessed using APHV) than the standard teams, suggesting chronological age and physical maturity are not necessarily linked within the context of a one-year age group band. The utilization of a futures team highlights a perceived flaw in the current talent ID system in soccer by the RBFA. Clearly, the RBFA perceives that there are late-maturing players who will eventually emerge as top-level adult performers who would ordinarily have been deselected from the national squads without a futures team. Another view is that soccer institutions simply do not know what qualities they are looking for in young players and the initiation of a futures team allows a widening of the net and an opportunity to nurture more players in the hope that some emerge as top-level performers.

Delorme & Raspaud (2009b) found that relatively older youth basketball players (those born near the start of the selection year) were taller and heavier than relatively younger players (those born near the end of the selection year). They showed that players born in the first and second quarters of the selection year were significantly taller than those born in the fourth quarter when measured at the same time.

However, stature and mass are not strong indicators of maturity status (Malina *et al.* 2004). These findings suggest a tenuous link between relative age and physical maturity in a one-year age band.

No significant differences in stature or mass between birth quartiles were observed in young elite Belgian soccer players ranging in age from 10-19 years (Deprez *et al.* 2012). The authors also reported the counterintuitive finding that in some of the age groups, late born players displayed an earlier APHV than early born players. This suggests that relatively younger players were in fact more physically mature than their older counterparts. Such a finding was likely due to the formation of a homogenous group. It is probable that only the most physically advanced late-born players are selected for elite level teams. The young athletes observed by studies investigating the RAE and maturity status are frequently of an elite standard representing regional and even national boundaries. In this way, on-time and late maturing late-born players are perhaps not included in the samples of most studies investigating elite youth soccer teams. This is an issue pertinent to the present study since participants were players from a Scottish Premier League youth academy. As such it is possible that within the cohort of participants, very few late maturing individuals were present due to previous, potentially biased, selection favoring more mature players.

Maturity status and key performance indicators

If the RAE in soccer exists because relatively older players are more physically mature a relevant question is; do more mature players perform better in tests of strength, speed and endurance?

Soccer players aged between 11-12 and 13-14 years, categorized by maturity status have been shown not to differ significantly in many functional capacities (Figueiredo *et al.* 2009). The only variable the 11-12 year olds varied in was the yo-yo intermittent endurance level one (IE1) test (which encompasses repeated changes of direction) where the late maturing group outperformed the on time and early maturing players. An explanation for this counterintuitive finding may be that late maturing players were more efficient at decelerating and re-accelerating when running due to the reduced body mass reported in the late maturing compared to early maturing players. Figueiredo *et al.* (2009) also observed few differences between 13-14 year olds of contrasting maturity status. Lower body power (measured by squat and counter movement jumps) was the only variable where a significant difference was observed with the early maturing group out performing their peers. Greater skeletal muscle mass among the early maturing players may explain their superior performance in the jumping tasks, however, muscle mass was not measured so such a suggestion is based only on conjecture. Equally, if greater skeletal muscle mass among the early maturing players was a factor then it would be unclear why they did not also outperform the less mature players on the agility task. It remains unclear why the more physically mature players in the 13-14 year old group outperformed their less mature peers only in the jumping tasks.

Vandendriessche *et al.* (2012) observed older soccer players aged 15-16 years separated into different squads based on maturity status. The players were selected for the late maturing squad based on coach evaluation. Subsequent analysis of the groups revealed that the late maturing group did display a significantly later APHV as calculated by the regression equation formulated by Mirwald *et al.* (2002). The more mature squads outperformed their less mature counterparts on the majority of key performance indicator tests (sprint tests, t-tests, counter movement jump and broad jump). The squads did not differ in any of the motor coordination tests, some of which included a ball. This finding suggests that technical soccer skills may not be influenced by maturity status.

Similarly, differences in physiological capacities have been shown in 13-year-old soccer players based on maturity status as assessed via the Greulich-Pyle method (Carling *et al.* 2012). Maturity differences were apparent in sprinting speed and vertical jump height with early maturing players outperforming late maturing players. The data were also collected over the course of ten years revealing that the maturity differences observed were a consistent finding.

The results reported by Figueiredo *et al.* (2009) and Vandendriessche *et al.* (2012) seem to contradict each other. The former study suggests that maturity differences in key performance indicator tests are not apparent and the latter states the opposite view. The difference in chronological age of the two samples may be a factor. Perhaps maturity differences are not widespread during childhood and early adolescence but develop subsequently as temporarily more mature players who have gone through PHV dominate the late-maturing players who have not. The low number of late maturing players within the sample reported by Figueiredo *et al.* (2009) may also have contributed to the lack of differences between maturity groups.

Maturity status and sport-specific skill

Success in professional soccer is achievable with moderate fitness levels if technical and tactical proficiency are of a high enough standard (Reilly *et al.* 2000a) therefore physiological measures of performance should not be the only consideration of talent ID programmes. Within a homogenous sample of elite young soccer players, physiological measures failed to separate those who went on to sign professional senior contracts from their unsuccessful peers (Franks *et al.* 1999). Reilly *et al.* (2000a) suggested that a threshold might exist above which any differences in physiological capacities do not differentiate players who progress from youth to senior levels. Above this threshold technical ability may be a better discriminator. Youth teams containing boys around the chronological age of 13-14 may not be homogenous groups in some cases due to wide variations in the timing of PHV. This potential discrepancy in physiological maturity between players of this chronological age means physical prowess may dominate a scout's perspective of a player, more so than their technical ability. This may be problematic since technical ability may be a more important attribute than physiological capacity in identifying top-level adult soccer players.

Many studies have reported that groups based on maturity status do not differ in tests designed to measure technical skill (Matthys *et al.* 2012; Vandendriessche *et al.* 2012; Figueiredo *et al.* 2009; Malina *et al.* 2005). 'Technical skill' is not a well-defined concept but studies designed to measure it often use motor coordination tasks relevant to the sport in question. In the case of soccer, tests measuring dribbling speed, shooting accuracy and ball control are common (Vandendriessche *et al.* 2012; Malina *et al.* 2005). Technical ability is not limited to these tasks but it is difficult, if not impossible to quantify equally important attributes such as tactical awareness, positioning, vision and decision-making.

Relative differences between young players in attributes such as strength, speed and aerobic capacity are not necessarily stable throughout puberty (Wolstencroft *et al.* 2002; Reilly *et al.* 2000a). As such, a player who is the fastest in the squad at age 14 may not still be the fastest at age 18. Since performances in physical tests of fitness are unstable through adolescence, they may not be the best factors to judge young players on when making predictions on future success. Judgment based on technical proficiency may be a more sensible route to follow when selecting players for academy teams. Psychological and even sociological factors should also be considered when evaluating young players' suitability for inclusion in academy teams as used by the English Football Association four corner model (http://www.thefa.com/News/st-georges-park/2013/jan/social-focus). Consideration of personality traits, how the individual is likely to affect the social dynamic of the existing squad, how often they will be able to attend training sessions and many other issues are important factors when it comes to the long term success of the player and the team.

<u>Coaches' perspectives on the RAE</u>

Technical ability is widely professed to be the main attribute scouts, coaches and managers look for in young soccer players (personal communication – J.McGlynn, J.Murray) yet the RAE supports the idea that the most physically mature are selected for elite squads. A logical starting point for talent ID programmes is to establish the traits and abilities of successful elite athletes (Wolstencroft *et al.* 2002). Once typical profiles have been compiled, such programmes may then focus on identifying young athletes who display such qualities, however, caution should be exercised when adopting such an approach. Youth athletes are not mini-adults (Reilly *et al.* 2000a) and trying to match adult qualities to youth athletes will likely lead to the identification of indicators of performance rather than indicators of potential (Wolstencroft *et al.* 2002). In addition to technical skill, coaches still appear keen to recruit youth players with advantageous physical qualities such as stature, speed and strength (personal communication – J.McGlynn, J.Murray). This suggests that, to some extent, coaches in Scotland are still selecting youth players based on desirable adult qualities, in turn granting an advantage to more physically mature individuals. Separating indicators of performance and potential is an issue fraught with difficulty. After all, what is potential? An indicator of performance is a quality that demonstrates current ability while an indicator of potential is a quality that may suggest future success. In some cases, such indicators may be one and the same thing but equally they may not. The landscape of youth player recruitment in Scotland is reportedly changing from one concentrated on physical attributes such as size and speed to one more concerned with technical ability (personal communication – J.McGlynn, J.Murray, S.Pressley). It is likely a talent ID programme centered on technical ability would be less susceptible to result in a RAE than one centered on physical attributes. Some influential figures within the Scottish game subscribe to the view that the RAE is not a major problem (personal communication – J.McGlynn, J.Murray, S.Pressley). If such views are held widely within professional football, then it is no surprise that the issue is prevalent despite the acknowledgment of its existence.

<u>Alternative explanations for the RAE</u>

Soccer and ice hockey have been investigated extensively in relation to the RAE (Hancock *et al.* 2011; Helsen *et al.* 2005) yet whether a RAE is present in less physical sports is not well understood. The presence of a RAE or lack thereof in less physical sports could help improve our understanding of the phenomenon in soccer. Delorme & Raspaud (2009a) investigated the sport of shooting in relation to the presence of a RAE in France (the French Federation for Shooting Sports organizes members into age categories based on the calendar year). The authors found that a RAE did not exist in women within shooting. However, they reported that a RAE was present within men in certain age categories but not always in favour of relatively older individuals. A RAE in favour of older children was reported in the under-11 years category. The proposed explanation for this finding was related to differences in mental as opposed to physical maturity. The authors stated that shooting sports have no *a priori* reliance on physicality. They postulated the RAE was more likely due to relatively older and hence more mentally mature children being perceived by parents as responsible and capable of safely partaking in shooting sports. An inverse RAE was observed in the 15-17 year old age group whereby late born individuals were over represented and early born individuals were under represented. Delorme & Raspaud (2009a) suggested that this may be have been due to high drop out rates amongst late born boys in other sports such as soccer. They proposed that late born individuals wanting to remain in sport may have sought out sports such as shooting that do not discriminate based on physical maturation. The explanations offered for the RAE in the sport of shooting are based on conjecture. They do, however, highlight the point that forces other than physical maturation may contribute to the RAE in certain sports. In contrast, Van Rossum (2006) stated that a RAE is unlikely to be found in sports where physicality is not important.

One such factor could be competition for places (Wattie *et al.* 2008) as supported by the assertion Musch & Grondin (2001) have made that the greater the number of potential players the more severe the RAE. Intuitively, this argument makes sense since the fewer the number of potential players the less scope for selection. Experience and practice have also been highlighted as contributors to the RAE in soccer. Among children aged 10 years a relative age difference of almost one year can exist. This means that an early born child can have almost 10% more life experience than a relatively younger player (Musch & Grondin, 2001). This difference in accumulated training experience could grant an advantage to older players. Also, even if young players are initially selected for elite teams based on physiological and anthropometric attributes based on differences in maturity status, these are not necessarily the same factors that perpetuate it. Physical precocity may provide the initial advantage for early born children in terms of selection into academy teams but once selected the RAE may be perpetuated by the accelerated accumulation of practice hours compared to late born children who are not selected for academy teams. In this way, practice rather than physical maturity status may be the driving force behind reinforcing the RAE in soccer. Helsen *et al.* (2000a) reported that the number of practice hours was a strong predictor of level of success within soccer. International, national and provincial level players could be identified based on accumulated practice hours. Such a theory would be supported by the 10,000-hour rule that stipulates the average number of quality practice hours required to realize excellence in a given task (Ericsson *et al*. 1993). It is likely a combination of physiological, psychological and sociological factors contribute to the existence of the RAE in soccer.

<u>Potential solutions to the RAE</u>

Several possible solutions for the RAE have been presented within the scientific literature (discussed below), however, few of these potential measures have been implemented over the last decade (Helsen *et al.* 2012). If advanced physical development is accepted as the primary cause of the RAE in soccer, then rule changes that reduce the influence of physicality may have an effect. Ice hockey suffers from a RAE to a similar extent as soccer, however, banning body checking in ice hockey did not eradicate the RAE (Hancock *et al.* 2011) although a rebalancing effect was observed between the second and third quartiles within some skill categories. Within some of the lower leagues, the banning of body checking resulted in the number of players born in the second and third quarters to more closely mirror the expected distribution based on the general population. The greater the skill level the more pronounced the RAE was, suggesting that the level of competition is a contributing factor to the presence of a RAE. The findings hint that at lower skill levels at least, rule changes may be capable of tempering the RAE. In soccer, such a rule change may manifest itself as a 'no slide tackle' or 'no shoulder barging' rule. A possible explanation for the finding is that at the lower skill levels, this one rule change was enough to alter the way coaches selected their players. Whereas, at the higher skill level the competition for places may be so fierce that even with no inherent need for relatively older and more mature players coaches selected them anyway.

Rotating cut off dates has been suggested as a way of tempering the RAE. Adopting such a policy would not necessarily eliminate the RAE but would allow all birth quartiles to periodically be the most advantageous (Helsen *et al.* 2005; Musch & Grondin, 2001). Administratively such a system would be challenging to manage. Altered age group classification bands are another option. A six-month age band may reduce the impact of developmental differences between players. The main practical obstacle would be the increased demand for coaching staff and facilities. Classification based on physical maturity rather than chronological age is a theoretical option, however, this would be an extremely difficult system to operate (Musch & Grondin, 2001). Different methods of measuring physical maturity exist and they do not always produce equivalent results. Such a classification system would not be practical in an applied setting. Reserving a set number of spaces on elite squads for late born players could address the RAE but it is likely that this proposal would be unpopular among coaches, players and parents alike as it could potentially elicit the perception that individuals were not being selected on merit.

Conclusion

Despite ten years of research into the RAE the problem has actually become worse, with the severity of the skewed birth date distribution in professional soccer increasing in most European countries (Helsen *et al.* 2012). A potential explanation for this worsening – in England and Scotland at least – is the oft-maligned cliché that the sport is increasingly becoming more physical and aggressive every year. There are currently no scientific studies documenting this mentality, however, it is prevalent and regularly a topic of discussion on television and radio programmes. Managers and coaches may feel under pressure to select players able to cope with the increasingly physical and aggressive nature of the sport. The RAE among young players selected for elite academies in France did not improve over the course of ten years from 1992 to 2003 (Carling *et al.* 2012). The fact that the RAE among young academy players hasn't improved over ten years shows that major attempts to solve the problem do not appear to have been successful. This is possibly because many within the sport do not perceive the RAE as a problem. With a seemingly never ending supply of players to choose from clubs perhaps lack any incentive to address the issue.

Soccer is not the only sport to fail to address the RAE. The RAE observed in ice hockey also remained unchanged from 1984 to 2010 (Nolan & Howell, 2010). Many studies have assumed the RAE is a result of differences in physical maturation between children in the same age group yet this view has not always been supported by the literature. Advanced physical maturity does appear to grant players an advantage in physiological tests of speed, strength and power yet relatively older players are not necessarily the most physically mature.

The present study will determine the existence, or not, of a RAE in Scottish youth soccer through the comparison of birthdate distribution of a large sample of elite academy players to the general population. Further, reporting of average scores for various measures of physical performance at different age groups will produce normative data for use by sports professionals. Finally, the data collected will allow for exploration of the potential causes of the RAE by elucidating whether relatively older players are also more physically mature than their younger counterparts and how age and maturity influence measures of physical performance and anthropometry. These issues have not previously been investigated within a Scottish population, yet with the intensifying financial restrictions experienced by most professional teams in this country and the resultant need to rely on youth player recruitment, a greater understanding of the talent ID practices they utilize is warranted.

Research Article

Introduction

Youth soccer in Scotland is structured according to chronological age with the intention of creating fair competition. Eligibility for a squad is a date of birth between 1st January and 31st December of the relevant year, which allows for an almost one-year difference in chronological age between players in the same squad. 'Relative age' refers to the differences in chronological age between players in the same age category (Wattie *et al.* 2008). The most widely reported RAE in youth soccer is that athletes born at the start of a selection year are over-represented and those born at the end are under-represented compared with the birth date distribution in the general population (Musch & Grondin, 2001; Boucher & Mutimer, 1994). The RAE has been reported within many countries, such as Belgium, Spain, Germany and Sweden (Helsen *et al*. 2005), however, to date Scotland has not been investigated. The RAE may result in potentially talented players being released prematurely from elite academies or indeed not being selected in the first place because they were unfortunate enough to be born in the last quarter of the selection year. The RAE has been observed to disappear among professional players over the age of 30 years old demonstrating that whatever causes it at the youth level is no longer relevant to selection in adulthood (Jimenez & Pain 2008). In Scotland, youth players are scouted and recruited by professional clubs for their academies from the sub-elite boys club tier. This scouting process is based on the subjective appraisal of players' performance in games by club scouts and coaches (Unnithan *et al*. 2012). The most popular theory explaining the RAE is that, wittingly or unwittingly, scouts recruit the relatively older players due to them supposedly being more physically mature. The inference is that advanced physical maturity equates to being taller, heavier, stronger and faster than less physically mature players causing the older individuals to catch the eye of the scouts (Augste & Lames 2011; Hancock *et al*. 2011; Musch & Grondin 2001). Whether significant differences in physical maturity and physical performance exist between relatively older and younger children within the context of a one-year age band has not been definitively examined. There were three main aims of the present study; the first was to establish whether or not the RAE existed within Scottish youth soccer. The second aim was to examine whether significant differences existed between birth quartiles in measures of anthropometry and physical performance (sprinting speed and change of direction ability). Thirdly, the influence of physical maturity on measures of anthropometry and physical performance was investigated.

Methods

Participants

Data was collected from youth players registered at a Scottish Premiership club academy over the course of six seasons from 2007 to 2012. All players were selected via a scouting system. Players in the under 11, 12, 13, 14, 15 and 17 age categories were assessed each year for physical performance. In total, 94 under 11, 83 under 12, 101 under 13, 107 under 14, 84 under 15 and 39 under 17 players were assessed. Data for the under 17 age category was only available from the years 2010, 2011 and 2012. Players representing the club in more than one age category during the sampling period were analyzed for each age band in which they were selected. Participant assent and written parental consent were obtained as necessary prior to all physiological testing.

Experimental design

Within each age category players were grouped according to their quartile of birth. Quarters one, two, three and four included those born between the months of January-March, April-June, July-September and October-December respectively. Each age category contained players born in a range of different years. For example the under 13 age category contained players born in the years 1995, 1996, 1997, 1998, 1999 and 2000. The General Registrars Office for Scotland provided data on the number of births within the general population by month for all the relevant years for each age category. Expected birthdate distributions were calculated from the appropriate years using this information. In the case of the under 13 age category this meant summing the number of births in each quarter for the years 1995, 1996, 1997, 1998, 1999, 2000 within the general population and then comparing the birthdate distribution with that of the sample distribution.

At the start of each new season – during the first week of September – players completed a series of physical assessment protocols. All assessment protocols were completed during one day each year. All age categories completed a 0-15 meter sprint test (Figure 1) with two attempts per player allowed and the fastest time being recorded. Players had approximately three minutes rest between efforts. Approximately 10 minutes after completion of the 0-15m sprints players in the under-11 to under-14 age categories also performed the T-test (Figure 2) with two attempts turning right and two attempts turning left allowed with three minutes rest between efforts. Players were instructed to turn at each pole so they were always facing the way they were travelling. This ensured the players were always running forward and not side shuffling or running backwards. The fastest time out of all four attempts was recorded. A bespoke test (Figure 3) was used to assess change of direction ability within the under-15 and under-17 age categories. Similarly this protocol was performed approximately 10 minutes after the 0-15m sprints. Players were allowed two attempts turning right and two attempts turning left with the fastest of all four attempts being recorded and three minutes recovery allowed between efforts. All speed and change of direction assessments were measured using electronic timing gates (Smartspeed) and conducted on an indoor synthetic pitch. During these physical tests all participants wore playing boots with moulded studs. Prior to starting the speed and change of direction assessments all players completed a 15-minute warm up comprising light aerobic exercise and dynamic stretches. Mass along with standing and seated stature was recorded each year using calibrated Avery Weigh-Tronix scales and a Harpenden stadiometer respectively. Anthropometric measurements were collected before the speed and change of direction assessments. For the anthropometric assessments players removed their footwear and wore a training t-shirt and shorts. Maturity offset was calculated using the equation developed by Mirwald *et al*. (2002). To calculate maturity status using this equation, standing

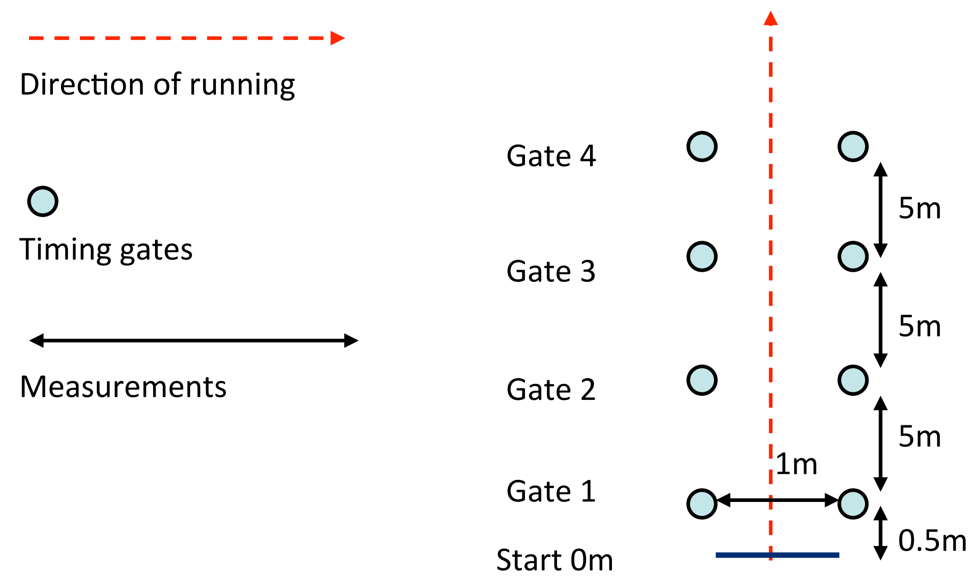

Figure 1. Linear 0-15m sprint test diagram

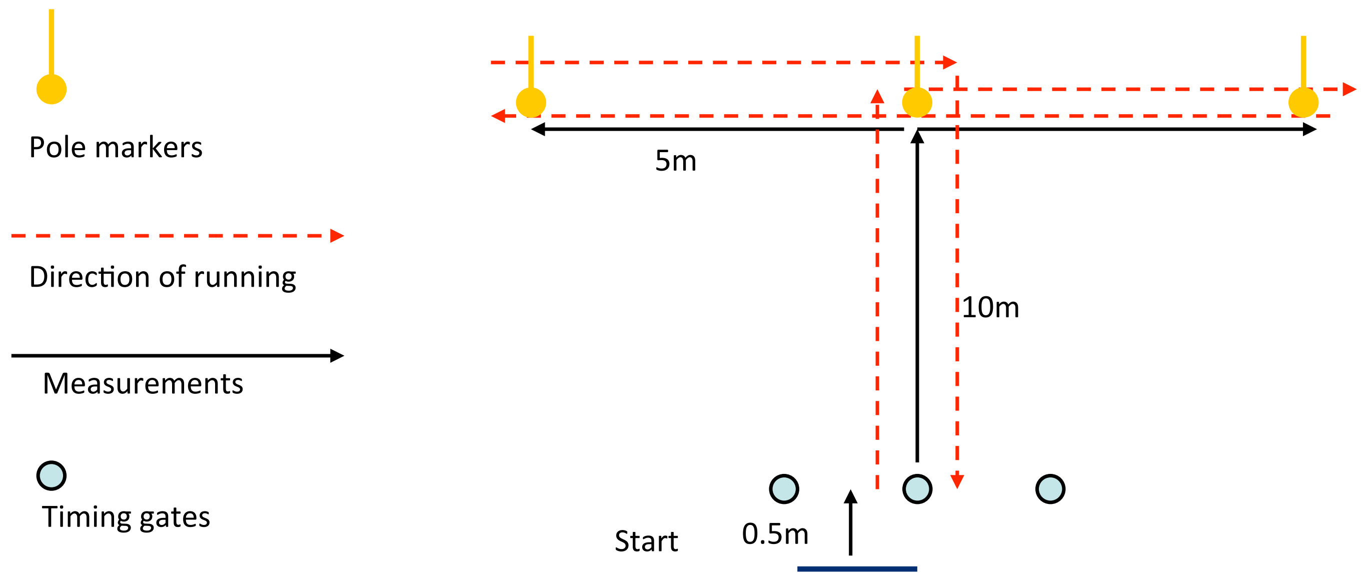

Figure 2. T-test diagram

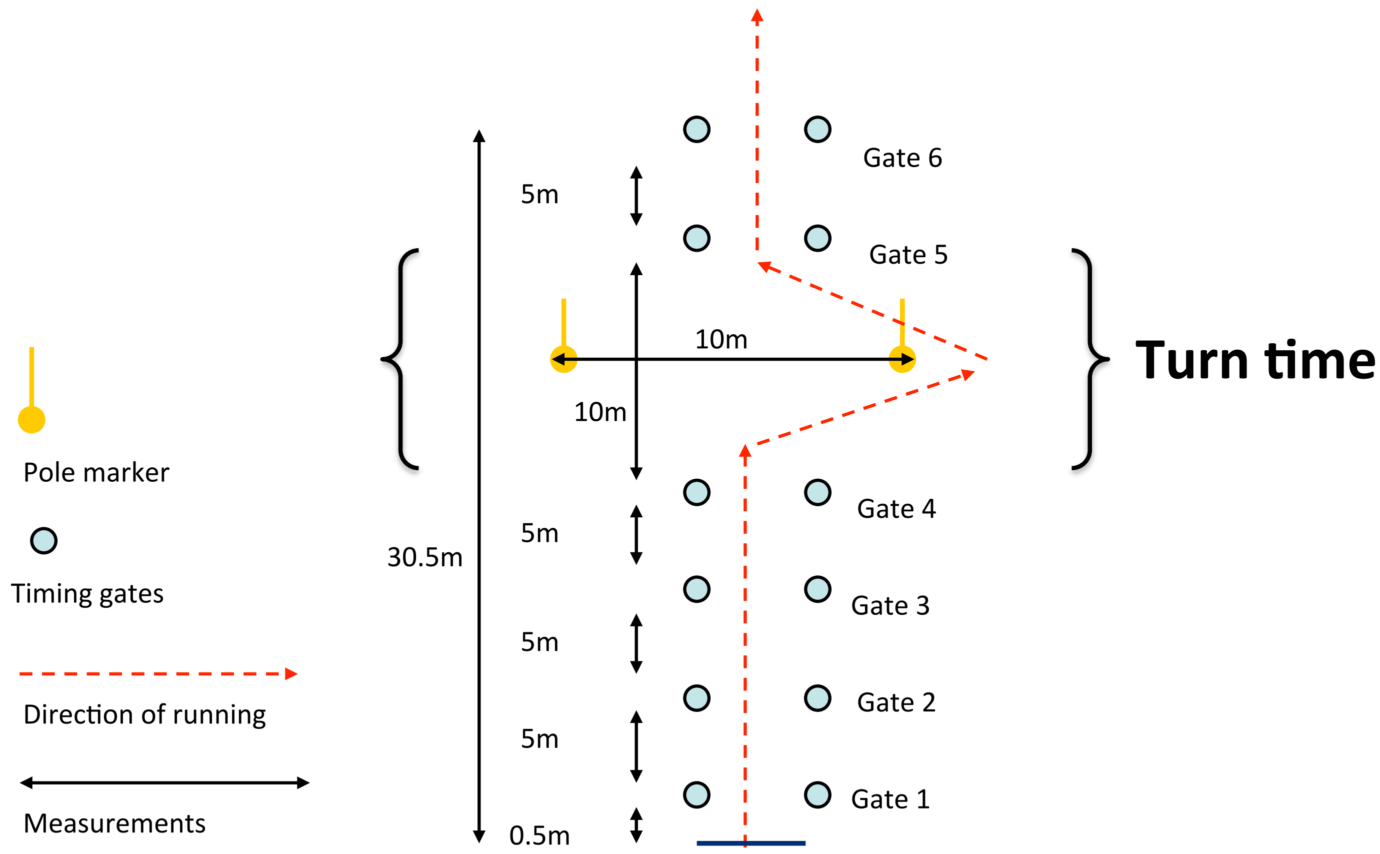

Figure 3. Change of direction test diagram (‘turn time’ is the time taken to travel between gate 4 and 5)

stature, seated stature, mass, the participant's date of birth and the date of the test are required. These values are entered into the equation to generate each individual's maturity offset status. For each age category the players' maturity offset values were used to perform a median split forming a 'more' and a 'less' mature group. If an age category contained an odd number of players a coin was tossed to determine which group the player representing the median value would be included in.

Statistical analyses

All results presented are means ± standard deviation. Data were analysed using an SPSS statistics package (PASW Statistics, version 17.0). To determine the existence of a RAE, chi-square goodness-of-fit tests were performed. In the event of statistically significant chi-square values, *post-hoc* tests (standardized residuals) were performed to establish which quartiles differed from the expected distribution. Chi-square *w* effect sizes were calculated to assess the strength of any relationships. One-way ANOVA tests were used to determine if differences existed between quartiles with regard to maturity offset, stature, mass, 0-15m sprint time, T-test time and turn time. If significant differences were revealed *post-hoc* tests (Tukey test) were performed to show which birth quartiles differed from each other. Independent samples t-tests were conducted to check for differences between the 'more' and 'less' mature groups within each age category with regard to stature, mass, 0-15m sprint time, T-test time and turn time. In addition, effect sizes (Cohen's *d*) were calculated to show the degree of difference between birth quartiles and maturity groups. Significance was accepted at $p<0.05$.

Results

An unequal birthdate distribution was observed within all age categories with over- and under-representation of those born in the first and fourth quarters of the selection year respectively compared to the general population (Table 1, Figure 4). Cohen's *w* effect sizes were medium (>0.3) for the under 11, 12, 13 and 15 age categories while they were large (>0.5) for the under 14 and 17 age categories.

Significant differences in maturity offset were observed between quartiles. As can be seen from Table 2 and Figure 5, within the under 11, 13, 14 and 15 age categories players born in the first quarter displayed a greater maturity offset value than those born in the fourth quarter. That is to say players in the first quartile were more physically mature than those born in the fourth. Within the under 11 and 15 age categories those born in the second and third quarters also displayed a significantly greater maturity offset value than those born in the fourth quarter. The under 14 players born in the first quarter were advanced in physical maturity compared to their peers born in the fourth and third quarter. Correspondingly large effect sizes (Cohen's *d*) were observed for the under 11, 13, 14 and 15 age categories with regard to maturity offset. Significant differences were also observed for stature within the under 11 age category with those born in the first and third quarters of the year found to be taller than those born in the fourth quarter (Table 3, Figure 6). No significant differences in mass between birth quartiles were observed (Table 4, Figure 7). Large effect sizes (Cohen's *d*) between the first and fourth quartiles for 0-15m sprint times were observed within the under 14 and 15 age categories (Table 5, Figure 8). Similarly, a large effect size between the first and fourth birth quartiles for the T-test was observed within the under 14 age category (Table 6, Figure 9), however, no significant differences were observed between quartiles with regard to turn times (Figure 10).

When age categories were grouped according to maturity status (‘more mature’ or ‘less mature’) significant differences were observed at all age groups for stature and mass (Table 7, Figure 11, Figure 12). More mature players were found to be taller and heavier compared to their less mature counterparts. The only age categories where significant differences were observed between maturity groups in sprinting speed were the under 14 and 15 age groups (Table 8, Figure 13). Similarly, only the under 14 age category displayed a significant difference in the T-test time between maturity groups (Table 8, Figure 14). No significant differences were observed between maturity groups with regard to turn time for either the under 15 or 17 age categories (Figure 15). Generally, more physically mature players were found to be faster and better at turning than less mature players within the under 14 and 15 age categories.

Table 1. Birthdate distribution within each age category

				Relative age percentages (%)				Standardized residuals			
Age Group	n	x^2	*w*	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
U11	94	15.14	0.40	40.4	26.6	19.1	13.8	3.02**	0.31	-1.21	-2.12*
U12	83	19.72	0.49	45.8	20.5	15.7	18.1	3.80***	-0.83	-1.66	-1.31
U13	101	18.84	0.43	42.6	23.8	19.8	13.9	3.57***	-0.24	-1.12	-2.18*
U14	107	28.33	0.51	43.9	28.0	18.7	9.3	3.98***	0.62	-1.40	-3.19**
U15	84	18.94	0.47	38.1	34.5	17.9	9.5	2.46*	1.77	-1.38	-2.81**
U17	39	10.66	0.52	43.6	28.2	20.5	7.7	2.34*	0.38	-0.60	-2.15*

* = $p<0.05$ ** = $p<0.01$ *** = $p<0.001$

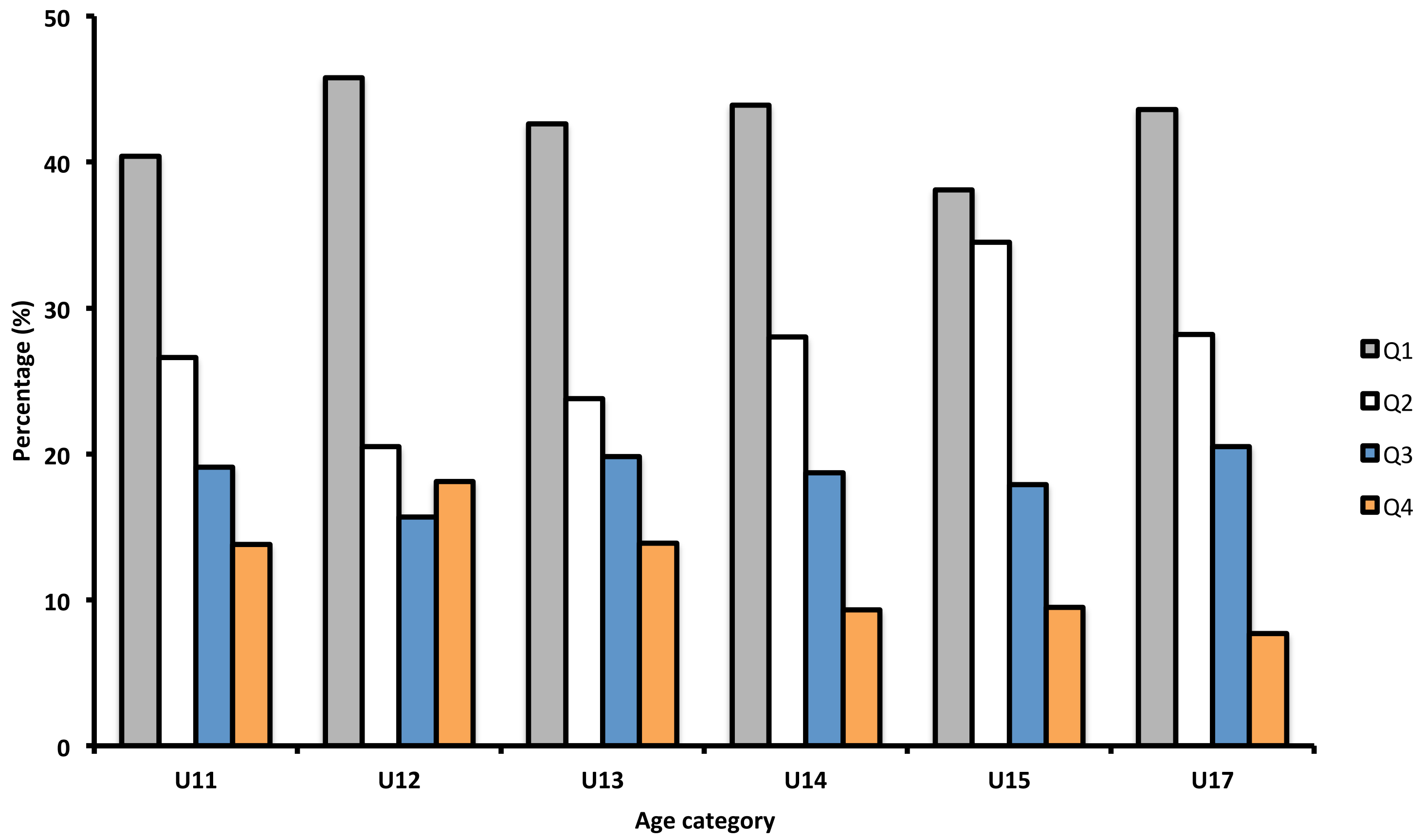

Figure 4. Birthdate distribution within each age category

Table 2. Maturity Offset values for each birth quartile

	Maturity Offset (years from PHV)				
Age Group	Q1	Q2	Q3	Q4	Cohen's *d* Q1 v Q4
	n=36	n=22	n=18	n=11	
U11	-2.73 ± 0.24 $^{\pi}$	-2.84 ± 0.38 $^{\varphi}$	-2.81 ± 0.28 $^{\varphi}$	-3.22 ± 0.30	1.8
	n=31	n=17	n=11	n=13	
U12	-2.14 ± 0.39	-2.12 ± 0.47	-2.20 ± 0.30	-2.40 ± 0.36	0.7
	n=39	n=22	n=18	n=14	
U13	-1.24 ± 0.46 $^{\beta}$	-1.38 ± 0.45	-1.45 ± 0.29	-1.61 ± 0.32	0.9
	n=45	n=29	n=19	n=7	
U14	-0.04 ± 0.58 $^{\delta}$	-0.17 ± 0.56	-0.44 ± 0.57	-0.74 ± 0.41	1.4
	n=26	n=25	n=14	n=7	
U15	1.07 ± 0.6 $^{\varphi}$	0.91 ± 0.44 $^{\beta}$	0.88 ± 0.38 $^{\beta}$	0.25 ± 0.51	1.5
	n=16	n=10	n=8	n=3	
U17	2.10 ± 0.48	1.83 ± 0.65	1.99 ± 0.54	2.35 ± 1.10	0.3

β = significantly different to Q4 ($p<0.05$)
δ = significantly different to Q3 and Q4 ($p<0.05$)
π = significantly different to Q4 ($p<0.001$)
φ = significantly different to Q4 ($p<0.01$)

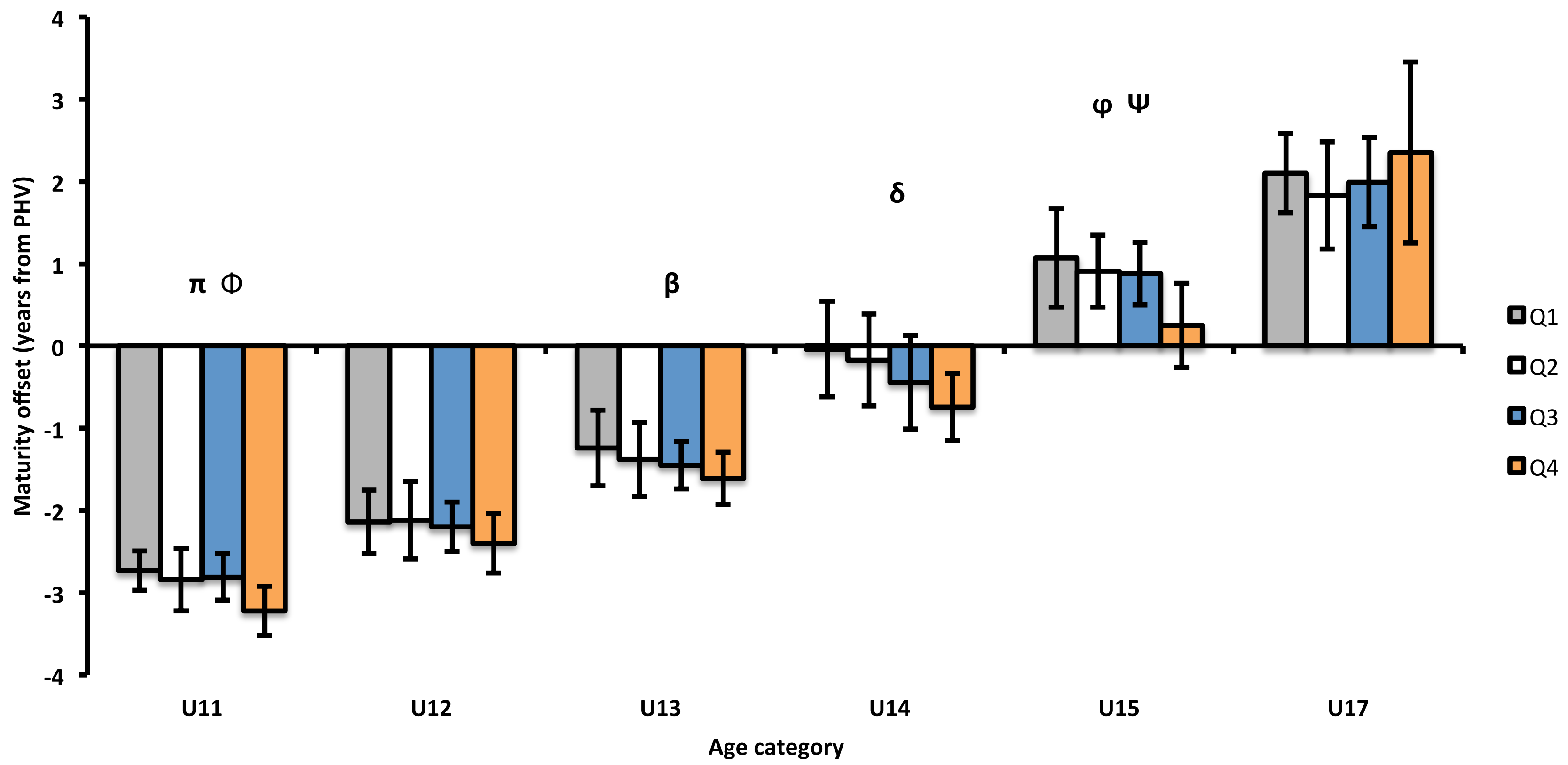

Figure 5. Maturity offset values for each birth quartile

β = Q1 significantly different to Q4 ($p<0.05$)
δ = Q1 significantly different to Q3 and Q4 ($p<0.05$)
π = Q1 significantly different to Q4 ($p<0.001$)
φ = Q1 significantly different to Q4 ($p<0.01$)
Φ = Q2 and Q3 significantly different to Q4 ($p<0.01$)
Ψ = Q2 and Q3 significantly different to Q4 ($p<0.05$)

Table 3. Stature for each birth quartile

	Stature (cm)				
Age Group	Q1	Q2	Q3	Q4	Cohen's *d* Q1 v Q4
	n=36	n=22	n=18	n=11	
U11	143.6 ± 3.2 β	142.8 ± 6.4	144.2 ± 4.9 β	139.3 ± 3.2	1.3
	n=31	n=17	n=11	n=13	
U12	146.4 ± 5.3	148.0 ± 7.4	149.1 ± 3.5	147.1 ± 4.5	0.1
	n=39	n=22	n=17	n=13	
U13	154.4 ± 5.7	153.7 ± 7.0	152.5 ± 4.4	151.5 ± 3.6	0.6
	n=45	n=29	n=19	n=7	
U14	164.1 ± 6.6	164.5 ± 6.9	161.0 ± 6.5	159.5 ± 3.9	0.9
	n=26	n=25	n=14	n=7	
U15	171.5 ± 6.2	171.5 ± 5.9	171.5 ± 5.5	167.5 ± 4.7	1.4
	n=16	n=10	n=8	n=3	
U17	175.2 ± 4.8	173.8 ± 6.0	174.2 ± 2.4	181.6 ± 7.2	1.3

β = significantly different to Q4 ($p<0.05$)

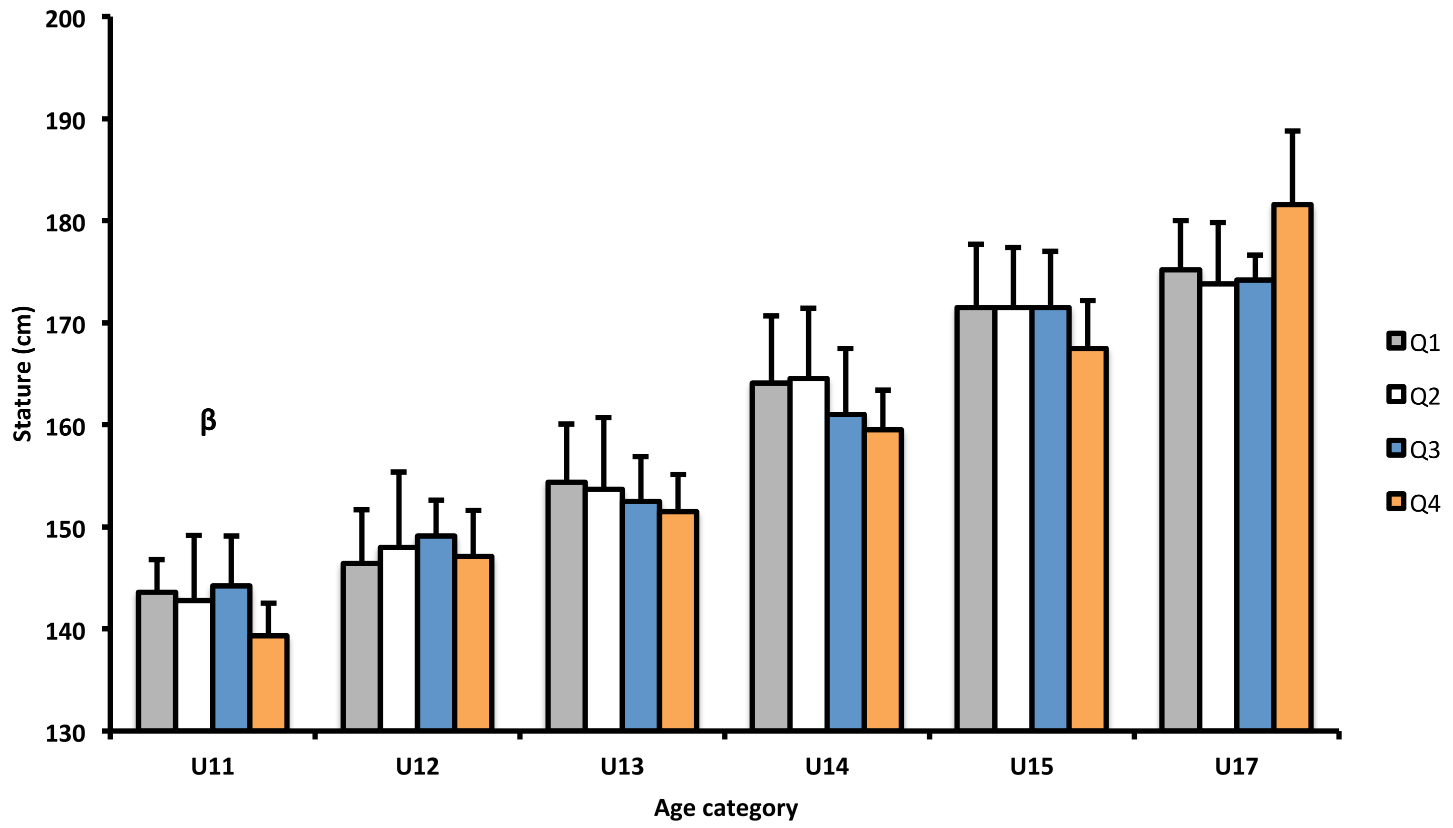

Figure 6. Stature for each birth quartile

β = Q1 and Q3 significantly different to Q4 ($p<0.05$)

Table 4. Mass for each birth quartile

	Mass (kg)				
Age Group	Q1	Q2	Q3	Q4	Cohen's *d* Q1 v Q4
	n=36	n=22	n=18	n=11	
U11	34.9 ± 3.9	35.2 ± 5.4	36.4 ± 5.3	32.9 ± 3.0	0.6
	n=31	n=17	n=11	n=13	
U12	36.6 ± 4.7	38.8 ± 6.5	40.3 ± 5.1	38.1 ± 3.5	0.4
	n=39	n=22	n=17	n=13	
U13	42.5 ± 8.3	43.6 ± 5.7	41.4 ± 5.1	41.5 ± 3.5	0.2
	n=45	n=29	n=19	n=7	
U14	51.2 ± 8.7	53.6 ± 9.0	50.6 ± 5.5	47.2 ± 4.9	0.6
	n=26	n=25	n=14	n=7	
U15	60.9 ± 7.8	60.3 ± 7.3	60.6 ± 5.3	54.0 ± 4.8	1.1
	n=16	n=10	n=8	n=3	
U17	65.4 ± 6.2	67.7 ± 12.6	65.7 ± 4.1	74.9 ± 15.5	0.8

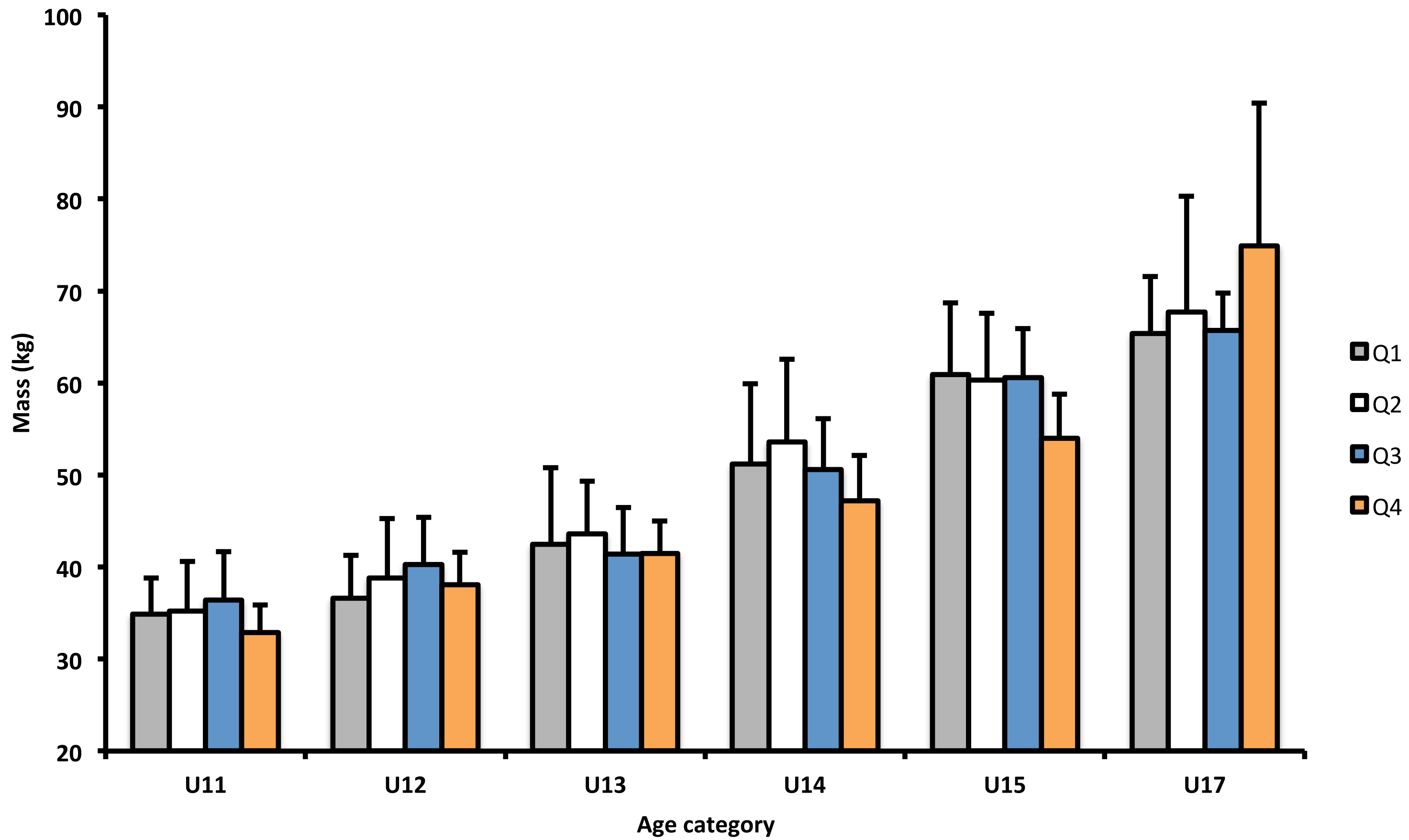

Figure 7. Mass for each birth quartile

Table 5. Sprint times for each birth quartile

	0-15m (s)				
Age Group	Q1	Q2	Q3	Q4	Cohen's *d* Q1 v Q4
	n=37	n=23	n=18	n=10	
U11	2.92 ± 0.13	2.93 ± 0.11	2.95 ± 0.08	2.96 ± 0.11	0.3
	n=34	n=16	n=12	n=14	
U12	2.88 ± 0.13	2.86 ± 0.20	2.89 ± 0.09	2.84 ± 0.11	0.3
	n=33	n=24	n=18	n=11	
U13	2.78 ± 0.10	2.74 ± 0.09	2.77 ± 0.09	2.81 ± 0.13	0.3
	n=40	n=25	n=15	n=8	
U14	2.66 ± 0.13	2.65 ± 0.12	2.65 ± 0.11	2.76 ± 0.09	0.9
	n=31	n=28	n=14	n=8	
U15	2.58 ± 0.16	2.64 ± 0.12	2.65 ± 0.17	2.72 ± 0.13	1.0
	n=17	n=11	n=8	n=3	
U17	2.46 ± 0.12	2.45 ± 0.06	2.48 ± 0.09	2.50 ± 0.05	0.4

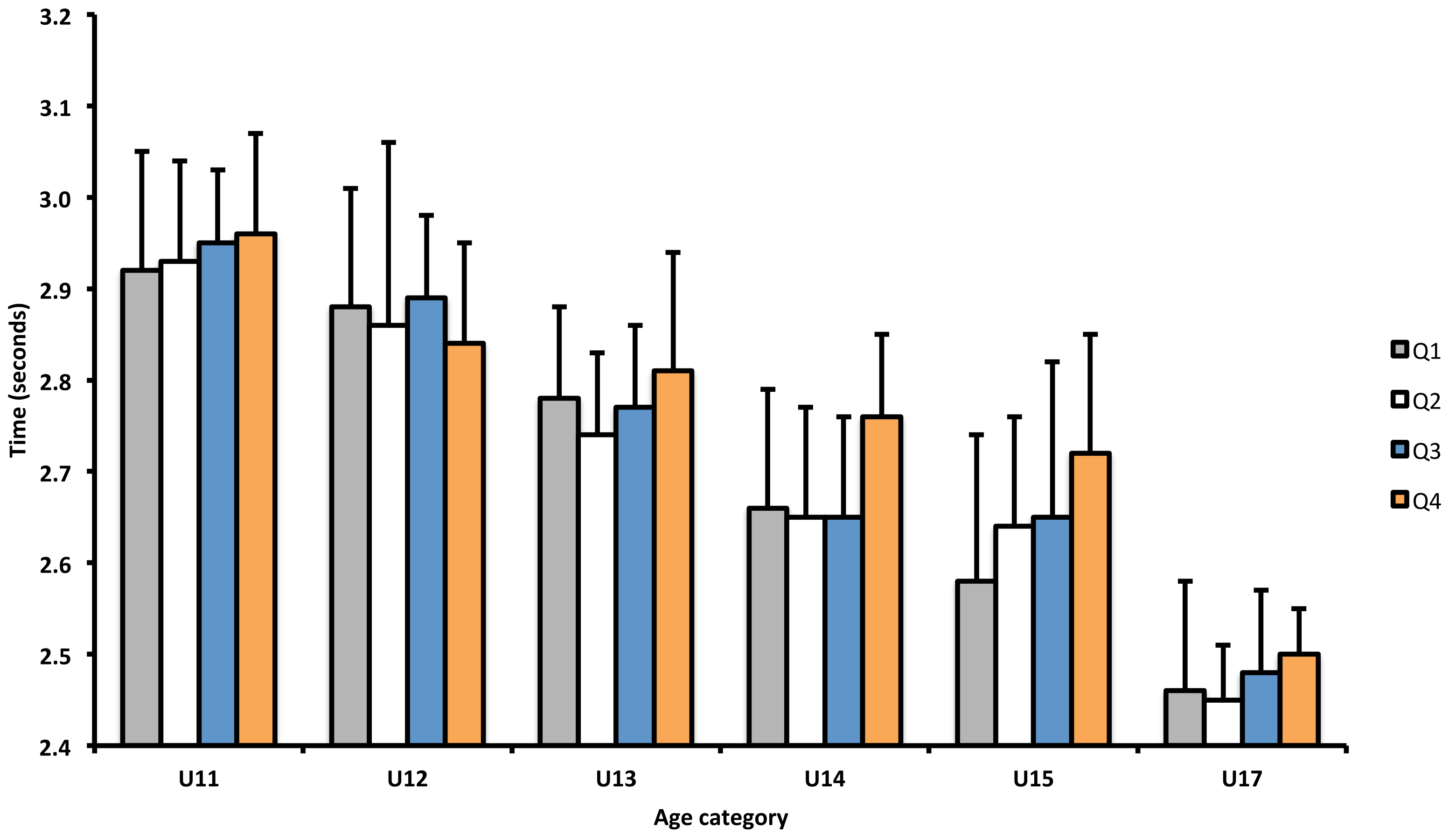

Figure 8. Sprint times (0-15m) for each birth quartile

Table 6. Change of direction test times for each birth quartile

	T-test (s)					Turn time (s)				
Age Group	Q1	Q2	Q3	Q4	Cohen's *d* Q1 v Q4	Q1	Q2	Q3	Q4	Cohen's *d* Q1 v Q4
	n=26	n=17	n=15	n=7						
U11	11.06 ± 0.49	11.03 ± 0.46	11.02 ± 0.42	11.04 ± 0.45	0.0					
	n=24	n=14	n=10	n=10						
U12	11.06 ± 0.58	10.77 ± 0.44	11.22 ± 0.38	11.15 ± 0.34	0.2					
	n=28	n=18	n=13	n=8						
U13	10.85 ± 0.41	10.72 ± 0.36	10.76 ± 0.52	10.90 ± 0.28	0.1					
	n=33	n=20	n=11	n=4						
U14	10.50 ± 0.32	10.51 ± 0.43	10.47 ± 0.39	10.87 ± 0.48	0.9					
						n=30	n=27	n=12	n=8	
U15						2.99 ± 0.17	3.03 ± 0.15	3.04 ± 0.11	3.00 ± 0.19	0.1
						n=16	n=10	n=8	n=3	
U17						2.95 ± 0.10	3.00 ± 0.13	3.01 ± 0.06	3.04 ± 0.17	0.7

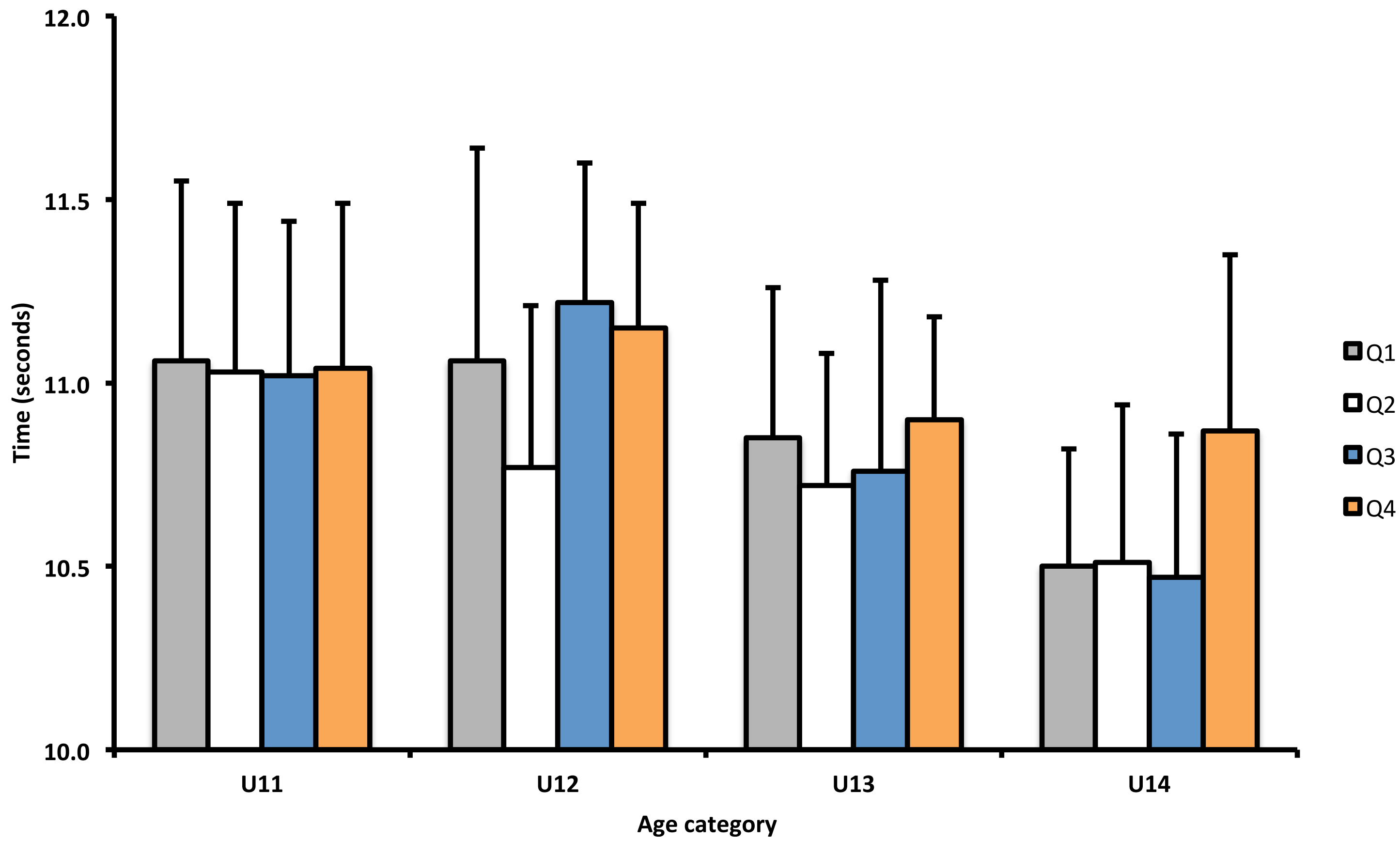

Figure 9. T-test times for each birth quartile

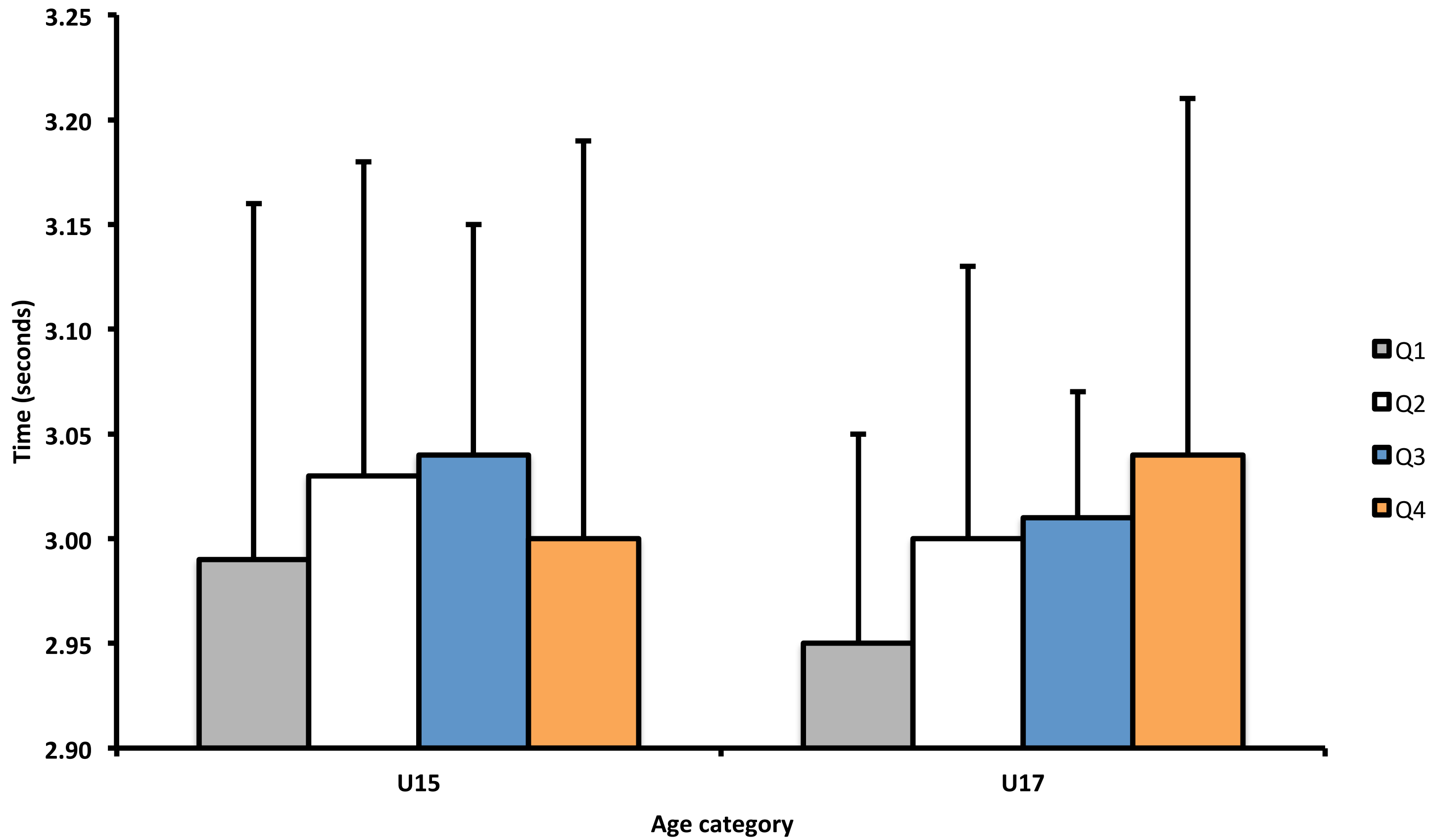

Figure 10. Turn times for each birth quartile

Table 7. Anthropometric measurements for physical maturity groups within each age category

	Stature (cm)				Mass (kg)			
Age Group	Less	More	*p* value	Cohen's *d*	Less	More	*p* value	Cohen's *d*
	n=44	n=43			n=44	n=43		
U11	140.4 ± 3.7	145.6 ± 4.1	<0.001	1.3	32.5 ± 2.6	37.7 ± 4.7	<0.001	1.4
	n=36	n=36			n=36	n=36		
U12	144.3 ± 3.2	150.3 ± 5.7	<0.001	1.3	35.7 ± 3.5	40.3 ± 5.5	<0.001	1.0
	n=45	n=46			n=45	n=46		
U13	150.3 ± 3.1	156.5 ± 5.8	<0.001	1.3	39.3 ± 3.2	45.4 ± 7.7	<0.001	1.0
	n=50	n=50			n=50	n=50		
U14	158.8 ± 3.9	167.8 ± 5.8	<0.001	1.8	46.8 ± 4.4	56.2 ± 8.4	<0.001	1.4
	n=36	n=36			n=36	n=36		
U15	167.8 ± 4.3	174.5 ± 5.2	<0.001	1.4	54.8 ± 4.5	65.1 ± 5.2	<0.001	2.1
	n=19	n=18			n=19	n=18		
U17	172.3 ± 4.0	178.1 ± 4.7	<0.001	1.3	62.8 ± 6.6	71.1 ± 9.2	<0.01	1.0

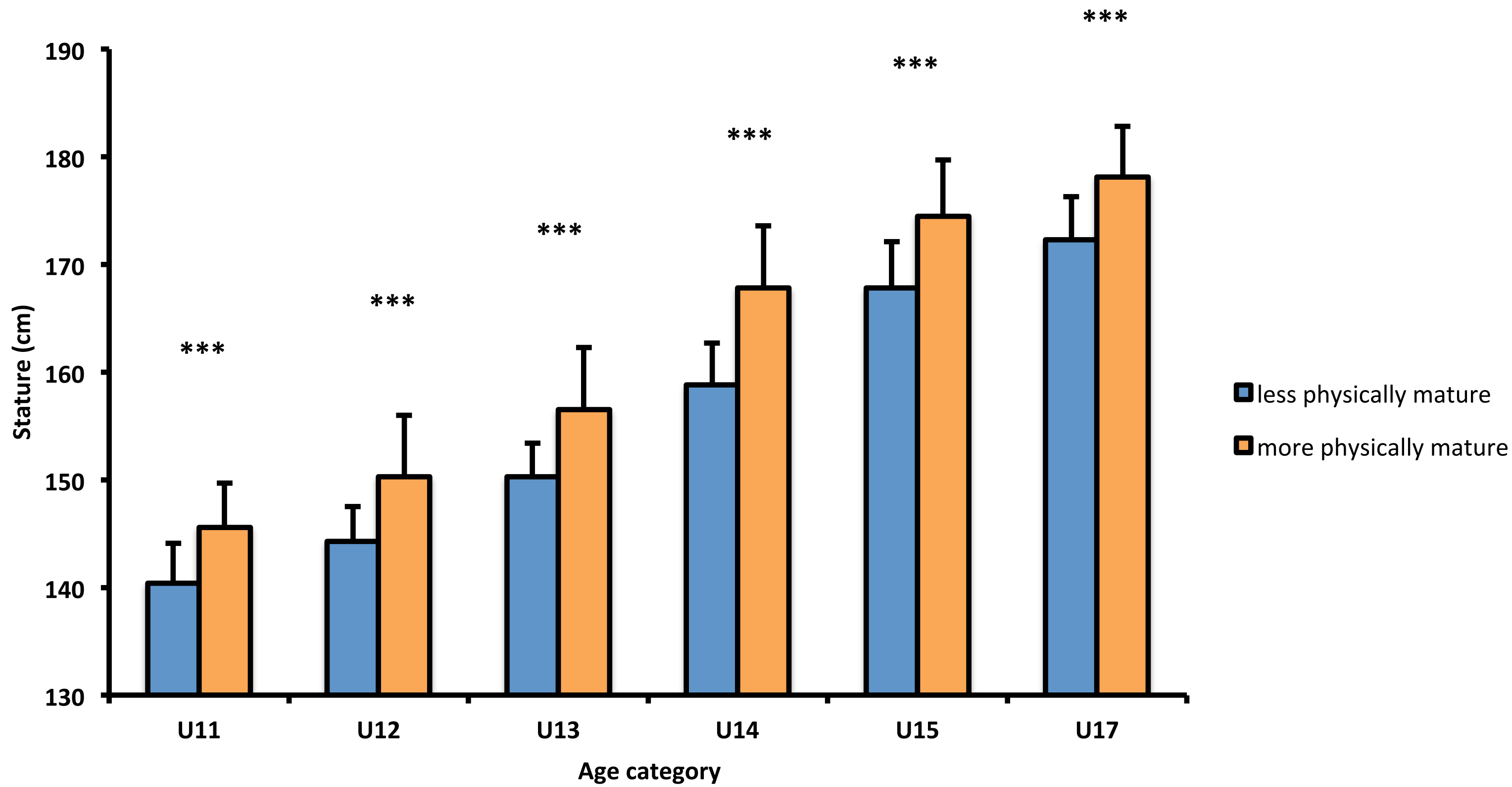

Figure 11. Stature of maturity groups for each age category

*** = p<0.001

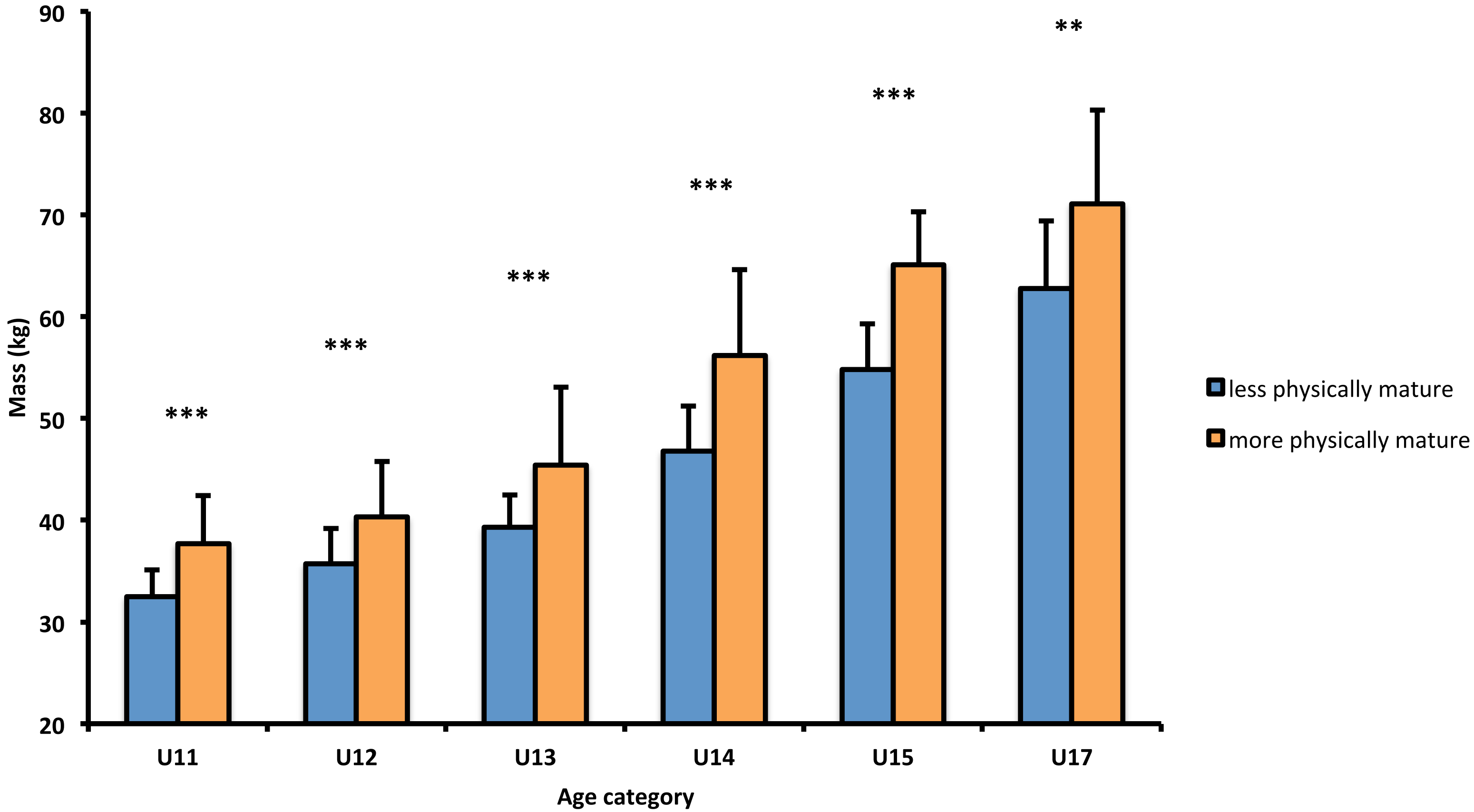

Figure 12. Mass of maturity groups for each age category

** = p<0.01
*** = p<0.001

Table 8. Sprinting and change of direction test times for physical maturity groups within each age category

	0-15m (s)				T-test (s)				Turn time (s)			
Age Group	Less	More	*p* value	Cohen's *d*	Less	More	*p* value	Cohen's *d*	Less	More	*p* value	Cohen's *d*
	n=43	n=42			n=31	n=31						
U11	2.93 ± 0.13	2.94 ± 0.09		0.1	11.10 ± 0.46	11.01 ± 0.43		0.2				
	n=33	n=34			n=24	n=25						
U12	2.87 ± 0.14	2.86 ± 0.12		0.1	10.95 ± 0.39	11.02 ± 0.46		0.2				
	n=39	n=40			n=31	n=30						
U13	2.78 ± 0.08	2.75 ± 0.11		0.3	10.76 ± 0.36	10.81 ± 0.46		0.1				
	n=42	n=42			n=34	n=33						
U14	2.71 ± 0.09	2.61 ± 0.13	<0.001	0.9	10.67 ± 0.38	10.37 ± 0.32	<0.01	0.9				
	n=35	n=34							n=33	n=32		
U15	2.69 ± 0.11	2.54 ± 0.13	<0.001	1.3					3.01 ± 0.18	3.04 ± 0.13		0.2
	n=19	n=18							n=18	n=17		
U17	2.48 ± 0.11	2.45 ± 0.08		0.3					3.00 ± 0.08	2.98 ± 0.13		0.2

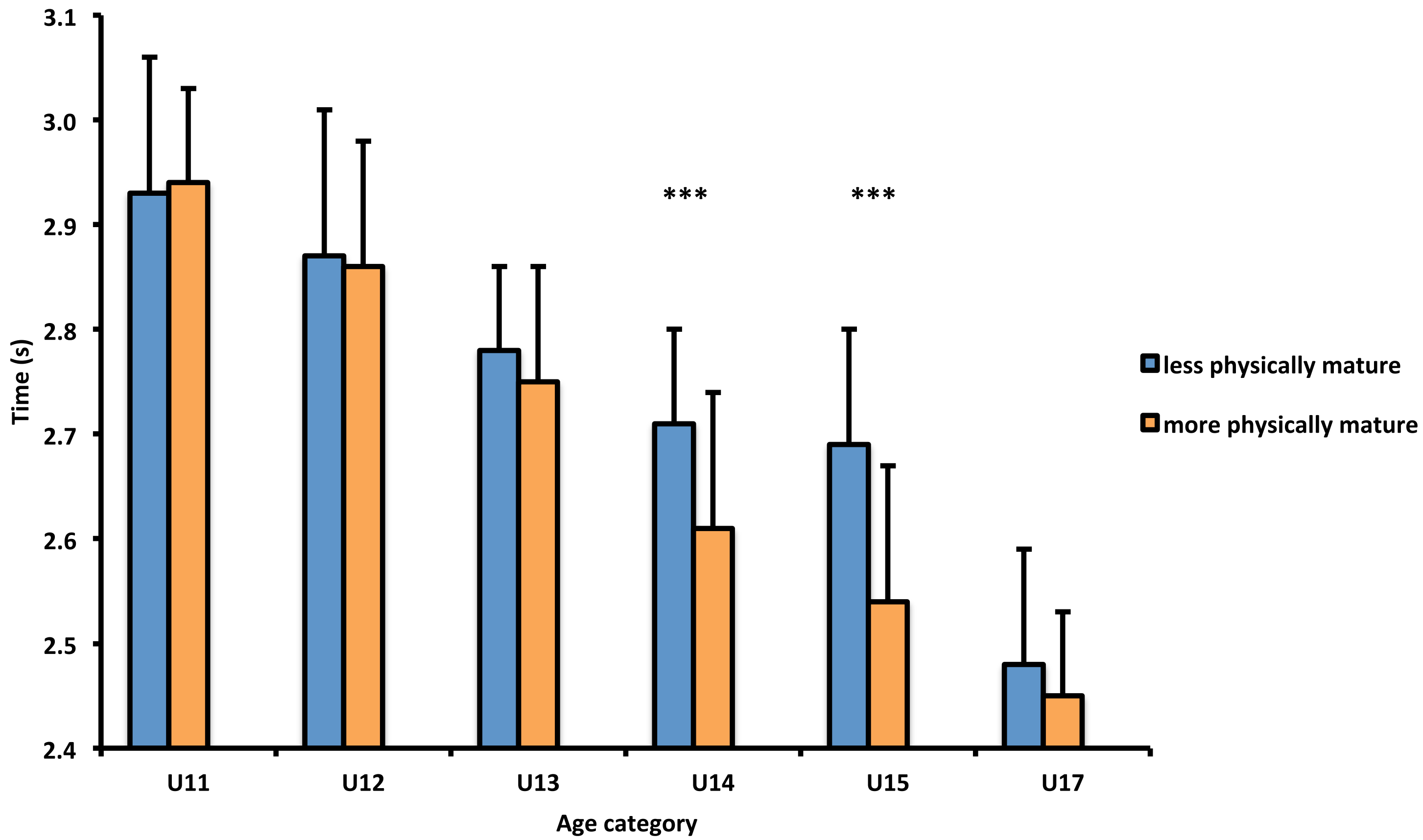

Figure 13. Sprint times (0-15m) of maturity groups for each age category

*** = p<0.001

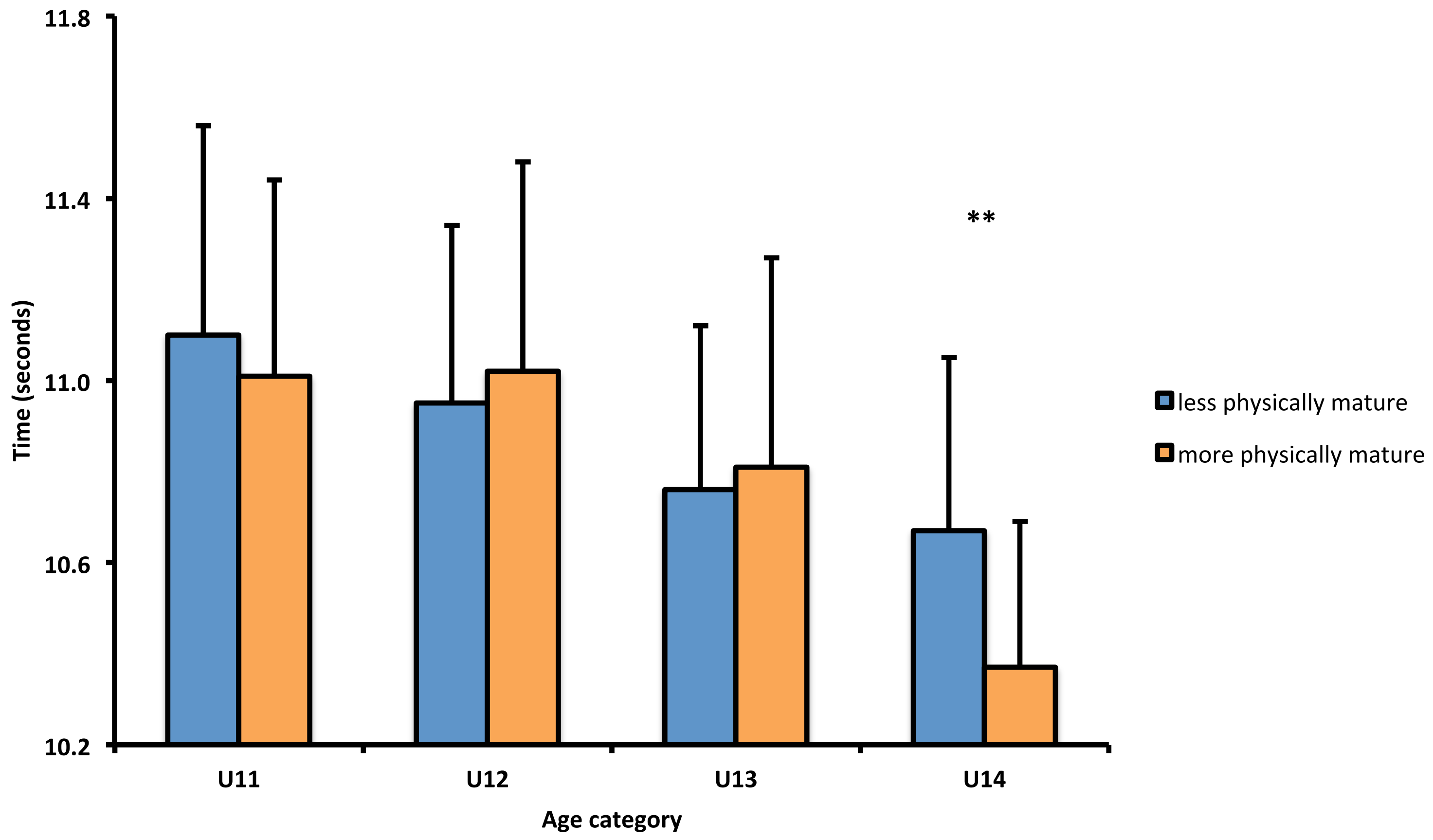

Figure 14. T-test times of maturity groups for each age category

** = p<0.01

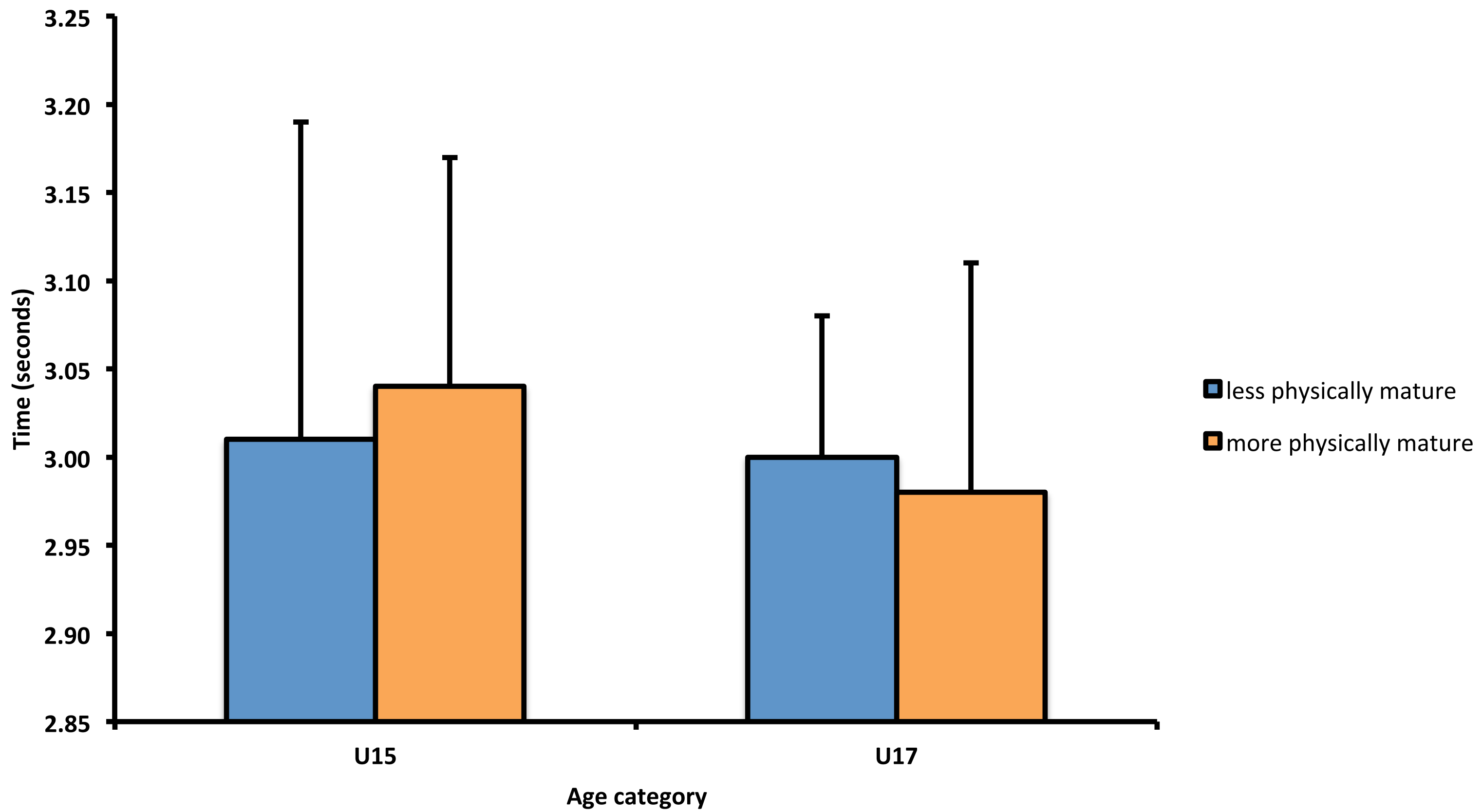

Figure 15. Turn times of maturity groups for each age category

Discussion

The aims of the present study were to establish if a RAE existed in Scotland and to investigate if differences existed between players physical capacities based on birthdate and physical maturation within the context of a one year age band.

Does a RAE exist within Scottish youth soccer?

The presence of a RAE within youth soccer has been reported in many countries (Helsen *et al*. 2005), however, Scotland has not been investigated to date. The present results confirm that a RAE exists within Scottish youth soccer (Table 1). In line with other countries, players born within the first and last quarters of the selection year were over and under represented compared to the birth date distribution of the general population. This skewed distribution was present as early as the under-11 age category, revealing that by age 10 players born late in the selection year were less likely to be selected for elite academy teams than those born in the first quarter. Similarly, Helsen *et al*. (1998) reported a RAE in Belgian elite youth soccer players as young as six years old. The under-12 age category was the only group where the proportion of players born in the last quarter of the selection year did not differ from the general population. It is unclear why this anomalous finding was observed in this age category, however, a large over representation of players born in the first quarter (45.8%) compared to that expected in the general population (25%) was seen in this group underlining the presence of an asymmetrical birth date distribution. Cohen's *w* effect size was used to demonstrate the strength of the RAE in each age category. A *w* effect size of 0.1, 0.3 and 0.5 can be considered small, moderate and large respectively (Cohen 1992). The birth date distributions of the under 11, 12, 13 and 15 age categories differed from the general population to a moderate degree whereas large effect sizes were observed for the under 14 and 17 groups. It is notable that the effect size was large among the under 14 age category - where one would expect to see the greatest variation in physical maturity between players. This observation would support the idea that differences in physical maturity between older and younger players are what cause the RAE. Jimenez & Pain (2008) showed that within Spanish professional soccer the birth date distribution of players aged 30 years and over mirrored that of the general population. This finding demonstrates that by adulthood whatever elicits the RAE is no longer relevant to selection. If transient differences in physical maturation between players are what cause the RAE at youth level then it would be reasonable to assume that it should be most prominent around the adolescent years but not exist among adult professionals. By the time youth players face selection to the elite senior side it is likely that differences in physical maturity between relatively older and younger individuals will have disappeared. By adulthood it is conceivable that relatively younger players who have made it through an academy system may possess superior technical/tactical attributes than their older peers due to having had to compensate for their potential physical disadvantage during adolescence. This may explain why the RAE is not as prevalent in senior squads. Upon graduation to the senior side relatively younger players may be selected in proportionally greater numbers than their older counterparts.

Does birth quartile influence physical performance?

One of the aims of the present study was to investigate whether differences existed in measures of physical performance and anthropometry between players grouped according to birth quartile. Variables exhibiting significant differences between birth quartiles were maturity offset and stature (Tables 2 and 3). The maturity offset equation developed by Mirwald *et al*. (2002) calculates how many years an individual is from their predicted peak height velocity (PHV). A negative value shows an individual is pre-PHV and a positive value shows they are post-PHV. In all age categories, with the exception of the under 12 and 17 groups, players in the first quarter of the selection year displayed greater maturity offset values than their counterparts born in the fourth quarter with correspondingly large effect sizes. With the exception of the under 12 and 17 age categories, chronologically older players were more physically mature than younger ones. Among the under 17 players, transient physical maturity differences may have started to disappear as less physically mature players started to 'catch up' with their more physically mature counterparts, explaining the observed finding. However, the low number of players born in the fourth quarter indicates that within this cohort the less physically mature players may simply have been released by this stage. It is unclear why differences in maturity status between quarters were not observed in the under 12 age category. The only other variable where significant differences occurred between quarters was in stature within the under 11 age category. Players born in the first and third but not the second quarters were taller than those born in the fourth quarter of this age category. The lack of difference between the second and fourth quarters is an anomaly. The under

11 age category is currently the youngest age at which clubs can sign players in Scotland. Since this age category represents professional clubs' first opportunity to sign players the competition between rival institutions to capture the best young players is likely heightened. It is possible that in their attempts to identify the most talented players at this age, scouts mistake physical precocity for talent. Homogeneity of technical proficiency amongst very young players may leave scouts with few attributes to appraise and identify talented players. As a result their attention may be drawn to the taller, more physically dominant players. No significant differences existed between quarters with regard to mass, sprinting speed and change of direction ability at any age category (Tables 4, 5 and 6). The lack of differences between quarters questions the assumption made in some studies (Augste & Lames 2011; Baxter-Jones & Helms 1994) that – within a one-year age band – older players demonstrate superior physical performance.

The physiological demands of soccer are multifactorial (Stølen *et al*. 2005). Two measures of physical performance – sprinting speed and change of direction ability – were investigated in the present study. Little and Williams (2005) reported that although linear speed and change of direction ability may seem like similar abilities they are discrete attributes. Stølen *et al*. (2005) observed that 11% of the distance covered by players during a soccer match is made up by sprinting clearly demonstrating the importance of this attribute. It has also been shown that the majority of sprints in-game last between two and four seconds vindicating the choice of assessment used in the present study (Andrzejewski *et al*. 2013; Stølen *et al*. 2005). The use of a 0-15m sprint test provided a relevant measure of physical performance.

Change of direction ability is also widely accepted as an important attribute necessary for success in team sports and has been shown to successfully differentiate between elite and sub-elite level soccer players (Mirkov *et* al. 2010; Kaplan *et al*. 2009; Brughelli *et* al. 2008). Despite the lack of significant differences between quarters with regard to sprinting and change of direction ability some large effect sizes were observed. Large effect sizes were recorded when comparing 0-15m sprinting time between those born in the first and fourth quarters at both the under 14 and 15 age categories suggesting that differences in chronological age may have an impact at this stage of player development with regard to speed over this game specific distance. Similarly, a large effect was observed between those born in the first and fourth quarters with regard to T-test time in the under 14 age category. Adolescent boys typically pass through their PHV around 14 years of age and peak weight velocity follows soon after (Philippaerts *et* al. 2006; Malina 2004). In boys this increase in mass is made up largely by skeletal tissue and muscle mass. The greatest discrepancies in stature and hence muscle mass are likely to occur around the chronological age of 14 – this would occur within the under 14 and 15 age categories – when some players will have passed through their PHV and others will not. Indeed, the largest effect sizes for stature and mass between the first and fourth birth quartiles were observed within the under 15 age category. Taking all of the effect sizes into account a plausible conclusion is that in the under 14 and 15 age categories chronologically older players may be faster than their younger counterparts due to advanced maturity status and hence greater stature and muscle mass. The key point to remember is that the differences between older and younger players at this age are temporary and likely to diminish as the younger players also pass through their PHV. The potential for players to be released from their clubs based on transient maturational differences may result in a loss of talent to the eventual adult pool. A talent identification process based on physical or anthropometric attributes will identify those who excel at the time of observation and not necessarily those who have the potential to excel in the future (Unnithan *et al*. 2012; Wolstencroft *et al*. 2002). The separation of current performance and potential is an important consideration for those selecting players for elite academies since the ultimate goal of a professional youth system is to produce players for the senior side and not necessarily successful youth teams. A RAE driven by disparity in physical maturation between chronologically older and younger players would be symptomatic of a selection policy focused on current performance rather than potential. Within the under 14 and 15 age categories this appears to be the case. Chronologically older players tended to be more physically mature than their younger counterparts within the under 11 to 13 age categories, however, this advanced maturity did not influence physical performance with regard to speed and change of direction ability. Therefore it is less clear why a RAE should exist in these age categories.

Does physical maturity influence physical performance?

Another aim of the study was to investigate whether differences existed in measures of performance and anthropometry between players grouped according to physical maturity status. Each age category was divided into a 'more mature' and a 'less mature' group based on a median split according to maturity offset as calculated by Mirwald *et al*. (2002). Bucheit *et* al. (2013) also used a median split to create two maturity groups, however, it is important to remember that this method makes no statement about whether the players are early, on time or late maturing. It simply creates a ‘less mature ‘ and a ‘more mature’ group. While some questions surround the validity of the maturity offset equation compared with classification by hand-wrist X-rays, numerous other studies (Portas *et* al. 2013; Mendez-Villanueva *et al*. 2011) have used this method to assess physical maturity status as it is a practical method for use in the applied field. Within all age categories, the more mature group was significantly taller and heavier than the less mature group (Table 7). The more mature groups demonstrated superior sprinting speed at the under 14 and 15 age categories. Similarly the under 14 category was the only year group where differences between maturity groups existed in the T-test with the more mature players demonstrating superior change of direction ability (Table 8). The results show that the under 14 and 15 age categories are the most likely to be affected by transient differences in physical maturity. Conversely, physical maturity did not influence sprinting and change of direction ability in the under 11, 12 and 13 age categories. The results show that within the under 14 and 15 age categories advanced physical maturity is related to superior scores in measures of physical performance and that chronologically older players are likely to be more physically mature than younger ones. It is conceivable that the RAE present within these age categories is a result of chronologically older players demonstrating high levels of performance as a result of advanced physical maturity and overshadowing their younger counterparts. Helsen *et al*. (2000a) suggested that much of what coaches see as ‘talent’ could be explained by physical precocity among young players. At least among under 14 and 15 age category players this seems a reasonable suggestion based on current results. Neither advanced chronological age nor physical maturity appear to have a bearing on sprinting speed and change of direction ability among under 11, 12 and 13 age category players. Stature and mass were the only variables affected by advanced physical maturity in these age categories. It is not clear why a RAE existed within the under 11, 12 and 13 age categories since differences in physical maturity between players did not equate to differences in sprinting speed or change of direction ability. It is possible that psychological maturity may play a role in the development of the RAE within the under 11, 12 and 13 age categories. Two players born on January 1st and December 31st of the same calendar year differ in chronological age by almost exactly one year yet will play in the same age category. Within an under 11 team this amounts to almost a ten percent difference in life experience. Assuming these two hypothetical players started to play soccer at age five the difference in training/playing experience would be well in excess of ten percent. This relatively large discrepancy in playing experience could manifest itself as greater tactical awareness and game intelligence in the chronologically older player. It is perhaps these hard to quantify yet vitally important traits that predispose chronologically older children for selection to elite academy teams within the younger age groups. Psychosocial models including the Galatea effect have been proposed by Hancock *et al*. (2013) as contributors to the RAE in youth soccer. The Galatea effect refers to players' own expectations of themselves and how they affect performance. For example, chronologically older players may feel that they should be better than their younger counterparts simply because they are older. This internal expectation may result in a self-fulfilling prophecy. It is likely that a combination of physical and psychosocial influences combine to elicit the RAE in youth soccer.

Limitations

A limitation of the present study is that only one club was investigated and this should be remembered when considering the data from a national perspective. However, to the author's knowledge, drastic differences in how Scottish professional soccer clubs select young players for their academies do not exist and so it is not unreasonable to expect similar findings nationally. Due to the nature of the RAE, the number of players born in the fourth quarter for all age categories was low. The participants for this study were of an elite standard for their chronological age and as such the findings can only be applied to this tier of players. Due to the fact the data was collected longitudinally each age category included numerous years of birth. For example the under 15 age category contained data from players born in 1998, 1997, 1996, 1995, 1994 and 1993 therefor it was not possible to compare the combined birth date distribution of the sample directly with one calendar year for the general population. An even birthdate distribution within the general population was assumed and used within the chi square statistical tests to establish the presence of a RAE within the sample. No measure of strength or aerobic capacity was included in the present study. The reason these variables were not investigated is that numerous different protocols were used to record these attributes over the six year data collection period preventing the accumulation of the data longitudinally.

Practical applications and future research

The data reveal that physical maturity is likely to have the greatest influence in terms of player selection within the under 14 and 15 age categories. While physical maturity differences exist between chronologically older and younger players within the other age categories, it is only in the under 14 and 15 squads where these maturity differences manifest as physical performance advantages. At these age groups, chronologically older players possibly experience a selection advantage over their younger counterparts due to being faster and better at changing direction quickly since coaches may mistake physical precocity for talent (Helsen *et al*. 2000a). A practical measure to address this physical maturity bias may be to limit the number of players clubs can release at these two age categories. Such a measure may give less physically mature players the chance to 'catch up' with their more physically mature peers. Technical skill is often expressed as the most important aspect of soccer play yet objective quantification of this attribute is lacking (Ali 2011). A greater emphasis on the appraisal of technical skill would likely reduce the influence of physical maturity on the selection process since this attribute is not influenced by physical maturity status (Vandendriessche *et al*. 2012; Malina *et al*. 2005). An avenue for future research is the quantification of technical skill, the application of this knowledge to the talent identification process and the resulting outcomes on player birthdate distribution. Future research should also investigate the various sub-elite tiers of Scottish soccer to elucidate if a RAE exists and if differences in measures of performance are apparent between birth quarters at that level. Ultimately, it is the sub-elite (boys club) tier of Scottish soccer that elite young players are selected from and it would add insight to know when chronological age and physical maturity start to influence physical performance, team selection and participation.

Conclusion

In conclusion, the RAE does exist within Scottish youth soccer, however, players born early and late in the selection year did not demonstrate significantly different scores in measures of physical performance. Advanced physical maturity does appear to provide an advantage in terms of sprinting speed and change of direction ability among players in the under 14 and 15 age categories. Encouraging coaches and scouts to focus on and appraise players' technical skill rather than their physical prowess is one avenue that may begin to reduce the severity of the RAE in Scotland since physical maturity has been shown to have little influence on this attribute (Vandendriessche *et al*. 2012; Malina *et al*. 2005). In addition, limiting the number of players that clubs can release from the under 14 and 15 age categories would likely save many talented players from being released due to transient disparities in physical maturation.

References

Ali, A. (2011). "Measuring soccer skill performance: a review." Scand J Med Sci Sports 21(2): 170-183.

Andrzejewski, M., J. Chmura, B. Pluta, R. Strzelczyk and A. Kasprzak (2013). "Analysis of sprinting activities of professional soccer players." J Strength Cond Res 27(8): 2134-2140.

Augste, C. and M. Lames (2011). "The relative age effect and success in German elite U-17 soccer teams." J Sports Sci 29(9): 983-987.

Baxter-Jones, A. and P. Helms (1994). "Born too late to win?" Nature 370(6486): 186.

Borms, J. (1986). "The child and exercise: an overview." J Sports Sci 4(1): 3-20.

Boucher, J. L. and B. T. Mutimer (1994). "The relative age phenomenon in sport: a replication and extension with ice-hockey players." Res Q Exerc Sport 65(4): 377-381.

Brughelli, M., J. Cronin, G. Levin and A. Chaouachi (2008). "Understanding change of direction ability in sport: a review of resistance training studies." Sports Med 38(12): 1045-1063.

Buchheit, M., B. M. Simpson, V. Di Salvo and A. Mendez-Villanueva (2013). Effects of maturation and body mass on match running performance in highly-trained under-15 soccer players. 18th Annual Congress of the European College of Sport Science. Barcelona.

Carling, C., F. Le Gall and R. M. Malina (2012). "Body size, skeletal maturity, and functional characteristics of elite academy soccer players on entry between 1992 and 2003." J Sports Sci 30(15): 1683-1693.

Cohen, J. (1992). "A power primer." Psychol Bull 112(1): 155-159.

Delorme, N. and M. Raspaud (2009). "Is there an influence of relative age on participation in non-physical sports activities? The example of shooting sports." J Sports Sci 27(10): 1035-1042.

Delorme, N. and M. Raspaud (2009). "The relative age effect in young French basketball players: a study on the whole population." Scand J Med Sci Sports 19(2): 235-242.

Deprez, D., R. Vaeyens, A. J. Coutts, M. Lenoir and R. Philippaerts (2012). "Relative Age Effect and Yo-Yo IR1 in Youth Soccer." Int J Sports Med 33(12): 987-993.

Diamond, G. H. (1983). "The birthdate effect--a maturational effect?" J Learn Disabil 16(3): 161-164.

DiPasquale, G. W., A. D. Moule and R. W. Flewelling (1980). "The birthdate effect." J Learn Disabil 13(5): 234-238.

Dvorak, J., J. George, A. Junge and J. Hodler (2007). "Application of MRI of the wrist for age determination in international U-17 soccer competitions." Br J Sports Med 41(8): 497-500.

Figueiredo, A. J., C. E. Gonçalves, M. J. Coelho E Silva and R. M. Malina (2009). "Youth soccer players, 11-14 years: maturity, size, function, skill and goal orientation." Ann Hum Biol 36(1): 60-73.

Ford, P., M. De Ste Croix, R. Lloyd, R. Meyers, M. Moosavi, J. Oliver, K. Till and C. Williams (2011). "The long-term athlete development model: physiological evidence and application." J Sports Sci 29(4): 389-402.

Franks, A. M., A. M. Williams, T. Reilly and A. Nevill (1999). "Talent identification in elite youth soccer players: Physical and physiological characteristics. Communications to the Fourth World Congress of Science and Football." J Sports Sci 17: 807-840.

Gonaus, C. and E. Müller (2012). "Using physiological data to predict future career progression in 14- to 17-year-old Austrian soccer academy players." J Sports Sci 30(15): 1673-1682.

Gredler, G. R. (1980). "The birthdate effect: fact or artifact?" J Learn Disabil 13(5): 239-242.

Greulich, W. W. and S. I. Pyle (1959). Radiographic Atlas of Skeletal Development of the Hand and Wrist. Stanford, California, Stanford University Press.

Hancock, D. J., A. L. Adler and J. Cote (2013). "A proposed theoretical model to explain relative age effects in sport." Eur J Sport Sci.

Hancock, D. J., B. W. Young and D. M. Ste-Marie (2011). "Effects of a rule change that eliminates body-checking on the relative age effect in Ontario minor ice hockey." J Sports Sci 29(13): 1399-1406.

Helsen, W. F., J. Baker, S. Michiels, J. Schorer, J. Van Winckel and A. M. Williams (2012). "The relative age effect in European professional soccer: Did ten years of research make any difference?" J Sports Sci 30(15): 1665-1671.

Helsen, W. F., N. J. Hodges, J. Van Winckel and J. L. Starkes (2000a). "The roles of talent, physical precocity and practice in the development of soccer expertise." J Sports Sci 18(9): 727-736.

Helsen, W. F., J. L. Starkes and J. Van Winckel (1998). "The influence of relative age on success and dropout in male soccer players." Am J Hum Biol 10: 791-798.

Helsen, W. F., J. L. Starkes and J. Van Winckel (2000b). "Effect of a change in selection year on success in male soccer players." Am J Hum Biol 12(6): 729-735.

Helsen, W. F., J. van Winckel and A. M. Williams (2005). "The relative age effect in youth soccer across Europe." J Sports Sci 23(6): 629-636.

Howe, M. J., J. W. Davidson and J. A. Sloboda (1998). "Innate talents: reality or myth?" Behav Brain Sci 21(3): 399-407; discussion 407-342.

Jiménez, I. P. and M. T. Pain (2008). "Relative age effect in Spanish association football: its extent and implications for wasted potential." J Sports Sci 26(10): 995-1003.

Kaplan, T., N. Erkmen and H. Taskin (2009). "The evaluation of the running speed and agility performance in professional and amateur soccer players." J Strength Cond Res 23(3): 774-778.

Little, T. and A. G. Williams (2005). "Specificity of acceleration, maximum speed, and agility in professional soccer players." J Strength Cond Res 19(1): 76-78.

Malina, R. M., C. Bouchard and O. Bar-Or (2004). Growth, Maturation and Physical Activity. Champaign, Illinois, Human Kinetics.

Malina, R. M., M. J. Coelho E Silva, A. J. Figueiredo, C. Carling and G. P. Beunen (2012). "Interrelationships among invasive and non-invasive indicators of biological maturation in adolescent male soccer players." J Sports Sci 30(15): 1705-1717.

Malina, R. M., S. P. Cumming, A. P. Kontos, J. C. Eisenmann, B. Ribeiro and J. Aroso (2005). "Maturity-associated variation in sport-specific skills of youth soccer players aged 13-15 years." J Sports Sci 23(5): 515-522.

Malina, R. M., M. E. PeÒa Reyes, J. C. Eisenmann, L. Horta, J. Rodrigues and R. Miller (2000). "Height, mass and skeletal maturity of elite Portuguese soccer players aged 11-16 years." J Sports Sci 18(9): 685-693.

Matthys, S. P., R. Vaeyens, M. J. Coelho-E-Silva, M. Lenoir and R. Philippaerts (2012). "The contribution of growth and maturation in the functional capacity and skill performance of male adolescent handball players." Int J Sports Med 33(7): 543-549.

Mendez-Villanueva, A., M. Buchheit, S. Kuitunen, A. Douglas, E. Peltola and P. Bourdon (2011). "Age-related differences in acceleration, maximum running speed, and repeated-sprint performance in young soccer players." J Sports Sci 29(5): 477-484.

Mirkov, D. M., M. Kukolj, D. Ugarkovic, V. J. Koprivica and S. Jaric (2010). "Development of anthropometric and physical performance profiles of young elite male soccer players: a longitudinal study." J Strength Cond Res 24(10): 2677-2682.

Mirwald, R. L., A. D. Baxter-Jones, D. A. Bailey and G. P. Beunen (2002). "An assessment of maturity from anthropometric measurements." Med Sci Sports Exerc 34(4): 689-694.

Musch, J. and S. Grondin (2001). "Unequal competition as an impediment to personal development: A review of the relative age effect in sport." Dev Rev 21: 147-167.

Nolan, J. E. and G. Howell (2010). "Hockey success and birth date: The relative age effect revisited." Int Rev Sociol Sport 45(4): 507-512.

Philippaerts, R. M., R. Vaeyens, M. Janssens, B. Van Renterghem, D. Matthys, R. Craen, J. Bourgois, J. Vrijens, G. Beunen and R. M. Malina (2006). "The relationship between peak height velocity and physical performance in youth soccer players." J Sports Sci 24(3): 221-230.

Portas, M. D., G. Parkin, J. Roberts and A. M. Batterham (2013). The effect of maturity on functional movement screen score in young soccer players. 18th Annual Conference of the European College of Sport Science. Barcelona.

Reilly, T., J. Bangsbo and A. Franks (2000). "Anthropometric and physiological predispositions for elite soccer." J Sports Sci 18(9): 669-683.

Reilly, T., A. M. Williams, A. Nevill and A. Franks (2000). "A multidisciplinary approach to talent identification in soccer." J Sports Sci 18(9): 695-702.

Roche, A. F., W. C. Chumlea and D. Thissen (1988). Assessing the Skeletal Maturity of the Hand-Wrist: Fels Method. Springfield, Illinois, Charles C Thomas.

Schlossberger, N.M., R. A. Turner and C. E. Irwin (1992). “Validity of self-report on pubertal maturation in early adolescents.” J Adolescent Health 13: 109-113.

Stølen, T., K. Chamari, C. Castagna and U. Wisløff (2005). "Physiology of soccer: an update." Sports Med 35(6): 501-536.

Tanner, J. M. (1962). Growth at Adolescence. Oxford, Blackwell.

Tanner, J. M., R. H. Whitehouse and M. J. R. Healy (1962). A New System for Estimating Skeletal Maturity from the Hand and Wrist, with Standards Derived from a Study of 2,600 Healthy British Children. Paris, International Children's Centre.

Unnithan, V., J. White, A. Georgiou, J. Iga and B. Drust (2012). "Talent identification in youth soccer." J Sports Sci 30(15): 1719-1726.

van den Honert, R. (2012). "Evidence of the relative age effect in football in Australia." J Sports Sci 30(13): 1365-1374.

van Rossum, J. H. (2006). "Relative age effect revisited: findings from the dance domain." Percept Mot Skills 102(2): 302-308.

Vandendriessche, J. B., R. Vaeyens, B. Vandorpe, M. Lenoir, J. Lefevre and R. M. Philippaerts (2012). "Biological maturation, morphology, fitness, and motor coordination as part of a selection strategy in the search for international youth soccer players (age 15-16 years)." J Sports Sci 30(15): 1695-1703.

Wattie, N., S. Cobley and J. Baker (2008). "Towards a unified understanding of relative age effects." J Sports Sci 26(13): 1403-1409.

Williams, A. M. and T. Reilly (2000). "Talent identification and development in soccer." J Sports Sci 18(9): 657-667.

Williams, J. H. (2010). "Relative age effect in youth soccer: analysis of the FIFA U17 World Cup competition." Scand J Med Sci Sports 20(3): 502-508.

Wolstencroft, E. (2002). Talent Identification and Development: An Academic Review. Edinburgh, Sportscotland.