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# The Relative Age Effect in Alpine Ski Racing: A Review

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Abstract: The relative age effect (RAE), which refers to an over-representation of athletes born early in a selection year, represents a problem in various types of sport. The purpose of the present review is to draw together the existing literature concerning the full extent of the RAE, the influence of relative age on the overall performance/results and the influential mechanisms on the RAE in alpine ski racing. A RAE exists in all age categories of national and international alpine ski racing. Relatively older athletes are more successful. Relatively younger ski racers can counteract the relative age disadvantage if they show the same level of physical fitness and maturity as the relatively older athletes. Athletes selected for national final races were significantly more mature than those not selected.

**Keywords:**
Relative age effect, talent development, alpine ski racing, biological maturation

## Introduction

### The relative age effect in sports

In order to guarantee fair competition and to reflect age-related development, children and youth athletes are divided into competition categories based on their chronological age (Helsen, van Winckel, & Williams, 2005; Wattie, Cobley, & Baker, 2008). However, in this system age differences of up to twelve months between individuals are possible, leading to a phenomenon known as the *relative age effect* (RAE). The RAE was first documented in Canadian ice hockey (Barnsley, Thompson, & Barnsley, 1985), and since then its presence has been proven in many other sports, as well. A RAE exists when the relative age quarter distribution of selected sports groups shows a biased distribution with an over-representation of athletes born early in the selection year, meaning in the first months after the specific cut-off date for the competition category, which is January 1 in many sports, for example, in alpine ski racing (Helsen et al., 2005; Lames, Augste, Dreckmann, Görsdorf, & Schimanski, 2008), even though the relative age quarter distribution of the general population shows a nearly even distribution among the four quarters (Musch & Grondin, 2001; Raschner, Müller, & Hildebrandt, 2012).

A RAE is especially present in sports with high demands on power, strength and body size (Musch & Grondin, 2001). In contrast, most of the compositional sports, like gymnastics or rhythmical gymnastics, either are not affected by the RAE, or a reversed RAE is shown with an over-representation of athletes born late in the year (Baker, Janning, Wong, Cobley, & Schorer, 2014; Helsen et al., 2005). Next to the requirements of a sport, another prerequisite for the existence of a RAE is the selection pressure in this sport in a specific country. A RAE was shown to exist particularly in sports that are culturally popular and important; meaning the number of people competing for selection is high. In this setting, relatively older athletes are more likely to be identified as

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talented, and as a consequence, are more likely to be selected (Carling, le Gall, Reilly, & Williams, 2009; Musch & Grondin, 2001).

A RAE often does not occur in female contexts, as Delorme, Boiché, and Raspaud (2009) and Baker, Schorer, and Cobley (2010) demonstrated in the sports of handball and basketball. It was hypothesized that the female variant of these sports is not particularly strength and power related; therefore, the maturation-related development lead is not as decisive (Cobley, Baker, Wattie, & McKenna, 2009). In contrast, Romann and Fuchslocher (2011) found a significant RAE for young female Swiss soccer players, and also for soccer players at the women's under-17 FIFA World Cup (Romann & Fuchslocher, 2013a).

## Scope of review

Alpine ski racing requires a high level of physical fitness (Raschner et al., 2005; Raschner, Patterson, Platzer, & Lembert, 2008; Turnbull, Kilding, & Keogh, 2009). Different variables such as aerobic capacity, considerable lower limb muscle strength, power and power endurance, among others, have been documented (Bosco, 1997; Neumayr et al., 2003; Patterson, Raschner, & Platzer, 2009). Because of the importance of a high level of physical fitness, and the fact that in many countries (e.g. Austria, France, Switzerland, etc.) alpine ski racing is one of the most culturally popular sports, a high selection pressure is assumed. Therefore, the scope of the present review was to firstly investigate the full extent of the RAE in all age categories of national and international alpine ski racing in order to be able to assess in which step of the talent development system the selection error causing the RAE takes place. Secondly, the influence of the relative age on the overall performance/results in alpine ski racing should be evaluated. Thirdly, the influential mechanisms on the RAE in alpine ski racing should be assessed in order to revise the future strategies of the talent development system, hopefully resulting in the eventual minimization of the incidence of the RAE in this sport. The study was approved by the Board for Ethical Questions in Science and the Institutional Ethics Review Board for Human Research.

## The relative age effect in alpine ski racing

### *The extent of the relative age effect in alpine ski racing*

The RAE exists in all age categories of alpine ski racing, at national and international levels, as well as at youth and elite levels. The percentages of ski racers per relative age quarter (quarter 1 (Q1) includes the months January-March; quarter 2 (Q2) the months April-June etc.), the corresponding chi-square-($\chi^2$) and p-values and the effect sizes are represented separated for gender in Table 1. The relative age quarter distributions of the total samples of all categories of alpine ski racing are represented in Figure 1. Müller et al. (2012) were the first to investigate the occurrence of the RAE in alpine ski racing. They found a significant RAE in international elite alpine skiing at the FIS World Cup. All elite skiers who reached at least one FIS point in one discipline in the seasons of 2006/07-2011/12 were included in the analyses. A highly significant RAE was present in the total sample of World Cup athletes and among the male athletes. No significant RAE was present among the female World Cup ski racers (Müller et al., 2012). Baker et al. (2014) found a highly significant RAE for both male and female World Cup alpine ski racers, with the female athletes showing a smaller effect size. In the next level of international elite alpine ski racing, Müller et al. (2012) found a highly significant RAE in the participants of the FIS Junior World Ski Championships 2009-2011 (aged 16-20 years), for both male and female athletes, with a larger effect size ($\omega$=0.32-0.33) than for the World Cup athletes ($\omega$=0.08-0.11). Since the RAE is more pronounced in very popular sports, Müller et al. (2012) sought to determine whether this effect is present only in European alpine ski racers of countries in which this is one of the most popular sports (Austria, France, Italy, Switzerland), or whether the RAE also affects alpine ski racers from North American countries (Canada, USA), where other types of sport are more popular. A highly

significant RAE was found among alpine ski racers of the World Cup and the Junior World Ski Championships for both groups, the European, as well as the North American countries. Further analyses in both levels of ski racing revealed that the RAE was present in all three groups of disciplines: technique (Slalom, Giant slalom), speed (Downhill, SuperG) and mixed (technique and speed) (Müller et al., 2012). In the next level of international youth ski racing, the relative age quarter distribution of the participants of the 1st Winter Youth Olympic Games (YOG) in 2012 in Innsbruck, Austria, was evaluated (Raschner et al., 2012). In total, 15 different types of winter sport were included in the analyses and alpine skiing was considered to be a strength-related sport; the most pronounced RAE was present in this group of sports. The odds ratio calculations revealed that the likelihood of participation at the YOG was 11.5 times higher for an athlete of the first relative age quarter than for one of the last in a strength-related type of sport. Additionally, a closer examination of the different competitive events revealed that the highest RAE was in alpine ski racing (Raschner et al., 2012).

At the national level of youth ski racing, ski boarding schools play an important role in the talent development in Austria. In this context, a highly significant RAE was present in a total sample of 989 male and female youth ski racers, who participated in the entrance exams of such schools (Müller, Müller, Kornexl, & Raschner, 2015a). Müller, Müller, Hildebrandt, Kornexl, and Raschner (2015c) additionally compared the relative age quarter distribution of 10 to 13 year old pupils of Austrian ski boarding schools with the distribution of pupils of normal secondary modern schools of the same age and region. Among the youth ski racers, a highly significant RAE was present, whereas the relative age quarter distribution of the comparison group of non-athletes showed a nearly even distribution among the quarters, indicating that the RAE also is problematic at the national youth level (Müller et al., 2015c). However, it was demonstrated that the selection at the entrance exams of the ski boarding schools did not further intensify or strengthen the RAE, since of all participants the relatively older athletes were not once more favorably selected. These findings indicate that the selection of the relatively older youth ski racers, and in this context the selection error causing the RAE, occurs before youth athletes enter the ski boarding schools, meaning before the ages of 9 to 10 years (Müller et al., 2015a). This implies that the selection error seems to be caused by the competition system in alpine ski racing. Therefore, in a next step, Müller, Hildebrandt, and Raschner (2015b) examined the existence of the RAE at the youngest levels of youth ski racing in Austria, in the Kids Cup (7-11 years) and the Teenager Cup (12-15 years). In both categories a highly significant RAE was present. These results indicate that already at the youngest level of national youth ski racing, when the children begin ski racing, a RAE is present. A higher competition level (national versus provincial) was associated with a stronger RAE, since the RAE was even more pronounced among the athletes selected for the national final races of the Kids Cup, with a large effect size ($\omega$=0.42). The likelihood of participating at the national final races was 4.7 times higher for a ski racer of the first relative age quarter compared to the last (Müller et al., 2015b). Similar results were found in Switzerland. Romann and Fuchslocher (2014) investigated the existence of a RAE in Swiss youth skiing competitions with athletes aged 7 to 14 years. They did not find a significant RAE for the total sample of all participants in the Swiss youth ski races at provincial levels. However, they found a significant RAE among the youth ski racers selected for the final races of the Migros Ski Grand Prix, and who actually finished these races (Romann & Fuchslocher, 2014). When comparing the relative age quarter distribution of the youngest level of Austrian youth ski racing (Kids Cup) with that of the next category (Teenager Cup), no significant difference in the relative age quarter distribution was observed, which means that the percentage of relatively older athletes did not increase from the first (Kids Cup) to the second level (Teenager Cup) of national

Table 1. Summary of studies that have investigated the relative age effect in alpine ski racing

| Reference | Sample size | Group of ski racers | Gender | Relative age quarter distribution Q1 (%) | Q2 (%) | Q3 (%) | Q4 (%) | $\chi^2$ | p | Effect size |
|---|---|---|---|---|---|---|---|---|---|---|
| Müller et al. (2012) | 1363 | FIS World Cup | males (n=742) | 31.8 | 20.4 | 22.4 | 25.5 | 22.3 | <0.001 | ω=0.17 |
| | | | females (n=621) | 24.6 | 23.8 | 25.8 | 25.8 | 0.66 | n.s. | no |
| Baker et al. (2014) | 15565 | FIS World Cup | males (n=9737) | 28.6 | 26.3 | 23.6 | 21.5 | 111.2 | <0.01 | ω=0.11 |
| | | | females (n=5828) | 27.2 | 26.7 | 23.9 | 22.2 | 40.4 | <0.01 | ω=0.08 |
| Müller et al. (2012) | 875 | FIS Junior World Ski Championships | males (n=497) | 37.8 | 25.1 | 20.7 | 16.3 | 40.5 | <0.001 | ω=0.32 |
| | | | females (n=378) | 33.6 | 28.0 | 27.0 | 11.4 | 41.2 | <0.001 | ω=0.33 |
| Müller et al. (2015a) | 989 | Participants of entrance exams of ski boarding schools (AUT) (aged 10-18 years) | males (n=610) | 28.9 | 24.3 | 27.7 | 19.1 | 13.8 | 0.003 | ω=0.15 |
| | | | females (n=379) | 29.8 | 26.9 | 25.9 | 17.4 | 12.9 | 0.005 | ω=0.18 |
| Müller et al. (2015b) | 1004 | Provincial Teenager Cup races (AUT) (aged 12-15 years) | males (n=617) | 30.5 | 21.6 | 26.1 | 21.9 | 13.0 | 0.005 | ω=0.08 |
| | | | females (n=387) | 28.9 | 25.8 | 23.0 | 22.2 | 4.32 | n.s. | no |
| Müller et al. (2015b) | 150 | National Teenager Cup races (AUT) (aged 12-15 years) | males (n=83) | 43.4 | 22.9 | 20.5 | 13.3 | 1.61 | 0.001 | ω=0.21 |
| | | | females (n=67) | 29.9 | 29.9 | 14.9 | 25.3 | 3.99 | n.s. | no |
| Romann & Fuchslocher (2014) | 3670 | Finalists of the Migros Ski Grand Prix (SUI) (aged 7-14 years) | males (n=1839) | 34.7 | 25.2 | 24.4 | 15.7 | 109.1 | <0.01 | v=0.14 |
| | | | females (n=1831) | 30.0 | 29.0 | 21.2 | 19.8 | 58.3 | <0.01 | v=0.10 |
| Müller et al. (2015c) | 282 | Pupils of ski boarding schools (AUT) (aged10-13 years) | males (n=155) | 36.8 | 24.5 | 21.3 | 17.4 | 13.9 | 0.003 | ω=0.34 |
| | | | females (n=127) | 29.1 | 26.0 | 19.7 | 25.2 | 8.0 | 0.047 | ω=0.26 |
| Müller et al. (2015b) | 1438 | Provincial Kids Cup races (AUT) (aged 7-11 years) | males (n=903) | 30.2 | 25.4 | 25.0 | 19.4 | 14.6 | 0.002 | ω=0.16 |
| | | | females (n=580) | 30.3 | 25.3 | 25.3 | 19.1 | 21.3 | <0.001 | ω=0.16 |
| Müller et al. (2015b) | 241 | National Kids Cup races (AUT) (aged 7-11 years) | males (n=119) | 42.0 | 27.7 | 19.3 | 10.9 | 25.1 | <0.001 | ω=0.42 |
| | | | females (n=122) | 36.1 | 32.8 | 18.0 | 13.1 | 18.2 | <0.001 | ω=0.42 |

youth ski racing. This finding revealed that the error in the talent selection and development system in alpine ski racing occurred at or before the youngest level of national youth ski racing. This selection error implies that the relatively older athletes are favorably selected, and many talented relatively younger athletes go unnoticed (Müller et al., 2015b). When comparing the relative age quarter distributions of the single levels of national and international alpine ski racing, it becomes obvious that the over-representation of athletes is more pronounced at youth levels: for example, nearly 38% of the male participants of the FIS Junior World Ski Championships were of the first relative

age quarter, whereas only 16% were of the last quarter (Müller et al., 2012). These findings are in line with those of Schorer, Cobley, Büsch, Bräutigam, and Baker (2009) in German handball. Schorer et al. (2009) assessed that the strength of the RAE decreased as the competition level increased, meaning that early development processes are more germane in the creation of a RAE. Indeed, similarities can be seen when comparing the results of Schorer et al. (2009) with the progression of the RAE from the youngest level of national youth ski racing all the way up to the international elite level, the FIS World Cup. In the latter, the over-representation of relatively older athletes and the effect sizes decreased, although a RAE is still present. Additionally, it is obvious that the higher the selection pressure (because of a higher level of ski racing (national versus provincial)), the stronger the RAE. Forty-two percent of the male participants of the Austrian Kids Cup races were of the first relative age quarter, which means that nearly half of all participants were born in the first three months of the year, whereas only 10% of youth ski racers of the last quarter were selected for the national final races (Müller et al., 2015b).

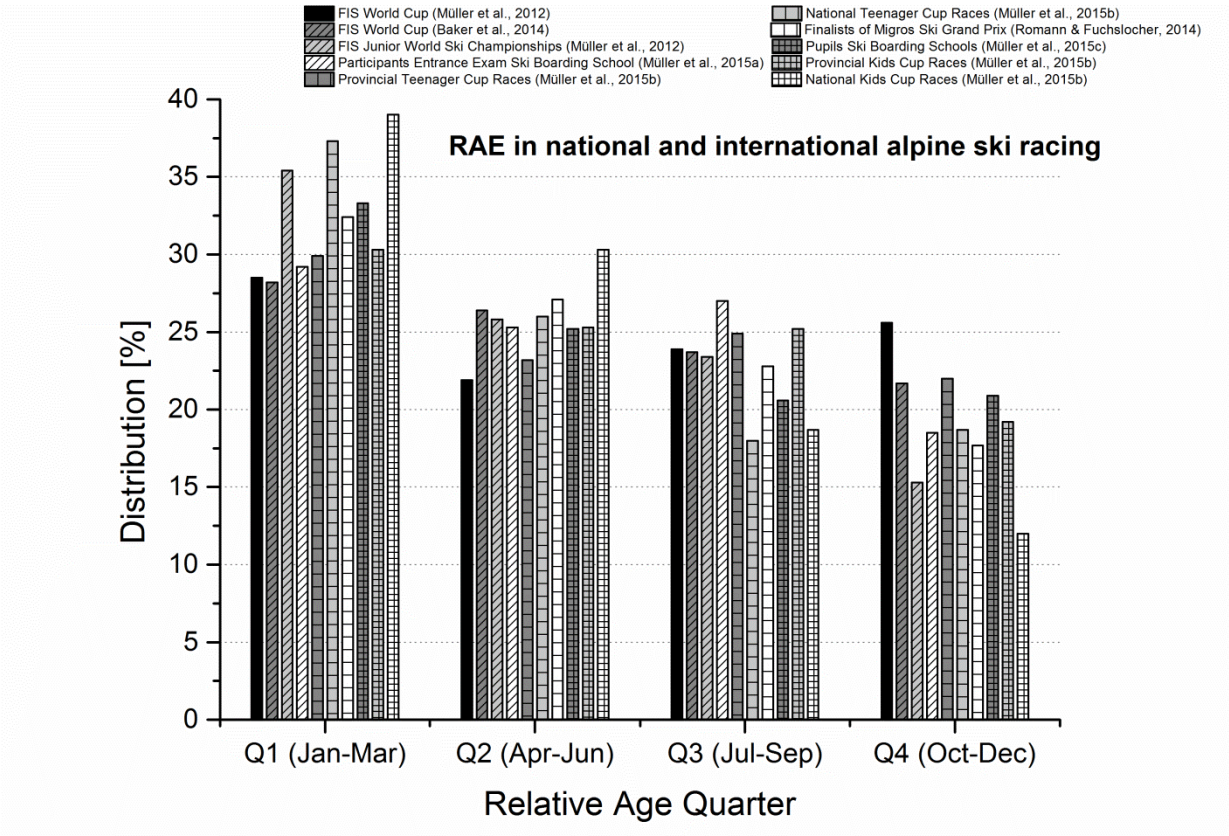


*Figure 1.* Relative age quarter distributions of all categories of national and international alpine ski racing

The findings of the studies investigating the RAE in alpine ski racing revealed that the RAE represents a problem at national and international levels, and in both genders. In Figure 2, the existence of the RAE in all age categories, beginning at the youngest levels of national youth ski racing, all the way up to the elite level, the FIS World Cup, is represented schematically (modified according to Müller et al., 2015b, p.21). Due to the fact that talent in a sport does not depend on the birth month (Helsen et al., 2005; Lames et al., 2008), it can be assumed that there is a severe loss of talent as a consequence of the existing RAE in all age categories of alpine ski racing. Additionally, from an ethical point of view, the existence of a RAE throughout the entire talent development process

indicates that it is biased against young talented kids because the relatively younger athletes, those born late in the selection year, have fewer opportunities of reaching the elite level despite their talents and efforts. Since it was shown that the selection error takes place at or before the youngest level of youth ski racing, strategies in the talent development system and the competition system should be changed. Before this can be done, the influence of the relative age on the overall performance/results, and the influential mechanisms on the RAE have to be assessed (Müller et al., 2015c).

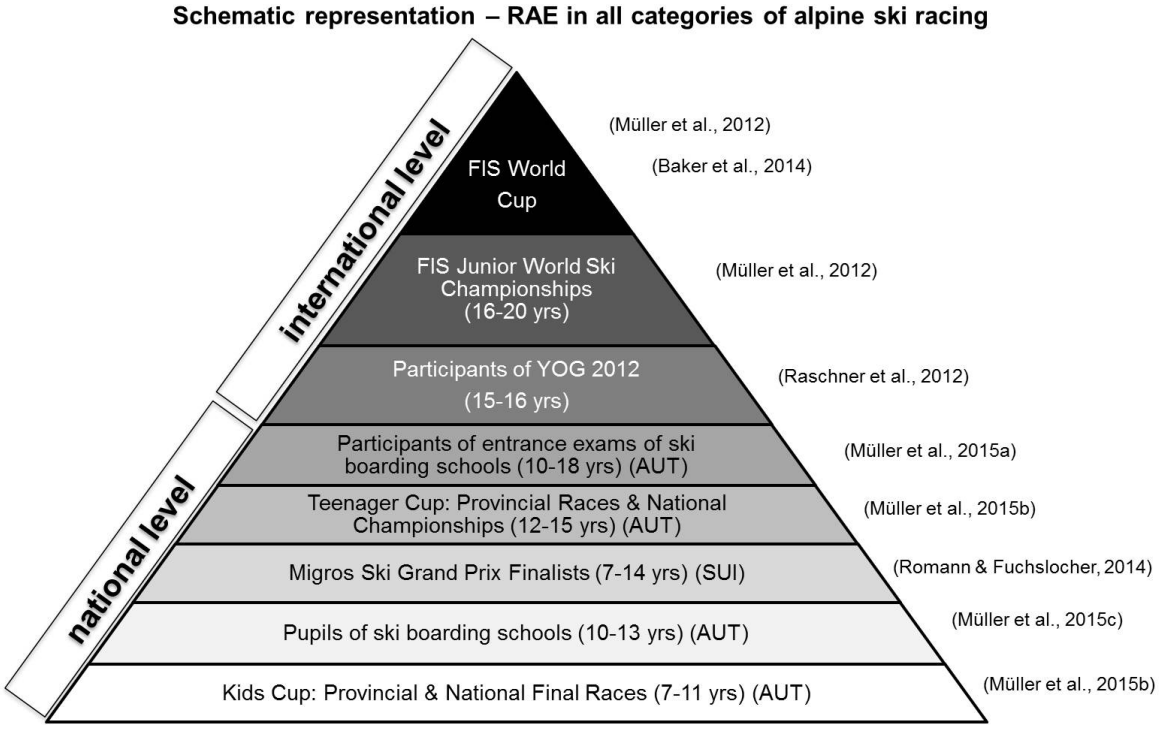


*Figure 2.* Systematic representation of the RAE in all age categories of national and international alpine ski racing (modified according to Müller et al., 2015b, p.21)

*The influence of relative age on the performance/results*

Engebretsen et al. (2010) reported that winning is associated with considerable rewards, national prestige and individual fame. Additionally, Delorme, Chalabaev, and Raspaud (2011) assessed higher drop-out rates in relatively younger and less successful athletes. These findings led to the assumption that relative age could also influence the performance in a sport, not only the participation rate. Raschner et al. (2012) found a significant influence of the relative age on the performance/results at the 1st YOG in 2012: nearly 30% of the medal winners in the 15 different types of winter sport were of the first of eight possible relative age quarters (two birth years were allowed to participate; hence, the months were split into eight relative age quarters). Further analyses revealed that in the alpine ski races at the YOG, 13 of the 19 medals, including all seven gold medals, were won by athletes born in the first three (of eight) relative age quarters (Raschner et al., 2012). These findings were in line with the study of Müller et al. (2015b), who also found a significant influence of the relative age on the performance in national youth ski racing in Austria, in the Kids Cup (7-11 years) and the Teenager Cup (12-15 years) participants. Approximately 35% of the Kids Cup participants who placed in the top three positions were of relative age quarter one, and only 13% of quarter four. The likelihood of being among the top three athletes in the Kids Cup races was 3.4 times higher for an athlete of the first relative age quarter compared to an athlete of the last. This shows that a relatively younger ski racer has a lesser chance of being successful in the Kids Cup races, which can contribute to lower motivation for continuing in this sport

and could possibly increase the drop-out rate among relatively younger ski racers compared to relatively older ones. However, the relative age not only influences the participation rate of youth ski racing, but also the results (Müller et al., 2015b).

*The influential mechanisms on the relative age effect in alpine ski racing*

As already mentioned, talent in a sport does not depend on the birth month (Helsen et al., 2005; Lames et al., 2008). As a consequence, a severe loss of talented alpine ski racers can be assumed because of the existing RAE in all age categories of this sport (Müller et al., 2015b). Wattie, Schorer, and Baker (2015) argue that a domain-specific model should be used to better explain a RAE in a sport; this means that the diverse interacting factors influencing the participation, and consequently, causing the RAE, should be assessed for each specific sport, due to the fact that they can differ from sport to sport. In order to be able to change strategies in the talent development system in a sport to be able to minimize the RAE, it is necessary to find the most important influential mechanisms on the RAE (Müller et al., 2015c). To date, three possible influential mechanisms were examined: physical performance, anthropometric characteristics and biological maturation (Müller et al., 2015a; 2015c).

Alpine skiing is a sport that requires a great level of physical fitness (Raschner et al., 2005; Raschner et al., 2008; Turnbull et al., 2009). Therefore, Müller et al. (2015a; 2015c) hypothesized whether the level of physical performance could represent one possible causal mechanism of the RAE. The importance of a high level of physical performance in youth ski racing was emphasized again in the study of Müller et al. (2015c). In this study, the group of 10 to 13 year old youth ski racers of ski boarding schools highly significantly performed better in all physical performance tests (postural stability, jump agility, explosive leg strength, reactive strength, maximal isometric leg extension strength, maximal isometric core flexion and extension strength) than the comparison group of non-athletes of the same age and from the same regions. However, concerning the influence of the level of physical performance on the RAE, it was demonstrated that no significant differences in the single performance tests were present between 10 to 13 year old pupils of ski boarding schools (Müller et al., 2015c) and 10 to 18 year old participants of the entrance exams of ski boarding schools (Müller et al., 2015a) born in the four relative age quarters. These findings were in line with those of the studies of Carling et al. (2009) in Portuguese and French youth soccer and of Till, Cobley, O'Hara, Cooke, and Chapman (2014) in UK youth rugby, in which no significant differences were found in the performance characteristics between players born in the single relative age quarters. Based on the assumptions of these authors, which is that coaches select similar archetypal athletes regardless of their relative age quarter, Müller et al. (2015c) hypothesized that only well trained and physically homogeneous young ski racers are selected in the development system. Thus, the level of performance of motor skills does not further intensify the RAE in alpine ski racing. The findings of Müller et al. (2015c) did lead to the assumptions that relatively younger youth ski racers are more likely to be selected only if they are advanced in their physical characteristics.

In other types of sport, authors explain the over-representation of athletes born early in the selection year as a result of being chosen for their larger anthropometric dimensions (Helsen et al., 2005). Additionally, Raschner, Müller, Schwameder, Haid, and Männel (1995) demonstrated that alpine ski racers with higher body mass and height have advantages. Although in studies of soccer (Carling et al., 2009; Deprez, Vaeyens, Coutts, Lenoir, & Philippaerts, 2012; Hirose, 2009) no significant influences of anthropometric characteristics on the RAE could be assessed, in diverse winter sport disciplines at the YOG (Raschner et al., 2012) and in alpine ski racers (Müller et al., 2015c) a significant influence of body mass and height on the RAE could be shown. At the YOG in 2012, male

participants of the first relative age quarter were significantly taller and heavier than the athletes of the other quarters (Raschner et al., 2012). Müller et al. (2015c) revealed that 10 to 13 year old youth ski racers of ski boarding schools of the first two relative age quarters were significantly taller and heavier than the comparison group of non-athletes. Additionally, the youth ski racers of the first relative age quarter were significantly taller and heavier than the ski racers of the other three relative age quarters, whereas the pupils of the comparison group of non-athletes born in the four relative age quarters did not significantly differ in their anthropometric characteristics. Since it was demonstrated that the selection error of favorably selecting relatively older youth ski racers has already occurred at or before the youngest level of national youth ski racing in Austria (Müller et al., 2015a; 2015b), it can be assumed that as early as this young age, relatively older ski racers have an increased likelihood of being selected if they have advanced anthropometric characteristics.

Athletes with advanced biological maturation are more likely to be selected due to performance advantages in various fitness parameters (Figueiredo, Gonçalves, Coelho E Silva, & Malina, 2009; Gonçalves, Rama, & Figueiredo, 2012; Sherar, Baxter-Jones, Faulkner, & Russell, 2007). Torres-Unda et al. (2013) revealed that selected elite basketball players were taller, heavier and more mature compared to non-selected basketball players. Based on these findings, the biological maturation was considered to be one possible influential mechanism on the RAE in various sports, for example, in soccer (Deprez et al., 2013; Gil et al., 2014). The results of these studies in soccer were in line with the study of Müller et al. (2015c) in alpine ski racing in which no significant differences were found in the biological maturity status of 10 to 13 year old athletes of the four relative age quarters. For assessing the biological maturity status, the sex-specific prediction equations to calculate the age at peak height velocity (APHV) of Mirwald, Baxter-Jones, Bailey, and Beunen (2002), was used; the validity of this method has previously been proven for youth alpine ski racers of the same age by comparing the results of the APHV-method with the results of the x-ray of the left wrist (Müller, Müller, Hildebrandt, Kapelari, & Raschner, 2015d). The findings of Müller et al. (2015c) indicate that youth ski racers will reach their individual peak growth spurt (PHV) at nearly the same age, independent of their relative age quarter. Based on the assumptions of Deprez et al. (2012; 2013), who suggested that the smaller number of soccer players born late in the selection year have better chances of being selected when they are advanced in biological maturation, and consequently, can counteract the RAE and the associated disadvantages if they enter puberty at an earlier age, Müller et al. (2015c) hypothesized that the missing difference in APHV between the ski racers of the four relative age quarters could be partly attributed to this reason. The authors further assert that relatively younger ski racers have better chances of being selected when they represent the same or an advanced maturational status. Further analyses (Müller, Hildebrandt, Müller, & Raschner, 2015e) in alpine ski racing revealed that male and female Austrian youth ski racers (10-12 years), who were selected for the national final races and who represented the most talented athletes of the given age, were significantly more mature compared to athletes who were allowed to participate only at provincial levels. The national ski racers will reach their individual peak growth spurt at a significantly earlier age than the provincial ski racers (Müller et al., 2015e). Additionally, Sherar et al. (2007) showed that the increase in APHV of one month (the earlier an athlete reaches the individual PHV, the more mature he/she is) decreases the likelihood of adolescent athletes for selection in a competitive team of 17%. This indicates that early maturing athletes have better chances of selection (Wattie et al., 2014). Deprez et al. (2013) divided their sample of youth soccer players intro three maturity groups according to the APHV (late, normal, early maturing) and compared the distribution of these maturity groups among the athletes of the four relative age quarters. It could be shown that within the first relative age quarter, late maturing athletes were overrepresented compared to early maturing athletes, and within the last relative age quarter early maturing athletes were overrepresented. The authors

concluded that soccer players born in the last relative age quarter may have increased chances of selection if they reach their PHV at an earlier age; conversely, being born in the first relative age quarter increased the chance of selection for the elite level independent of the maturation status (Deprez et al., 2013). Based on these assumptions, Müller et al. (2015e) divided the samples of provincial and national ski racers in normal, early and late maturing athletes. Among the provincial ski racers, most of the athletes were normal maturing and an equal distribution of late and early maturing athletes was given. However, among the national ski racers, results were similar to those found by Deprez et al. (2013) in soccer. Results showed that 50% of the ski racers of the last relative age quarter were early maturing and the others were normal maturing, whereas among the athletes of the first relative age quarter, only 10% were early maturing. These results obviously demonstrate that youth ski racers of the last relative age quarter are likely to be selected only if they are early maturing, and therefore, are more mature compared to their relatively older counterparts (Müller et al., 2015e). In summary, it can be assumed that the higher the level of youth ski racing, the higher the influence of biological maturation on the selection process and hence, on the RAE, is present.

## Conclusion

The relative age effect represents a problem in all age categories of national and international alpine ski racing, for both male and female athletes. The relative age not only influences the participation rate of youth ski racing, but also the performance. Since the selection error causing the RAE already has taken place before or at the youngest level of national youth ski racing, the competition system has to be changed. In this context, the system for the competition category classification based on a rotating cut-off date by Hurley et al. (2001) in Canadian ice hockey and modified by Müller et al. (2012) for alpine skiing, seems to be an interesting proposal for reducing and preventing a RAE from occurring. Additionally, it was demonstrated that the relatively younger ski racers can counteract the relative age disadvantage if they show the same level of physical fitness and maturity as the relatively older athletes. Furthermore, the talent selection process in alpine ski racing seems to be influenced by anthropometric characteristics, as relatively older ski racers are taller and heavier than relatively younger ones. Additionally, athletes selected for national final races were significantly more mature than those not selected and relatively older athletes have an increased likelihood of selection for national races independent of their biological maturation status, whereas relatively younger athletes for the most part only have a chance of selection if they are early maturing. This said, talent development systems in alpine ski racing have to consider anthropometric and maturational characteristics in order to contribute to more fairness.

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