Improving talent identification through analysis and consideration of biological and relative age

by

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Abstract

Modern talent identification (TID) and talent development (TD) models should include biological development. This requires practicable methods for the consideration of biological age (BA) and relative age (RA). Until 2008, most Swiss sports federations selected young athletes on the basis of current competition results rather than development potential. This meant that many of these talent selection processes failed to integrate important indicators when assessing young talent. Because of these shortcomings, a new standardised national talent selection instrument for all Swiss sports federations was developed. In addition to having six major assessment criteria, the instrument includes biological development, which is subdivided into BA, RA, and relative age effects (RAEs).

However, in the current sports system, the participants are categorised into annual age groups to reduce the developmental differences during childhood and adolescence. In this regard, an unfortunate problem remains because of the potential for RA and BA differences among individuals within an annual age cohort. This means that in many TID processes, the athletes do not have equal opportunities, the resources are used inefficiently, and potential talent is lost.

This thesis summarizes the last eight years of research in RA and BA. Questions arose about the prevalence and evolution of RAEs at the various development stages and selection levels. Furthermore, gaps exist in the research on RAEs in female athletes. The number of extant studies was limited, and the data were inconsistent. Therefore, this cumulative habilitation aims to show: (1) the prevalence of

RAEs by sport type, competition level, and gender; (2) the underlying mechanisms in RAEs; and (3) the possible approaches for considering BA and RA in the selection process.

Studies on RA and BA have shown that even a small age difference of a few months could exert a significant effect on talent selection and TD. The current sports system, which uses chronological age categories, results in the selection of a disproportionate number of biologically and/or chronologically older athletes. This phenomenon has been observed throughout the Swiss TD program, particularly with regard to male athletes. RAEs also influence the selection of female athletes; therefore, these effects must be taken into account. Comparisons of sports have shown that high physical demands and high performance density (many selection levels) strengthen RAEs.

Differences in BA are the principal cause of RAEs. This can lead to performance differences, which, along with parental influence, can trigger selection and self-selection processes. The most important environmental factors are the popularity (i.e. number of participants and economic factors), requirement profiles, and selection levels of the sports. The athletes who are selected benefit from greater support, better training, access to higher competition levels, higher involvement, and positive feedback, which have a positive influence on performance. This leads to an upward spiral for athletes at higher BAs and RAs and a negative spiral for those at lower BAs and RAs (the “vicious circle”). ”False” talent is encouraged, and ”true” talent is lost. Thus, many athletes with the potential for success in adulthood are overlooked. The suggested solutions to counteract the differences in RA and BA are: (1) the implementation of corrective adjustments to reduce RAEs and (2) low-dose hand–wrist imaging or coaches’ subjective evaluations to account for BA. TID programmes must seek to reduce the risk of RAEs by raising awareness, monitoring the athletes’ BAs, and avoiding early selection or deselection. If selection is necessary because of a lack of resources, RA and BA considerations should be integrated into a long-term multidisciplinary approach. With the implementation of these measures, TID can be more equitable, and the available resources can be used more efficiently.

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General background

Several international scientific studies have discussed the advantages of a national framework for sports development. The objective is to optimise the synergies of the individual stakeholders who contribute to sports promotion (Abbott & Collins, 2004; Bergeron et al., 2015; Gulbin, Croser, Morley, & Weissensteiner, 2013). In Switzerland, the Rahmenkonzept zur Sport- und Athletenentwicklung (FTEM) was developed to systematise sports promotion and to optimise limited resources (Fuchslocher, Romann, & Gulbin, 2013; Grandjean, Gulbin, & Bürgi, 2015). The concept provides a framework for the development, planning, and implementation of strategies and programmes that benefit all athletes. It helps the federations to determine the types of support and inputs that are needed by athletes. In addition, the FTEM should help the associations to review their structures to systematise athlete development, to define the athletes' strengths and weaknesses, and to develop suitable measures. In principle, the objective is to optimise the processes in all the federations and sports through a uniform comprehensive system within a framework. The three principal objectives are to improve the coordination and systemisation of sports promotion, to keep people in sports throughout their lives, and to raise the level of competitive sports.

An examination of competitive sports has found that the early and sustained demand for young athletes exerts a positive influence on performance at the elite level. This is determinative for international competitiveness in top-level sports. For this reason, the Federal Office of Sport (FOSPO) and the Swiss Olympic have been investing approximately 11 million Swiss francs annually in the performance-oriented promotion of young talent as part of the Youth and Sport Promotion of Young Talent program. Competitive youth sports have been receiving additional support directly from the sports federations, cantons, municipalities, and private partners. The limited financial resources and the competition systems in youth sports inevitably lead to selection processes. Talent selection in Switzerland was based almost exclusively on competition results (Fuchslocher & Romann, 2013a; Fuchslocher et al., 2016). Important criteria, such as young athletes' biological and psychological development and their potential, were not sufficiently considered (Fuchslocher, Romann, Rüdisüli, Birrer, & Hollenstein, 2011). Since 2008, the Prognostic Integrative Systematic Trainer Evaluation (PISTE) has been used for talent selection. In accordance with the recommendations in the extant literature, the PISTE facilitates the repeated systematic multidisciplinary assessment of performance potential over longer periods of time (Abbott & Collins, 2004; Vaeyens, Lenoir, Williams, & Philippaerts, 2008). In addition to competition results, the following performance tests are taken into account: sport-specific motor and other performance tests; performance development (Baker, Cobley, & Schorer, 2011); psychological components, such as performance motivation and management of performance pressure (Abbott & Collins, 2004; Jean Côté & Abernethy, 2012; Jean Côté, Strachan, & Fraser-Thomas, 2008); resilience (Fröhner & Wagner, 2011; Franchi et al., 2019); biological and psycho-social development (Malina, Rogol, Cumming, Coelho e Silva, & Figueiredo, 2015); and young athletes' relative ages ([RAs]; Romann & Fuchslocher, 2014a; Romann, Rössler, Javet, & Faude, 2018). Each federation has adapted the PISTE criteria to suit its specific sports while consulting with the Swiss Olympic and the Swiss Federal Institute of Sport Magglingen (SFISM). Relevant performance-determining factors are to be integrated on the basis of developmental stage to enable an overall assessment of a young athlete's performance potential (Fuchslocher et al., 2013). The present habilitation thesis is intended to increase the understanding of the research on biological age (BA) and RA as talent selection indicators.

Scientific Background and Objective

Definition

Children and adolescents are usually placed into annual age groups to reduce age and developmental differences. Although this is done in good faith to establish fair competition and equitable selection, chronological age (CA) differences, i.e., RA differences, among the athletes remain. The differences between two individuals in a one-year category can be as much as 12 months. Relative age effects (RAEs) have been defined as the over-representation of chronologically older participants within an age category (Barnsley, Thompson, & Barnsley, 1985). BA, as distinct from CA, defines the skeletal, dental, and sexual maturation in childhood and adolescence (Malina et al., 2004).

Prevalence

The RAE phenomenon in youth sports is well known, and it has been well documented (Cobley, Baker, Wattie, & McKenna, 2009; Musch & Grondin, 2001). It can lead to biased views of children's potential in particular sports. Athletes born early in the selection year have more advanced physical and cognitive abilities than those born later in the year; therefore, they have a higher likelihood of being identified as being more talented (Cobley et al., 2009; Gil et al., 2014; Raschner, Müller, & Hildebrandt, 2012). RAEs are most prevalent in youth team sports (Cobley et al., 2009; Romann & Fuchslocher, 2014a). They have been extensively analysed in international male soccer (Cobley, Schorer, & Baker, 2008; W. F. Helsen et al., 2012; Takacs & Romann, 2016), rugby (Till, Cobley, O'Hara, Cooke, & Chapman, 2013), handball (Schorer, Cobley, Busch, Brautigam, & Baker, 2009), and baseball (Thompson, Barnsley, & Stebelsky, 1991). Only 2% of the existing RAE research includes female athletes. More recent studies have found that females and males in individual sports are also affected. Sports such as track and field (Romann & Cobley, 2015), Alpine skiing (Müller, Hildebrandt, & Raschner, 2015; Müller, Müller, Hildebrandt, & Raschner, 2016; Romann & Fuchslocher, 2014b), swimming (Cobley et al., 2018, 2019; Costa, Marques, Louro, Ferreira, & Marinho, 2013), and tennis (Edgar & O'Donoghue, 2005), as well as a variety of other strength, endurance, and technique-based events, were identified in a study of Youth Winter Olympics participants and the entire Swiss TD system (Raschner et al., 2012; Romann et al., 2018). Conversely, in sports, such as golf, that emphasise skills more than physical ability, RAEs have not been reported (Côté, Macdonald, Baker, & Abernethy, 2006).

Origin and mechanisms

Children of higher RAs and/or BAs have a greater chance of being selected for representative teams or talent centres; thus, they tend to receive a greater amount and level of support. The reason for this temporary performance advantage in relatively older children is their higher average BAs (Malina, Eisenmann, Cumming, Ribeiro, & Aroso, 2004). A higher BA is associated with better physical ability, e.g., aerobic and muscle strength, speed, and endurance (Viru et al., 1999), and this is in turn associated with a physical performance advantage in most sports tasks (Malina et al., 2004). Relatively older people are more likely to have entered puberty earlier, thereby gaining physiological and psycho-social advantages (Beunen & Malina, 1988). Thus, in the short term, coaches are more likely to classify relatively older and more advanced athletes as being talented and to place them in higher selections (Helsen, van Winckel, & Williams, 2005; Romann & Fuchslocher, 2010, 2013a). Unfortunately, relatively younger and late-maturing athletes are more likely to be overlooked or excluded in selection processes (Malina et al., 2004).

As was previously mentioned, BA is also central to talent selection (Armstrong & McManus, 2011). Therefore, it is not surprising that higher junior squad levels are composed almost exclusively of “average” and “early developed” athletes (Beunen & Malina, 1996; Philippaerts et al., 2006). During puberty, athletes of the same CA may have BA differences of up to 5 years (Malina et al., 2004). Thus, it is necessary to assess young athletes’ BAs to classify their performance potential correctly. Some young athletes might not be selected because of their later biological development and current lower performance levels. In addition, young athletes who develop early and have few long-term prospects might be promoted (Romann & Fuchslocher, 2011, 2013a). This means that in many selection processes, talent selection is inequitable, resources are used inefficiently, and potential talent is lost.

The reasons for RAEs are complex. The sports that are particularly affected are those that are characterised by physical characteristics and those that enjoy high popularity. For example, 18,000 basketball players are licensed in Switzerland; however, there are 268,000 players

(Romann et al., 2018). Therefore, RAEs in soccer, the most popular sport in Switzerland, are more likely (odds ratio [OR]: 4.6) than in basketball (OR: 2.5). Furthermore, the requirement profile for each sport is determinative. On the one hand, physical sports are more susceptible to RAEs. On the other hand, disciplines in which small agile athletes have an advantage (e.g., gymnastics, figure skating, and dancing) often have minor, sometimes even inverse, RAEs. Studies have shown that the RAEs for left-handed tennis players are weaker than those for right-handed players. One possible explanation could be that left-handers face less competitive pressure because of their smaller population (Loffing, Schorer, & Cobley, 2010). Good data are available on the RAEs for male athletes at high performance levels (Cobley et al., 2009). Most of the studies focused on team sports, especially soccer and ice hockey (Cobley et al., 2009; Musch & Grondin, 2001).

The interactions among BA, RA, and RAEs in female athletes are not well understood. The data are inconsistent, and the number of available extant studies is limited. Gaps exist in the research on the evolution of RAEs at different development stages and selection levels. Furthermore, each sport's influence on the potency of RAEs remains largely unclear. Currently, the development of measures to prevent the systematic disadvantaging of biologically and/or relatively younger athletes is a priority. Therefore, this cumulative habilitation aims to show: (1) the prevalence of RAEs by sport type, competition level, and gender; (2) the underlying mechanisms in RAEs; and (3) the possible approaches for including RA and BA in the selection process.

Methodological Approach

Study populations

A study of the entire Swiss talent-development system included 5,353 female athletes and 13,506 male athletes in 70 sports (Romann, Rössler, Javet, & Faude, 2018). Two previous studies of Swiss youth soccer analysed the prevalence of RAEs among female players (n = 6,229) and male players (n = 50,581; Romann & Fuchslocher, 2011, 2013). Within the scope of this study, the development of RAEs from popular sports to junior national teams in soccer could be presented. In addition, differences in RAEs at various match positions could be analysed. Because of the gap in the international research on female athletes, an analysis of the women's FIFA U-17 World Cup was conducted and extended to specific Swiss individual (non-team) sports (e.g., Alpine skiing, track and field, and tennis; Romann & Fuchslocher, 2013a, 2013b).

In a third step, possible solutions were developed and tested to better evaluate BA and to correct RAEs (Romann & Fuchslocher, 2015, 2016; Romann, Javet, & Fuchslocher, 2017). These studies analysed the potential Swiss U-15 national team players (N = 144).

Procedure

In Switzerland, all sports use a reference date of 1 January for age group classification. Therefore, this informed the placement of the athletes into one of four relative quartile categories: Q1 = born January–March, Q2 = April–June, Q3 = July–September, and Q4 = October–December. The RA distributions across all athletes and age groups were then calculated and compared to the actual corresponding birth distributions within the Swiss population.

BA was determined by the gold standard: X-rays of the bones in the left hand (Malina et al., 2004). Dual X-ray absorptiometry (DXA) was then used for the comparison and validation of BA (Romann & Fuchslocher, 2016). In addition, the experienced coaches provided subjective visual assessments of each athlete's biological maturity. These were then validated with the gold standard (Romann, Javet, & Fuchslocher, 2017) and compared to the existing non-invasive method (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002).

Context and results

The results of the mentioned Studies were divided into sub-areas: prevalence of RAEs; origins and mechanisms of RAEs; methods for determining biological age; and possible solutions for integrating relative and biological age into selections.

Prevalence

The prevalence of RAEs is evident for female and male athletes in popular sports on regional, national and international selection levels (Cobley et al., 2019; Cobley et al., 2018; Romann & Cobley, 2015; Romann & Fuchslocher, 2013a; Romann & Fuchslocher, 2013b; Romann & Fuchslocher, 2014a; Romann & Fuchslocher, 2014b)

In one study the entire Swiss talent development system in 70 sports was analysed among female and male athletes (Romann, Rössler, Javet, & Faude, 2018). It could be shown that within the basic population of Swiss youth promotion lies a 'small' RAE for all athletes. Small RAEs also were evident for females (OR 1.35 [95%-CI 1.24, 1.47]) and males (OR 1.84 [95%-CI 1.74, 1.95]). At the highest selection level (national), a 'small' RAE (OR 1.30 [95%-CI 1.08, 1.57]) was found in female athletes and a 'large' RAE (OR 2.40 [95%-CI 1.42, 1.97]) in male athletes. Generally, it could be shown that RAEs are stronger among men than women, and that when the sport is highly popular (e.g., Olympic sports), RAEs increase. Higher selection level included higher RAEs only for males.

In a study 6,229 female soccer players from the entire Swiss women's soccer population were evaluated to determine the prevalence of RAEs (Romann & Fuchslocher, 2013b). Significant RAEs were found in self-selected extracurricular (n = 2,987) soccer teams and in the subgroup 'talent-promotion teams' (n = 450) in the 10- to 14-year-old age range. No significant RAEs were found for players ages 15 and up (n = 3,242) and in the subgroup 'all national teams' (n = 239). An analysis of player positions showed significantly stronger RAEs for defenders and goalkeepers than for midfielders.

Although no RAEs were found for players 15 years old and up (n = 3,242) and in the subgroup 'all national teams' (n = 239), significant RAEs were found in self-selected extracurricular (n = 2,987) soccer teams and in talent development (n = 450) within the 10- to 14-year-old age category. In addition, defenders born at the beginning of the year were over-represented significantly compared with goalkeepers, midfielders and strikers.

Another study was conducted at the international level on the U-17 Women's FIFA World Cup and the connection with player positions (Romann & Fuchslocher, 2013b). In the entire cohort of 672 players, we found significant RAEs in the Europe, North and Central America geographic zones; no RAEs in the Asia, Oceania and South America zones; and significant, inverse RAEs in the Africa zone.

In popular sports, the most popular Alpine skiing race for children ages 7 to 14 in Europe with 17,992 in 2010, 2011 and 2012 was analysed. Chi-square analyses showed no RAEs for the entire group of finishers in the qualifying race for girls in the U-8 to U-13 categories (n = 7,010) and all boys (n = 10,410). However, significant RAEs were found for the entire group of both female (OR = 1.49) and male (OR = 2.18) skiers who qualified for the final race. RAEs additionally were apparent in all age categories of female and male finalists. Results showed that RAEs already bias selections in popular sports in childhood (e.g., U-8), which may lead to unequal participation in competitive skiing.

To sum up, it could be shown that RAEs also influence selections of female athletes and, therefore, must be taken into account (Romann & Fuchslocher, 2014a; Smith, Weir, Till, Romann, & Cobley, 2018). In addition, it was shown that RAEs are stronger in male athletes than in female athletes. A comparison of various sports shows that high physical component, high performance density (many selection levels) and high popularity strengthen RAEs.

Origin and mechanisms

Children grow at different speeds and intervals, leading to different biological maturation states. In many sport systems, almost exclusively 'normal' and 'early developed' athletes are chosen in selections (Beunen & Malina, 1996; Philippaerts et al., 2006). This is not surprising, as children of exactly the same chronological age (CA) in puberty may show differences of up to five years in BA

(Malina et al., 2004). Therefore, the most widely supported hypothesis on the origin of RAEs is the maturation-selection hypothesis (Cobley et al., 2009), which states that a higher chronological age is equated with a higher probability of increased anthropometric features from normative growth and development. These developmental differences, induced by BA and RA, lead to short-term performance advantages for relatively older and/or earlier maturing athletes (Lovell et al., 2015). They are more likely to be regarded as better athletes and selected by coaches for higher cadres. Unfortunately, relatively younger and later-maturing athletes in various stages of development are rather overlooked and excluded until the end of puberty (Romann & Cobley, 2015).

In summary, the assertions illustrate how relatively older and/or earlier maturations are overrepresented, and relatively and biologically younger can be overlooked or excluded in sports-related selections (Romann & Cobley, 2015).

Further explanations for superior performance in relatively older children include psychological development, practical experience and mechanisms associated with selection procedures (Musch & Grondin, 2001). After selection, relatively older children also experience better coaching, more positive feedback, deeper engagement and more intense competition, all of which improve performance (Sherar et al., 2007). On the other hand, children with a relative age disadvantage play at a lower level competitively, with less support and training. As a result, these children are less likely to reach the highest levels of competitive sports (Helsen, Starkes, & Van Winckel, 1998) and more likely to drop out of a particular sport (Delorme, Boiche´ & Raspaud, 2010a). In line with this assumption, Delorme et al., (2010) reported an overrepresentation of male soccer from age categories U-9 to U-18 born late in the selection year. Musch and Grondin (2001) described factors related to the sports environment that can increase RAEs in men's sports, such as the sport’s popularity, competition level, early specialisation and the expectations of coaches involved in the selection process. Generally, soccer’s importance and popularity, for example, has increased over the past decade, leading to a larger number of players wishing to play (Cobley et al., 2008). Increasing participation and infrastructure are intensifying competition for elite teams. In addition, greater emphasis is being placed on clubs tracking down young players who are likely to become world-class athletes (Wattie, Cobley, & Baker, 2008).

Suggested solutions

Analogous to the maturation-selection hypothesis, a classification into categories according to biological age would be a possible option to prevent RAEs. For this reason, studies have been conducted to simplify the determination of BA in practice (Studies 2 and 3). Similarly, correction factors to reduce RAEs were developed and tested (Studies 4, 10 and 11).

Since the DXA technique uses 10 times less radiation than the gold-standard X-ray technique for determining BA, it was used to investigate whether imaging bones in the left hand with DXA allows for a valid determination of BA. Comparing X-ray and DXA images of 63 Swiss U-15 national players' left hands indicated excellent intrarater and interrater reliability. Bland-Altman plots showed that SA scores between X-rays and DXA did not differ significantly: by -0.2 years, with 95% of contract limits at ±0.6 years.

Another study compared BA, prediction of the age of peak height velocity (APHV) and coaches' visual estimates of 121 soccer players' biological maturation levels (Romann, Javet & Fuchslocher, 2017). The BA of soccer players was 13.9 ± 1.1 years and did not differ significantly from CA. The correspondence between BA-CA and APHV was 65.5%. The Spearman rank-order correlation (rs) between the maturities was moderate, and the kappa (k) was 0.25. The subjective classifications of coaches corresponded with the gold standard in 73.9% of the cases. The rs between maturity classifications was strong, with a k of 0.48, which was better than the widespread APHV rating.

In a study with 7,761 male athlete's aged 8-15 years, RAEs were analysed in athletic sprinting. When all athletes were included, typical RAEs occurred. RAE effect sizes grew with increasing performance levels (i.e., all athletes were in the top 10%) regardless of age group. In the second part, all athletes born in each quartile and within each annual age group were recorded linearly. Regression analyses showed that a relative age difference of almost one year resulted in average expected performance differences of 10.1% at age 8, 8.4% at age 9, 6.8% at age 10, 6.4% at age 11, 6.0% at age 12, 6.3% at age 13, 6.7% at age 14, and 5.3% at age 15. Correction adjustments then were calculated by day, month, quarter and year, and were used to show that RAEs can be removed effectively from all performance levels.

The same basic idea was applied to a population of Australian swimmers (Cobley et al., 2019). Based on raw swim times, RAEs were found at all performance levels and increased at each selection level. By correcting swimming times according to exact chronological age, RAEs also could be eliminated in swimming.

To sum up, it could be shown that DXA scans, which use significantly less radiation, still produce valid results in determining biological age. Furthermore, it could be shown that experienced trainers' subjective assessments of athletes' biological development indicates broad agreement with the gold standard and is superior to the currently used Mirwald method (Mirwald et al., 2002). Regarding RAEs, correction factors have been developed and tested in track and field (sprinting) and swimming, which eliminated RAEs.

Discussion

The prevalence of RAEs in the Swiss sports system and specific international sports has been shown. In addition, the causes and mechanisms have been described. BA has been considered to be the principal cause of RAEs; therefore, methods for its determination have been developed, validated, and implemented. In the current Swiss system, athletes who are favoured because of their RAs or BAs have benefitted from preferential selection, increased support, higher competition levels, additional training, longer playing times, more positive feedback, and improved coaching (Sherar et al., 2007). In Switzerland, biological development, specifically RA and BA, should be considered more systematically in talent identification (TID). In addition, before puberty, the focus should be less on current competition results and more on technical and tactical skills and the athletes' long-term potential (Vaeyens et al., 2008).

Prevalence

Generally, RAEs were found to play a role in athletes' trajectories at all selection levels, i.e., from participation in popular youth sports to junior competitive sports at the national level. For male athletes, RAEs increased at each selection level. Despite the presence of a systematic nationwide multi-level TID system, the RAEs in Switzerland were comparable to those of the other nations described in the extant literature (Cobley et al., 2009). However, knowledge of the prevalence of RAEs and the related activities in trainer education has not seemed to have exerted adequate influence. The challenge for the Swiss sports system is to retain the athletes who are physically or psychologically disadvantaged because of RAEs or BA. This applies particularly until the end of puberty.

Average RAEs were found in all 70 male sports in the Swiss TD programme. The effects were significantly greater at the national selection level. This finding was supported by the extant literature, which has shown an increasing risk for RAEs at a higher competitive level (Unnithan et al., 2012). Several factors can increase the risk of RAEs in a particular sport (see causes). In contrast to men's sports, all 63 women's sports registered few RAEs, with no relevant differences between the regional and national selection levels. Previous data have also shown differences in RAEs for girls and boys. Cobley et al. (2009) summarised the results of 38 studies published between 1984 and 2007. They found a larger OR (Q1 vs. Q4) of 1.65 (95% CI [1.54, 1.77]) for male athletes than for female athletes {OR 1.21 [95% CI (1.10, 1.33)]}. Raschner et al. (2012) also observed a difference between men (OR 3.32) and women (OR 1.89) in a study of the more than 1,000 athletes who participated in the 2012 Youth Olympic Games. In a recent study of more than 10,000 participants in the London Youth Games, fewer RAEs were found in the girls' sports than in the boys' sports, in general (Reed, Parry, & Sandercock, 2017). A possible additional explanation could be that the number of male athletes in the Swiss TD was 2.5 times that of the female athletes. Approximately 11% of the national athletes were boys, and approximately 18% were girls. This reflects a larger selection pool and greater selection pressure for male athletes, and it could explain the difference in the RAEs for boys and girls. As suggested by Vincent and Glamser, additional factors might determine the RAEs in women's sports (Vincent & Glamser, 2006). In some sports, young women born in Q1 and Q2 are more likely to participate than their younger counterparts. Those born in Q3 and Q4 exhibit a kind of self-selection before even trying an activity possibly because of their less-suited physical characteristics (Romann et al., 2018).

However, in a different sport, the popular women's skiing sport, significant inverse RAEs occurred in the qualifying races. Thus, more girls born in Q4 than in Q1 participated. One possible explanation could be that female anaerobic and aerobic capacities, speed, and physical fitness plateau shortly after the onset of menstruation (Thomas, Nelson, & Church, 1991). Therefore, some of the physiological benefits of a high RA in a competition year could disappear in the U-14 and U-15 age categories. Accordingly, later-developed women often catch up to peers who matured early, and they can even become outstanding athletes (Malina et al., 2004). This can influence participation in ski races. During and after puberty, the physical characteristics required for athletic performance are sometimes in conflict with the stereotypical thin dainty ideal female body in Western countries (Choi, 2000). Accordingly, social pressure could also prevent women from performing at their best in competitive sports, and this could lead elite female skiers to abandon sports such as Alpine skiing (Romann & Fuchslocher, 2011). In short, during and after puberty, female skiers in the first quarter may be more likely to drop out of ski racing than those in the fourth quarter.

Origin and mechanisms

The principal cause of RAEs is the differences in BA. This could result in performance differences that, together with parental influence, could trigger self-selection processes that determine a child's participation in organised sports. The next step entails the trainers' athlete assessments and selections, which enhance RAEs. The most important environmental factors are the sport's popularity (number of participants and economic factors), requirement profile, and selection level. Selection results in greater support, better training and higher competition levels, increased involvement, and more positive feedback, which positively influence performance. This results in a positive spiral for athletes at high RAs and a negative spiral for those at low RAs (the "vicious circle"), i.e., "false" talent is encouraged and "true" talent is lost. In this context, sociology and psychology play an important role. The Matthew effect (positive feedback: success always produces new success), the Pygmalion effect (individual performance matches external expectations), and the "self-fulfilling prophecy" (positive expectations lead to positive behaviour) are well-known mechanisms that influence current performance and promotion (Figure 1).

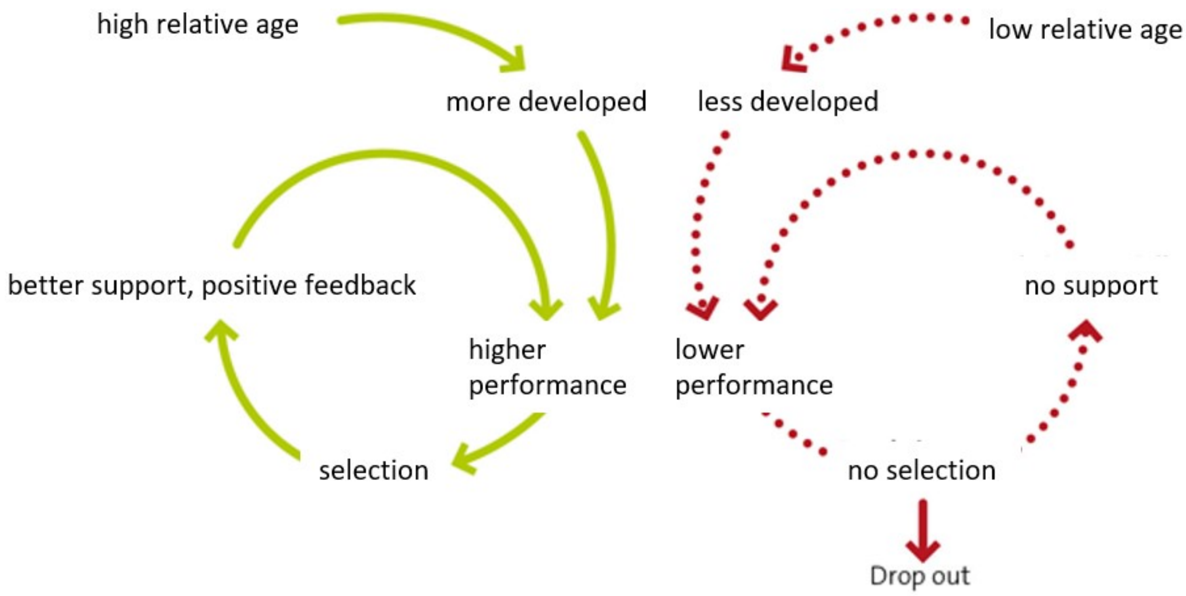

Figure 1. Vicious circle of RAEs in sports (Romann & Fuchslocher, 2010).

In the negative spiral, athletes are not selected because of their lower BAs and/or RAs and their lower performance levels. This leads to less support and training, lower competition levels, less involvement, and little positive feedback, which negatively influence performance. In addition, non-selected players might tend to have lower self-esteem and higher drop-out rates (Helsen et al., 1998). Delorme et al. (2010) offered two explanations for drop-out. First, it is common for children born late in the selection year to join a sport later or less often. Second, those who participate in sports have fewer chances of being selected or positively assessed; therefore, they have a higher drop-out rate.

Coaches or clubs are not the only entities that make selections. Because of a sport's popularity, stereotypes, and the associated social pressure, young athletes already might be performing self-selection upon entry (Romann & Fuchslocher, 2011, 2013a). A study of all Swiss sports showed that non-Olympic sports registered a lower risk of RAEs than Olympic sports. This could be attributed to the higher attractiveness of Olympic sports because of their greater media presence and funding. Non-Olympic sports are less popular and attract fewer young people (Fuchslocher et al., 2013). Higher attractiveness could lead to larger athlete pools for Olympic sports, and this increases the selection pressure (Musch & Grondin, 2001). This view is reinforced by the fact that only approximately 10% of the sample were involved in non-Olympic sports. The remaining athletes were active in Olympic sports.

Interestingly, 12.4% of the Olympic athletes and 21.6% of the non-Olympic athletes were admitted to the national level, thereby confirming the higher selection pressure in Olympic sports. Moreover, the higher professionalism and the talent selection tools could be another reason for an increased risk for RAEs in Olympic sports (Armstrong & McManus, 2011). On the basis of the available evidence (Albuquerque et al., 2012, 2013), no relevant RAEs were found in the promotion of men's weight-class sports to young people. Similar observations have been made for martial arts (Delorme, 2014). This phenomenon could be explained as a "strategic adjustment," i.e., the voluntary transfer of children to another sport in which their physical abilities are less critical to their performance.

Parents also exert significant influence on the timing of their children's joining a club and the types of sports that they play. These mechanisms can be found in the data for Swiss youth soccer (Lüdin, Javet, Hintermann, & Romann, 2018; Romann & Fuchslocher, 2011, 2013a). Figure 2 illustrates these influential factors and interrelationships in RAEs.

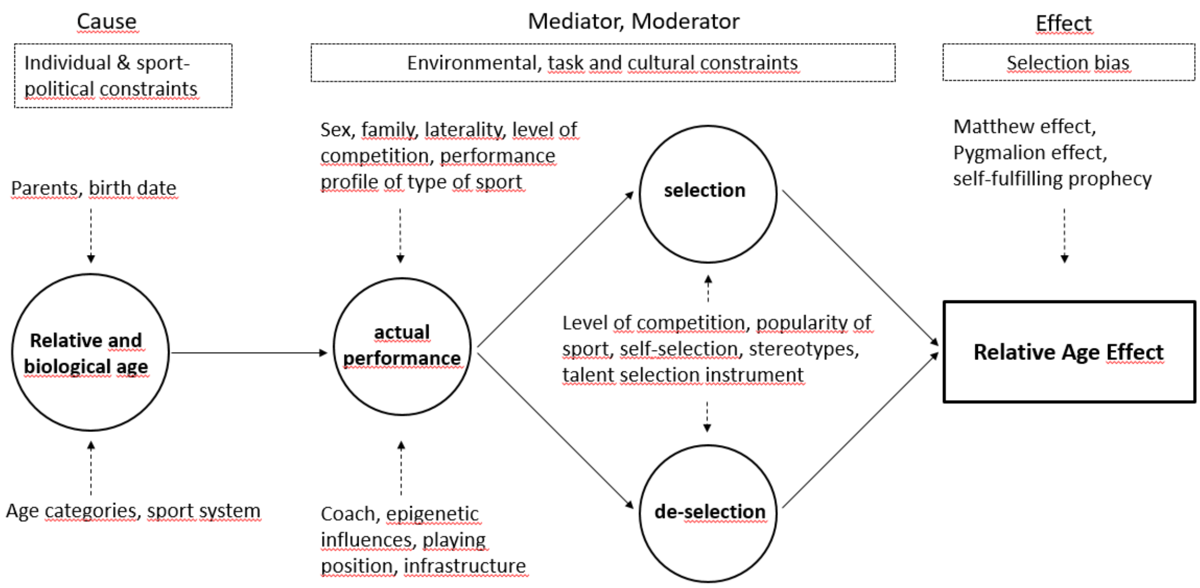

Figure 2: Mechanism of relative age effects

In the early childhood years, RA exerts the greatest influence within a one-year category in relation to CA. This influence decreases continuously as the CA increases (Figure 3). This means that by the end of puberty, athletes born in Q4 can catch up to or overtake those born in Q1. With the decreasing advantage of RA for Q1 birth and the decreasing talent pools (decreasing squad sizes), Q1 athletes in the older selection teams are less often. RA and BA explain the differences in the development of young athletes within an annual category. The fact that the greatest deviations in biological development occur during puberty means that some young athletes' physical and psychological advantages up to age 8 can be attributed mainly to differences in RA. From age 8, the influence of BA increases steadily. Simultaneously, the influence of RA decreases continuously. Therefore, it is estimated that from age 11 (young men), BA differences comprise the greater share of differing conditions. This larger proportion remains until the end of the growth spurt. It is clear then that the age category at which the selection is made is determinative. Before the eighth year of life, minor BA differences exist. Thus, it makes sense to pay attention to RA. Selections at a young age should generally be avoided because of the low prognostic validity (Höner & Feichtinger, 2016; Pearson, Naughton, & Torode, 2006). As athletes reach the age of 11, their BAs should be the focus.

A recent study by Müller et al. (2017) showed that selected young soccer players and Alpine skiers from the fourth quarter were classified disproportionately, relatively speaking, as physically early developed. Conversely, physically later-developed juniors were represented in only the first two quarters. In other words, the disadvantages caused by RA and BA seem to be "too much of a bad thing" for a junior athlete to overcome in selection. Either the disadvantages of RA can be compensated by advanced BA, or, conversely, these advantages can mask a low BA.

Suggested solutions

Modern TID and development models require that biological development be included in the selection processes (Unnithan et al., 2012), which require practical methods for determining and considering BA and RA. Therefore, assessments of BA through DXA and sports coaches' subjectivity were developed and validated. In addition, it could be shown that RAEs can be adjusted by the implementation of correction factors.

An association's or club's goal is to identify and to develop promising young players who can subsequently be promoted to elite teams. Thus, it is crucial that talent models be able to distinguish between the players' current and potential performance levels (Vaeyens et al., 2008). However, athletes' BAs strongly influence their performance levels. Therefore, for TID, it is necessary to classify young people according to their development levels so that the appropriate training and competition programmes can be designed.

Many sports clubs and associations already select their athletes on the basis of scouts' and coaches' subjective assessments. However, these assessments are often aimed at selecting players with early biological maturity because of the strong correlation between biological maturity and the development of physical characteristics, motor skills, and specific soccer skills. Invasive methods, such as X-rays of the hand bones to measure age, and the Tanner scale, are often ethically and financially unacceptable in junior sports. Because the non-invasive Mirwald et al. (2002) method is not applicable at young ages (under age 12), a new method for determining BA is needed (Malina & Koziel, 2014).

The study with Swiss elite coaches showed that the coaches' visual assessments of the athletes were a valid method for determining biological maturation in selecting the U-15 junior national team. Such assessments were even more reliable than the widely used APHV method. A comparison with the gold-standard X-ray method indicated that the trainer's eye has the advantage of much faster information retrieval, lower costs, and the absence of radiation exposure. Therefore, the classification and integration of biological maturity on the basis of the coach's eye could be the first step toward the more equitable and efficient identification and development of young athletes. In sports, the systematic and comprehensive implementation of maturity classifications could exert a significant influence on assessment, selection, training, and performance evaluation during athlete development (Romann et al., 2017).

Corrective adjustments calculated by day, month, quarter, and year showed that the influence of RA and, thus, normative growth and development can be taken into account, with the RAEs removed from sprint performance. Corrective adjustments could also be considered for other track and field disciplines (e.g., 100 m sprints, long jump, and throwing sports); however, evaluations will be needed. It is important that the results provide a possible solution for removing RAEs, increasing children and youth sports participation, and improving athlete assessment and selection. Corrective action can exert a significant influence on children and youths in team and individual sports measured in cm, grams or seconds (CGS) (Cobley et al., 2019; Romann & Cobley, 2014b, 2015). The elimination or lack of consideration of the influence of RA results in consistent and, sometimes, large RAE sizes. In Switzerland, corrective action can help to prevent potential sprinters from being ignored or missed because of RA or late maturity. For team sports, such as soccer and rugby, in which the players are often assessed through standard multi-anthropometric and physiology or fitness tests (e.g., sprint times, vertical jump), corrective action could inform and improve the validity of player assessment and selection procedures. Therefore, the implementation of testing and corrective action in specific junior CGS sports or sports in which physical performance components are measured are important directions for the future. However, whether sports instructors, federations, managers and athlete development systems would benefit from the implementation of such procedures remains to be seen. The greatest challenge might be to obtain a comprehensive reference dataset to generate accurate regressions and subsequent corrections. The possible measures for counteracting RAEs are summarised in Table 2.

Measure	Method	Note on the method; effort	Reference
Bio-Banding (biological indicators) Advantages: • Large reduction of BA differences • Large reduction of RAEs • Adjusted intensities	Age at peak height velocity (Mirwald)	Exact standardisation necessary; middle	(Mirwald, Baxter-Jones, Bailey, & Beunen, 2002)
	Subjective evaluation	High experience needed Control of interrater variability needed; small	(M. Romann, M. Javet, & Fuchslocher, 2017)
	Bone age (Hand-wrist X-Ray)	Minimal radiation exposure Gold standard; large	(Malina, Coelho, Figueiredo, Carling, & Beunen, 2012)
	Percent of adult height	Body height is just one indicator of biological age; small	(Cumming, Lloyd, Oliver, Eisenmann, & Malina, 2017)
	Actual height	Ethically problematic (heavy children at disadvantage); small	(Malina, Ribeiro, Aroso, & Cumming, 2007; Moore et al., 2015)
	Actual weight	Body height is just one indicator of biological age; small	(Reilly, Williams, Nevill, & Franks, 2000)

Corrective adjustments Advantages: • reduction of BA differences • Large reduction in RAEs	Bonus points for low relative/biological age	Only for selections; middle	(Fuchslocher et al., 2013)
	Corrective adjustment of relative age	Additional research is needed; middle	(Romann & Cobley, 2015)
	Shirt numbering, which indicates relative/biological age	Only for selections; middle	(Gil et al., 2014; Sherar et al., 2007)
	Quotas	High selection pressure for Q1/early maturing athletes; small	(Musch & Grondin, 2001)
Structural adjustments Advantages: • reduction of BA differences and RAEs	Rotating cut-of dates	Shift of RAEs; middle	(Barnsley et al., 1985)
	Change of category takes place on the birthday of the athlete	Constant change of individual athletes; small	(Cumming et al., 2017)
	Smaller age bands (e.g. 6 month)	Implementation complex more teams; large	(Boucher & Halliwell, 1991)
	Change grouping by sensitizing coaches to BA or RA issues	Effectivity low; middle	(W. F. Helsen et al., 2012)
	Q4/late mature selection days	Subsequent correction; middle	(Cumming et al., 2017)

Table 1: Measures to counteract RAEs.

Conclusive Summary

In sum, RAEs are present in many sports, and they expose the biases in many TID systems. Because of the incentives for short-term success in junior competitive sports, coaches select athletes who demonstrate highly competitive performance levels in the short term. This means that they select athletes with advanced physical and psychological development. In the current sports selection system, which is based on CA categories, this leads to the selection of a disproportionate number of biologically and/or chronologically older athletes.

The differences in BA are the principal cause of RAEs. This leads to differences in performance, which, together with parental influence, trigger the self-selection processes that determine a child's participation in organised sports. The next step is for coaches to make assessments and selections that enhance RAEs. The most important environmental factors are the sport's popularity (number of participants and economic factors), requirement profile, and selection level. Selection affords an athlete increased support, more training, participation at higher competition levels, greater involvement, and constructive feedback, which positively influence performance. This leads to a positive spiral for athletes with higher RAs and a negative spiral for those with lower RAs (the "vicious circle"). This means that "false" talent is encouraged and "true" talent is lost. Thus, many athletes with the potential for success in adulthood are overlooked. In particular, women's sports can benefit from knowledge about BA and RAEs.

TID programmes must seek to reduce the risk of RAEs by raising awareness, monitoring athletes' maturity, and avoiding early selection or deselection. If selection is necessary because of a lack of resources, BA and RA considerations should be integrated into a long-term multidisciplinary approach. The implementation of these measures can result in equity in talent selection and the more efficient use of available resources.

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