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# 1 Relative age effect in French alpine skiing : problem and solution

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14  
15 Keywords : Ski; Relative age effect; Performance; Maturity, Talent Identification

16 Objectives: To identify the potential bias of the relative age effect (RAE) in French  
17 alpine skiers and to propose a mathematical correction adjustment for such a bias.

18 Methods: All performances and birthdates of skiers on the national and  
19 international circuit were collected from the 2004 up to 2019. A goodness-of-fit  
20 chi-square test and the residuals were used to study distribution of birth trimesters  
21 in youth competitors. A linear relationship between the distribution of  
22 performances and the months obtain a calibration coefficient allowing to rebalance  
23 the performance by considering the effect of RAE.

24 Results: Individuals born at the beginning of the year are over-represented in the  
25 elite young selections in all disciplines for both genders. A coefficient based on  
26 the relationship between month of birth and performance adjusts individual  
27 performance and cancels out the effect of RAE.

28 Conclusion: The RAE is present in French alpine skiing. We present a method  
29 allowing to consider the effect of the RAE in the performances realized in each  
30 gender and discipline. This method allows coaches to have a more objective  
31 opinion on performance and to reduce selection bias.

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39 **Introduction**

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2 40 The relative age effect is defined as a bias that advantages individuals born close to the  
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4 41 age-group cut-off in the cohort entry (eg school tests, sports competitions) (Helsen,  
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6 42 Winckel, and Williams 2005). The relative age effect has been a subject studied in many  
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8 43 fields including education since Freyman (Freyman 1965) and Armstrong (Armstrong  
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10 44 1966) in the 1960s. The tendency of better success of the individuals born at the beginning  
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12 45 of the year in the school environment has been confirmed in other studies. For example,  
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14 46 Aune and al. showed a relative age effect in the Norwegian numeracy test for 5th, 8th,  
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16 47 and 9th graders, an effect more remarkable among boys than girls (Aune et al. 2018).  
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18 48 Coblely and al. (Coblely et al. 2009) studied the relative age effect in 657 pupils (aged 11–  
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20 49 14) at a secondary school in North England. He found that older children (born in the first  
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22 50 two trimesters) were more represented in gifted and talented programs.  
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28 51 In sports, a 2018 study on the talent selection in 70 different sports, concerning 18,859  
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30 52 young Swiss athletes showed a moderate effect of relative age in athletics and  
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32 53 synchronized swimming, as well as a slight effect but significant in tennis, volleyball,  
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34 54 football and alpine skiing among girls (Romann et al. 2018). The RAE has been shown  
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36 55 for both genders in young American football players (Tribolet et al. 2018), rugby and  
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38 56 cricket (McCarthy, Collins, and Court 2016) and potentiated with the level of  
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40 57 performance (Leyhr et al. 2021). Finally, Raschner and al. showed a relative age effect  
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42 58 for both girls and boys at the 2012 Winter Youth Olympic Games across all disciplines  
43  
44 59 investigated (Raschner, Müller, and Hildebrandt 2012). Individuals who won medals  
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46 60 were relatively older than their non-medalist counterparts. This bias results from an  
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48 61 earlier maturity with higher performances for those born in the first months of a same  
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50 62 year, the classification by age group favoring the performance of relatively older athletes  
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52 63 (Helsen et al. 2000).  
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64 Maturity is defined as the stage in which an organism is found which has reached its full  
65 development. Regarding performance, we will talk about the development of physical,  
66 physiological or cognitive faculties. This link between development and performance has  
67 been studied and theorized (Berthelot 2012; Berthelot et al. 2019; Moore 1975) by a bi-  
68 phasic function of progression and decline. Depending on the determinants of sports  
69 performance, this maturity can be achieved at different ages. For example, maturity in  
70 chess, with a cognitive dominance, is reached at the age of 31, while in 100 meters  
71 athletics, with a physical dominance, is reached at the age of 25. The determinants of  
72 performance vary depending on the sport and therefore also the phases of development  
73 and therefore the effects of RAE (Till et al. 2014).

74 This relative age effect generates long-term effects. Brustio and al. looked at the RAE to  
75 adulthood in world athletics (Brustio et al. 2019). They first of all confirmed the presence  
76 of bias in all disciplines in the youth categories (under 18 and under 20). They also  
77 identified an relative age effect that persisted into adulthood in some disciplines, notably  
78 throwing events. Likewise, Gennaro Boccia and al have shown that being relatively born  
79 earlier in the year can confer an advantage throughout men's careers in throwing events  
80 (Boccia, Cardinale, and Brustio 2021). Conversely, MacCarthy et al showed a reversal of  
81 the RAE advantage (McCarthy, Collins, and Court 2016). Although relatively young  
82 professional rugby and cricketer players were less likely to be selected into their  
83 respective national academy systems, they were more likely to advance to senior national  
84 teams. McCarthy and Collins (McCarthy and Collins 2014) confirm this "reversal" of the  
85 RAE in rugby. This reversal effect has been called the "underdog" effect (Gibbs, Jarvis,  
86 and Dufur 2012). Finally, de la Rubia et al showed a relative age effect still present in the  
87 adult male and female categories in international handball (de la Rubia et al. 2021).

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88 Other studie have demonstrated the existence of the RAE among international skiers  
89 (Baker et al. 2014). Analyzes of 1,474 ski jumpers, 7,501 cross-country skiers, 15,565  
90 alpine skiers, 4,179 snowboarders and 713 Nordic combined athletes revealed significant  
91 RAE for most of these disciplines for all genders. But no published study has investigated  
92 French alpine skiing. Since each country has its own system of talent identification,  
93 previous studies may not be simply extrapolated to the French spline skiing system. The  
94 presence of RAE in skiing was global and having not changed over the past 10 to 15 years  
95 (Steidl-Müller et al. 2019), it is useful to focus on this phenomenon in French alpine  
96 skiing specifically. In addition, no solutions regarding the RAE in alpine skiing has been  
97 proposed.

98 In other sports, solutions have been proposed to consider the RAE. In the National  
99 Hockey League, reducing the age groups; changing the annual limits for age groups; or  
100 to delaying the selection and identification processes beyond the stages of puberty and  
101 maturation have been tested (Barnsley and Thompson 1985). Nolan and Howell have  
102 shown that these biases have persisted in hockey despite the available option for adjusting  
103 this bias (Nolan and Howell 2010). Another study in basketball (de la Rubia Rianza et al.  
104 2020) proposed to evaluate the athlete on her/his performance in the long-term and not  
105 the immediate results only. They suggested to take into account the maturation of the  
106 athlete rather than the age groups, and to design models of evaluation of young athletes  
107 accounting for other parameters (psychology, emotional intelligence, cognitive skills,  
108 etc.). These methods include development parameters linked to maturation, but none has  
109 presently been validated that would more precisely detect future talent. Romann and  
110 Cobley proposed a linear correction in sprint athletics (Romann and Cobley 2015). They  
111 showed that a relative age difference of nearly one year resulted in expected average  
112 performance differences ranging from of 10.1% to 5.3% among Swiss junior sprinters.

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113 Other corrective adjustment procedures were constructed from the regressed relationship  
114 between chronological age and objective performance measures of swimming (Abbott et  
115 al. 2021, 2020; Cobley et al. 2019). A practical solution proposed by Helsen et al in soccer  
116 (Helsen et al. 2021) makes it possible, based on a longitudinal study examining secular  
117 changes in biological maturation in Belgian boys, to determine an appropriate  
118 developmental allocation date by knowing the anthropometric characteristics of the  
119 individual. Its new classification based on this allocation date and not its chronological  
120 date, makes it possible to cancel the RAE.

121 A systematic review (Webdale et al. 2020) identified ten independent solution to RAE  
122 types from sixty-three peer-reviewed publications between 1980 and 2018. Six of these  
123 solutions were “technical and policy-based”. This relates to modifying the age structures,  
124 correcting performance by a coefficient, achieving player quotas and making categories  
125 by anthropometric parameters. Three proposed solutions were pedagogical and  
126 informational focusing above all on pedagogical training to raise awareness of the RAE  
127 bias. They highlight the difficulty of applying the different methods proposed and that  
128 the implementation of these solutions has the potential to affect both positively and  
129 negatively the career and life outcomes of participants. The recommended solutions seem  
130 difficult to implement quickly because they require substantial changes in sports  
131 organizations.

132 Therefore, we aimed to 1) determine the relative age effect in French alpine skiers in  
133 young age groups and adulthood, and 2) recommend a method to consider the RAE. We  
134 hypothesized that a relative age effect is present in both genders among French alpine  
135 skiers and that a proper regression method could provide a robust solution to compensate  
136 for this effect.

137 **Methods**

138 *Studied population*

139 *Inclusion criteria*

140 The population studied included all male and female French alpine skiers having  
141 participated in at least one competition in Giant Slalom (GS), Slalom (SL) and Super  
142 Giant Slalom (SG) between the age of 13 up to 30 from the 2004/2005 season up to the  
143 2018/2019 season.

144 *Exclusion criteria*

145 Downhill (DH) performances have been included for adult categories only. (DH is not a  
146 discipline practiced in youth categories).

147 *Sample description*

148 The studied population consisted of 21348 individuals ,7672 women (36%) and 13661  
149 men (64%).Among these competitors, 2793,1917,1162 individuals participated to the  
150 national U14, national U16 championship and international U18 championship  
151 respectively. The distribution of performance and age for each category and gender are  
152 presented in the table .

153 *Data source*

154 The performance data on the national and international circuit as well as dates of birth  
155 were available on the website of the French Ski Federation: [http://www.ffs.fr/ski-](http://www.ffs.fr/ski-alpin/competitions/resultats)  
156 [alpin/competitions/resultats](http://www.ffs.fr/ski-alpin/competitions/resultats). Alpine skiing performance is quantified using FFS (French  
157 Ski Federation) points. The number of points scored on the day of the competition  
158 depends on the overall level of the race and the time achieved in relation to the winner of  
159 the race :  $(\frac{T_x}{T_0} - 1) \cdot F$ , with  $T_x$  the runner's time in seconds,  $T_0$  the winner's time in seconds

160 and  $F$  a discipline dependent factor. The data regarding of participation in elite youth  
161 competitions is private internal data that of the French Ski Federation made available for  
162 this study.

### 163 ***Data analysis***

164 The age group categories in alpine skiing are determined according to the skiers' year of  
165 birth. The U14 category is made up of skiers born in year  $y - 14$  and  $y - 13$  for the  
166 season  $y - 1/y$ . The U16 category is made up of skiers born in year  $y - 16$  and  $y - 15$   
167 and category U18 is made up of skiers born in year  $y - 18$  and  $y - 17$ . For example, a  
168 skier born in 2006 will be in the U14 category for the 2018-2019 season. An individual  
169 can be present in several categories if he has competed for several years. For Every year,  
170 there are two French (FFS) youth elite championships in U14 and U16 categories and one  
171 youth elite international (FIS : International Ski Federation) championships in U16  
172 category. Only skiers selected by their regional committees in each category (U14, U16)  
173 participated in these competitions.

### 174 ***Identifying the relative age effect***

175 To have a large sample size in each group and a higher statistical power, birth dates of  
176 participants in the elite young competitions (U14 and U16 FFS, U16 FIS) were  
177 categorized into trimesters (*January, February, March: Q1, April, May, June: Q2, July,*  
178 *August, September: Q3, October, November, December: Q4*). A Chi-squared test of  
179 adequacy was used to compare the distribution of birth trimesters with the distribution of  
180 birth trimesters for the entire French population over the study period. Historical public  
181 data for the entire French population were obtained from the INSEE (Institut national de  
182 la statistique et des études économiques):  
183 <https://www.insee.fr/fr/statistiques/serie/000436391>. In the presence of a global effect,

184 Haberman residuals (Haberman 1973) were calculated and compared to the quantiles of  
185 the normal distribution (of order 0.1,0.05,0.01) to determine the birth trimester over or  
186 under represented. These residuals represent the standardized deviation between the  
187 observed and expected values. They asymptotically follow a standard normal distribution.  
188 In the absence of a relative effect of age, the distribution of trimesters of birth is assumed  
189 to follow the distribution of the general French population, therefore a rejection of the  
190 null hypothesis of homogeneity will identify a relative age effect.

### 191 *Relative age effect in adulthood*

192 The homogeneity test was performed on the birth trimesters of individuals present on the  
193 international circuit (FIS) in adulthood (between 22 and 30 years) in GS, SG, SL and DH.  
194 The FIS circuit is the highest level of alpine skiing in the world. If the distribution of birth  
195 trimesters does not follow the French distribution, the relative age effect is present in  
196 adulthood.

### 197 *Rellocation RAE solution*

198 The method was developed for the U14, U16 and U18 categories, individuals of the same  
199 category were separated by their year of birth  $y$ (first year) and  $y + 1$ (second year). Each  
200 skier is represented only once per season, characterized by his best performance achieved.  
201 For each year, the dates of birth have been categorized into months of birth (January to  
202 December). At each age, a linear regression was performed between the month of birth  
203 and the skier best performance (in FFS points). If the slope coefficient  $\alpha$  is significantly  
204 different from 0, it is used as a calibration coefficient to rebalance the effect of relative  
205 age. We calculated the “adjusted” points for each individual  $i$  :

$$Ptscorr_j^i = Pts_i - \alpha_j * k$$

with  $j$ : age,  $k$  : Birth trimester

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208 These adjusted points allow to compare several skiers independently of their month of  
209 birth. The categories being composed in 12-month range, the coefficients will adjust the  
210 performance within each of the group (1st and 2nd year). For example, the U14 1st year  
211 and the U14 2nd year will have two distinct coefficients, and will allow each individual  
212 to be compared with regard to his category (1st or 2nd year). We used a cross validation  
213 method to check the robustness of our method. We cut our sample into two parts, one  
214 accounting randomly for 75% of the sample data, and another part with 25%. The 75%  
215 made it possible to calculate the calibration coefficients at each age category. Then, the  
216 calibration coefficients was applied on the remaining 25% data sample. The RAE bias is  
217 considered to be annulated cancelled out if the previous positive linear relationship  
218 between performance and month of birth on this “test” sample was now absent.

## 219 **Results**

### 220 *Identifying the relative age effect*

221 The birth trimesters of participants in elite youth competitions does not follow the  
222 distribution of the entire French population (proportion (%) = 24.4, 25.0, 26.1 24.4)  
223 (Figure 1) ( $p < 0.05$ ). A relative age effect was identified in all youth competitions for both  
224 genders. Skiers born in the first trimester are over-represented in all categories.  
225 (proportion (%) = 33.3, 31.7, 34.6, 27.1, 30.7, 29.2 for men’s U14 ; women’s 14 ; men’s  
226 U16 ; women’s U16 ; men’s U18 and women’s U18 respectively ,  $p < 0.01$ ). Skiers born  
227 at last trimester are underrepresented (proportion (%) = 16.7, 17.3, 15.8, 18, 16.6, 18.6  
228 for men’s U14 ; women’s 14 ; men’s U16 ; women’s U16 ; men’s U18 and women’s U18  
229 respectively,  $p < 0.01$ )

230 The proportion observed in each discipline (GS, SG and SL) are represented in the  
231 Supplementary figures. A different distribution of the French population is present in all

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232 disciplines (GS, SG and SL) for national competitions (FFS). The first and second  
233 trimesters are overrepresented and the 3rd and 4th trimesters are underrepresented in all  
234 men's and women's disciplines for U14 competitions. In U16, the 4th trimester is  
235 underrepresented in all disciplines for both genders, and the first trimester is  
236 overrepresented in SG and SL.

### 237 *Relative age effect in adulthood*

238 Figure 2 shows an imbalance in the distribution of the birth trimesters among adult skiers  
239 as well compared to the French population. Individuals born in the first trimester are over-  
240 represented in men GS (proportion=29.4%  $p<0.05$ ), GS female (35.2%  $p<0.01$ ), SG male  
241 (proportion=29.7%  $p<0.05$ ), SG female (proportion=41.7%  $p<0.01$ ), SL male  
242 (proportion=28%  $p<0.1$ ), SL female (proportion=34.7%  $p<0.01$ ) and DH women  
243 (proportion=47.5%  $p<0.01$ ). Individuals from the last trimester are underrepresented in  
244 GS male (proportion=20.5%  $p<0.1$ ), GS female (proportion=18.9%  $p<0.1$ ), SG female  
245 (proportion=16.7%  $p<0.1$ ), SL male (proportion=20.8%  $p<0.1$ ), SL female  
246 (proportion=16.5%  $p<0.1$ ) and DH women (proportion=12.5%  $p<0.1$ ).

### 247 *Relocation RAE solution*

248 The methodology allowing performance to be adjusted by the relative age effect  
249 developed in all categories for both genders in alpine skiing is presented for the densest  
250 category in terms of the number of performances achieved, the male GS. A linear  
251 relationship between performance and month of birth for each category in Giant Slalom  
252 is illustrated in Figure 3. In each age category, the slope coefficient is different from 0  
253 (3.27, 2.73, 2.09, 1.88, 2, 1.47 for men's U14 1st and 2nd year ; women's 14 1st and 2nd  
254 year; men's U16 1st and 2nd year; women's U16 1st and 2nd year; men's U18 1st and  
255 2nd year and women's U18 1st and 2nd year). This coefficient represents the potential

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256 gain in points for each additional birth month at each age in male GS. Calibration  
257 coefficients as well as the confidence intervals are summarized in Figure 4 for each  
258 category, gender and discipline.

259 After correcting the performance / age relationship using the calibration coefficient, the  
260 RAE was considered in Figure 5 ( $\forall$  age  $j$  :  $\alpha_j = 0$ ,  $p > 0.05$ ). All the confidence  
261 intervals of the performance averages for each month of birth follow the linear trend with  
262 a zero slope, except for the month of October for the U16 first year category.

263 Figure 6 also includes the calibration coefficients obtained with the methodology  
264 presented for women (bottom) also and for the disciplines SG, GS and SL (in column).

265 For each category (on the vertical axis) is represented the calibration coefficient as well  
266 as its confidence interval delimited by the two bars. If the value 0 (represented by the  
267 horizontal bar) is within the confidence interval, the assumption that the calibration  
268 coefficient is equal to 0 is not rejected. A null calibration coefficient means that the month  
269 of birth has no influence on performance. All the calibration coefficients for the U14  
270 categories (1st and 2nd year) are significantly different from 0. Conversely, 4 coefficients  
271 are significantly different from 0 in U18 1st year and 1 in U18 2nd year.

## 272 **Discussion**

273 This study shows a relative age effect in all disciplines and age categories among French  
274 alpine skiers. It also demonstrates that this effect lasts until adulthood in the international  
275 FIS circuit, with a higher proportion of individuals born at the beginning of each year.  
276 Based on such findings we propose a solution to adjust for this effect via a calibration  
277 coefficient calculated for each event, age category, and gender. This option allows  
278 coaches or regional selectors compare performances in a fairer way of several skiers born  
279 in different months of the same year.

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280 Several studies have investigated the relative age effect in other sports (Cobley et al.  
281 2019; de la Rubia Rianza et al. 2020; Helsen, Winckel, and Williams 2005; Nolan and  
282 Howell 2010; Tribolet et al. 2018). This work is the first one to quantify RAE in French  
283 alpine skiing disciplines. Development between 13 and 18 years has already been studied  
284 in other studies (Bottollier et al. 2020). The strong physical component of alpine skiing,  
285 with important energy needs partly explains why relatively older individuals find  
286 themselves advantaged in performance. The link between physical and cognitive abilities  
287 and RAE exists (Huertas et al. 2019) but some studies do not observe it (Carling et al.  
288 2009). It also depends on the selection criteria developed to reach the high level in the  
289 different sports.

290 The global relative age effect is probably due to the fact that selections at youngest ages  
291 are mostly made on the sole criterion of performance. Individuals in the same age  
292 category but months older have more time to further develop their physical, physiological  
293 and psychological characteristics (Helsen et al. 2000). Diry et al. (Diry et al. 2020)  
294 showed this dependence on maturity of physiological factors for rowing. Another study  
295 reinforced this hypothesis, showing that the relatively older male competitors were  
296 significantly taller and heavier than the younger competitors in youth winter Olympics  
297 (Raschner, Müller, and Hildebrandt 2012). Like in other studies, the RAE is exacerbated  
298 in the youngest categories and wanes in the proximity of the senior categories (Johnson,  
299 Farooq, and Whiteley 2017; Smith et al. 2018; Votteler and Höner 2017), with a greater  
300 presence of RAE in adulthood in men than in women (Boccia, Cardinale, and Brustio  
301 2021). This persisting effect in senior categories can find explanations probably because  
302 the skiers selected in the young categories benefit earlier from more investment in  
303 trainings, more experienced trainers and training partners, and the knowledges about the  
304 elite circuits, which facilitates their access to the highest level in adulthood. We therefore

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305 do not find here the so-called “underdog effect”, that is to say an inversion of the  
306 proportions of birth trimester in adulthood, yet present in different team sports such as  
307 rugby (McCarthy and Collins 2014) or basketball (de la Rubia Rianza et al. 2020). If this  
308 is not due to a statistical hazard, maybe team sports have more performance factors than  
309 alpine skiing which may lead to more subjective judgments from coaches which allow  
310 access even in late ages. Conversely, as in our study, we find a RAE in various individual  
311 disciplines, notably throws in athletics (Boccia, Cardinale, and Brustio 2021; Brustio et  
312 al. 2019). These individual sports have performance determinants closer to alpine skiing.  
313 Selection methods, which offer future benefits, may be carried out early in an athlete’s  
314 career, and leave little opportunity for new athletes.  
315 The methods proposed so far (Barnsley and Thompson 1985) have not made it possible  
316 to reduce the biases linked to the RAE (Nolan and Howell 2010). These are indeed fair  
317 measures, but proposals such as reducing the ages for regrouping or setting up quota  
318 systems in elite selections are costly and difficult to implement from a logistical point of  
319 view on an entire population of young athletes. An interesting idea would be to carry out  
320 standardized and quantifiable physical, physiological, psychological and sociological  
321 tests at regular intervals to monitor, on multiple indicators, long-term performance  
322 (several years). However,unlike the method proposed in this study, this approach can be  
323 complex to set up and requires individual monitoring over the long term.  
324 Our method is easy to set up and allows for a faster adaptation of institutional practice  
325 with regard to detection and selection of young people. This method is similar to what  
326 has been previsouly suggested in swimming sprint disciplines (Romann and Cogley 2015;  
327 Abbott et al. 2021, 2020; Cogley et al. 2019). The authors have used a linear regression  
328 between performance and chronological age to determine the potential gain in terms of  
329 performance according to the swimmer’s birth period. Their adjustment procedures

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330 Obviously, performances do not progress linearly; it follows a double intertwined  
331 exponential (Berthelot et al. 2019), but for the sake of implementation simplicity,  
332 compensation can be approximated through a linear relation over a 12 months period.  
333 Both methods allow researchers and coaches to compare in an equivalent manner all the  
334 swimmers of the same category regardless of the month of birth. This has two main  
335 practical advantages: in the short term, individuals may have their performances  
336 rebalanced in a fairer way for their real age. In the long term, individuals who were  
337 previously unselected due to their period of birth may reintegrate into a long-term training  
338 program for young skiers and the paths of high performance and thus be able to more  
339 easily exploit their potential to reach the top level. The method is simple to apply, and  
340 could be integrated directly into the coaches monitoring tools, providing more accurate  
341 evaluation of the performance of young skiers.

#### 342 ***Practical application***

343 This study therefore makes it possible for the coaches and federal staff of young skiers to  
344 become aware of the presence of a relative age effect in French alpine ski. We show that  
345 it may be necessary to assess young athletes on potential performance and not current one  
346 only. Second, this study proposes a method to better compare skiers of different  
347 chronological ages, integrating the RAE in a given category. For example, if two skiers  
348 have similar performances but at different chronological age, the calibration coefficient  
349 method will give the youngest one a fairer evaluation, suggesting a higher potential in the  
350 future. The proposed method does not recommend selecting athletes with a best potential  
351 estimated by our model, it aims to provide this additional information to make a decision.  
352 The person using the decision support tool, i.e. the coach or federal staff for example, will  
353 then adjust these coefficients himself by his personal knowledge. It is therefore a first  
354 step towards correcting the bias of the RAE in French alpine skiing. Skiers may no longer

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355 miss certain selections unfairly, while the federation can acquire a more accurate  
356 assessment of its young categories, that will better support long-term potentials by  
357 rebalancing the chances from the beginning.

### 358 *Limitations and perspectives*

359 The present study has two main limitations. First, the calibration equations depend on a  
360 performance dataset with a 15-year follow-up only. The volume of data is more important  
361 for the young categories and decreases over time. Hence, there is a greater uncertainty  
362 regarding the calibration coefficient in the adult ages. But the proposed method will get  
363 more precise as new data entries will increase the robustness of the model. In addition,  
364 the confidence interval of the coefficient makes it possible to add a nuance taking into  
365 account the sample size and the outliers. The second limitation of this study is that it only  
366 considers the age and performance variables to correct for the RAE. It would be  
367 interesting to take into account other factors allowing to calculate biological maturity  
368 (Mirwald et al. 2002) and its influence. It may therefore be worthwhile to include  
369 biological / biometrical variables of interest (height, seat height, leg length ... ) or other  
370 parameters of ski, and compare the performances of skiers according to the progression  
371 of these variables also. The method is mainly based on easily retrievable performance and  
372 age data, it would be interesting to apply it to other sports whose performance is measured  
373 quantitatively.

### 374 **Conclusion**

375 A relative age effect is present in all youth age categories of the French alpine skiing. In  
376 the French national ski teams, skiers born at the beginning of the year are over-  
377 represented compared to those born at the end of the year. This effect is also present in  
378 adulthood on the international elite circuit (FIS). We propose an easily implementable

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379 calibration method that corrects for such a bias. By adjusting the FIS points of each skier  
380 according to their month of birth, it allows for a fairer and more accurate performance  
381 evaluation. Ultimately, this tool could help rebalance the chances of reaching the highest  
382 levels, regardless of the month of birth.  
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384 Abbott, Shaun, Clorinda Hogan, Marcela Torres Castiglioni, Goshi Yamauchi, Lachlan  
385 J. G. Mitchell, James Salter, Michael Romann, and Stephen Cobley. 2021. "Maturity-  
386 Related Developmental Inequalities in Age-Group Swimming: The Testing of 'Mat-  
387 CAPs' for Their Removal." *Journal of Science and Medicine in Sport* 24 (4): 397–404.  
388 <https://doi.org/10.1016/j.jsams.2020.10.003>.

389 Abbott, Shaun, Kylie Moulds, James Salter, Michael Romann, Lucy Edwards, and  
390 Stephen Cobley. 2020. "Testing the Application of Corrective Adjustment Procedures for  
391 Removal of Relative Age Effects in Female Youth Swimming." *Journal of Sports*  
392 *Sciences* 38 (10): 1077–84. <https://doi.org/10.1080/02640414.2020.1741956>.

393 Armstrong, H. G. 1966. "A Comparison of the Performance of Summer and Autumn-  
394 Born Children at Eleven and Sixteen." *British Journal of Educational Psychology* 36 (1):  
395 72–76. <https://doi.org/10.1111/j.2044-8279.1966.tb01841.x>.

396 Aune, Tore K., Rolf P. Ingvaldsen, Ole P. Vestheim, Ottar Bjerkeset, and Terje Dalen.  
397 2018. "Relative Age Effects and Gender Differences in the National Test of Numeracy:  
398 A Population Study of Norwegian Children." *Frontiers in Psychology* 9.  
399 <https://doi.org/10.3389/fpsyg.2018.01091>.

400 Baker, Joseph, Christina Janning, Harmonie Wong, Stephen Cobley, and Jörg Schorer.  
401 2014. "Variations in Relative Age Effects in Individual Sports: Skiing, Figure Skating  
402 and Gymnastics." *European Journal of Sport Science* 14 (sup1): S183–S190.  
403 <https://doi.org/10.1080/17461391.2012.671369>.

404 Barnsley, Roger H., and A. H. Thompson. 1985. *Birthdate and Success in Minor Hockey:  
405 The Key to the NHL*.

406 Berthelot, G. 2012. "Exponential Growth Combined with Exponential Decline Explains  
407 Lifetime Performance Evolution in Individual and Human Species." *Age Dordr. Neth* 34  
408 (4): 1001–9, <https://doi.org/10.1007/s11357-011-9274-9>.

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409 Berthelot, Geoffroy, Avner Bar-Hen, Adrien Marck, Vincent Foulonneau, Stéphane  
410 Douady, Philippe Noirez, Pauline B. Zablocki-Thomas, et al. 2019. “An Integrative  
411 Modeling Approach to the Age-Performance Relationship in Mammals at the Cellular  
412 Scale.” *Scientific Reports* 9 (1): 418. <https://doi.org/10.1038/s41598-018-36707-3>.  
413 Boccia, Gennaro, Marco Cardinale, and Paolo Riccardo Brustio. 2021. “Elite Junior  
414 Throwers Unlikely to Remain at the Top Level in the Senior Category.” *International  
415 Journal of Sports Physiology and Performance*, March, 1–7.  
416 <https://doi.org/10.1123/ijsp.2020-0699>.  
417 Bottollier, Valentin, Nicolas Coulmy, Loïc Le Quellec, and Jacques Prioux. 2020.  
418 “Energy Demands in Well-Trained Alpine Ski Racers During Different Duration of  
419 Slalom and Giant Slalom Runs.” *The Journal of Strength & Conditioning Research* 34  
420 (8): 2156–64. <https://doi.org/10.1519/JSC.0000000000003311>.  
421 Brustio, Paolo Riccardo, Philip Edward Kearney, Corrado Lupo, Alexandru Nicolae  
422 Ungureanu, Anna Mulasso, Alberto Rainoldi, and Gennaro Boccia. 2019. “Relative Age  
423 Influences Performance of World-Class Track and Field Athletes Even in the  
424 Adulthood.” *Frontiers in Psychology* 10: 1395.  
425 <https://doi.org/10.3389/fpsyg.2019.01395>.  
426 Carling, C., F. le Gall, T. Reilly, and A. M. Williams. 2009. “Do Anthropometric and  
427 Fitness Characteristics Vary According to Birth Date Distribution in Elite Youth  
428 Academy Soccer Players?” *Scandinavian Journal of Medicine & Science in Sports* 19  
429 (1): 3–9. <https://doi.org/10.1111/j.1600-0838.2008.00867.x>.  
430 Cogley, S., J. McKenna, J. Baker, and N. Wattie. 2009. “How Pervasive Are Relative  
431 Age Effects in Secondary School Education.” <https://doi.org/10.1037/A0013845>.  
432 Cogley, Stephen, Shaun Abbott, John Eisenhuth, James Salter, Drew McGregor, and  
433 Michael Romann. 2019. “Removing Relative Age Effects from Youth Swimming: The

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2  
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434 Development and Testing of Corrective Adjustment Procedures.” *Journal of Science and*  
435 *Medicine in Sport* 22 (6): 735–40. <https://doi.org/10.1016/j.jsams.2018.12.013>.  
436 de la Rubia, Alfonso, Alberto Lorenzo, Christian Thue Bjørndal, Adam Leigh Kelly,  
437 Abraham García-Aliaga, and Jorge Lorenzo-Calvo. 2021. “The Relative Age Effect on  
438 Competition Performance of Spanish International Handball Players: A Longitudinal  
439 Study.” *Frontiers in Psychology* 12: 673434. <https://doi.org/10.3389/fpsyg.2021.673434>.  
440 de la Rubia Riaza, Alfonso, Jorge Lorenzo Calvo, Daniel Mon-López, and Alberto  
441 Lorenzo. 2020. “Impact of the Relative Age Effect on Competition Performance in  
442 Basketball: A Qualitative Systematic Review.” *International Journal of Environmental*  
443 *Research and Public Health* 17 (22): 8596. <https://doi.org/10.3390/ijerph17228596>.  
444 Diry, Allison, Sébastien Ratel, Joffrey Bardin, Neil Armstrong, Quentin De  
445 Laroachelambert, Claire Thomas, and Hugo Maciejewski. 2020. “Importance of  
446 Dimensional Changes on Glycolytic Metabolism During Growth.” *European Journal of*  
447 *Applied Physiology* 120 (10): 2137–46. <https://doi.org/10.1007/s00421-020-04436-z>.  
448 Freyman, Richard. 1965. “Further Evidence on the Effect of Date of Birth on Subsequent  
449 School Performance.” *Educational Research* 8 (1): 58–64.  
450 <https://doi.org/10.1080/0013188650080105>.  
451 Gibbs, Benjamin G, Jonathan A Jarvis, and Mikaela J Dufur. 2012. “The Rise of the  
452 Underdog? The Relative Age Effect Reversal Among Canadian-Born NHL Hockey  
453 Players: A Reply to Nolan and Howell.” *International Review for the Sociology of Sport*  
454 47 (5): 644–49. <https://doi.org/10.1177/1012690211414343>.  
455 Haberman, Shelby J. 1973. “The Analysis of Residuals in Cross-Classified Tables.”  
456 *Biometrics* 29 (1): 205–20. <https://doi.org/10.2307/2529686>.  
457 Helsen, Werner F., Martine Thomis, Janet L. Starkes, Sander Vrijens, Gerrit Ooms,  
458 Calum MacMaster, and Chris Towilson. 2021. “Leveling the Playing Field: A New

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459 Proposed Method to Address Relative Age- and Maturity-Related Bias in Soccer.”  
460 *Frontiers in Sports and Active Living* 3: 24. <https://doi.org/10.3389/fspor.2021.635379>.  
461 Helsen, Werner F., Jan van Winckel, and A. Mark Williams. 2005. “The Relative Age  
462 Effect in Youth Soccer Across Europe.” *Journal of Sports Sciences* 23 (6): 629–36.  
463 <https://doi.org/10.1080/02640410400021310>.  
464 Helsen, W. F., N. J. Hodges, J. Van Winckel, and J. L. Starkes. 2000. “The Roles of  
465 Talent, Physical Precocity and Practice in the Development of Soccer Expertise.” *Journal*  
466 *of Sports Sciences* 18 (9): 727–36. <https://doi.org/10.1080/02640410050120104>.  
467 Huertas, Florentino, Rafael Ballester, Honorato José Gines, Abdel Karim Hamidi,  
468 Consuelo Moratal, and Juan Lupiáñez. 2019. “Relative Age Effect in the Sport  
469 Environment. Role of Physical Fitness and Cognitive Function in Youth Soccer Players.”  
470 *International Journal of Environmental Research and Public Health* 16 (16): E2837.  
471 <https://doi.org/10.3390/ijerph16162837>.  
472 Johnson, Amanda, Abdulaziz Farooq, and Rod Whiteley. 2017. “Skeletal Maturation  
473 Status Is More Strongly Associated with Academy Selection Than Birth Quarter.”  
474 *Science and Medicine in Football* 1 (2): 157–63.  
475 <https://doi.org/10.1080/24733938.2017.1283434>.  
476 Leyhr, Daniel, Fynn Bergmann, Robert Schreiner, David Mann, Damir Dugandzic, and  
477 Oliver Höner. 2021. “Relative Age-Related Biases in Objective and Subjective  
478 Assessments of Performance in Talented Youth Soccer Players.” *Frontiers in Sports and*  
479 *Active Living* 3: 664231. <https://doi.org/10.3389/fspor.2021.664231>.  
480 McCarthy, Neil, and Dave Collins. 2014. “Initial Identification & Selection Bias Versus  
481 the Eventual Confirmation of Talent: Evidence for the Benefits of a Rocky Road?”  
482 *Journal of Sports Sciences* 32 (17): 1604–10.  
483 <https://doi.org/10.1080/02640414.2014.908322>.

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484 McCarthy, Neil, Dave Collins, and David Court. 2016. "Start Hard, Finish Better: Further  
485 Evidence for the Reversal of the RAE Advantage." *Journal of Sports Sciences* 34 (15):  
486 1461–5. <https://doi.org/10.1080/02640414.2015.1119297>.

487 Mirwald, Robert L., Adam D. G. Baxter-Jones, Donald A. Bailey, and Gaston P. Beunen.  
488 2002. "An Assessment of Maturity from Anthropometric Measurements." *Medicine &*  
489 *Science in Sports & Exercise* 34 (4): 689–94.

490 Moore, D. H. 1975. "A Study of Age Group Track and Field Records to Relate Age and  
491 Running Speed." *Nature* 253 (5489): 264–65. <https://doi.org/10.1038/253264a0>.

492 Nolan, Joseph E., and Grace Howell. 2010. "Hockey Success and Birth Date: The  
493 Relative Age Effect Revisited." *International Review for the Sociology of Sport*, July.  
494 <https://doi.org/10.1177/1012690210371560>.

495 Raschner, Christian, Lisa Müller, and Carolin Hildebrandt. 2012. "The Role of a Relative  
496 Age Effect in the First Winter Youth Olympic Games in 2012." *British Journal of Sports*  
497 *Medicine* 46 (15): 1038–43. <https://doi.org/10.1136/bjsports-2012-091535>.

498 Romann, Michael, and Stephen Copley. 2015. "Relative Age Effects in Athletic Sprinting  
499 and Corrective Adjustments as a Solution for Their Removal." *PLOS ONE* 10 (4):  
500 e0122988. <https://doi.org/10.1371/journal.pone.0122988>.

501 Romann, Michael, Roland Rössler, Marie Javet, and Oliver Faude. 2018. "Relative Age  
502 Effects in Swiss Talent Development - a Nationwide Analysis of All Sports." *Journal of*  
503 *Sports Sciences* 36 (17): 2025–31. <https://doi.org/10.1080/02640414.2018.1432964>.

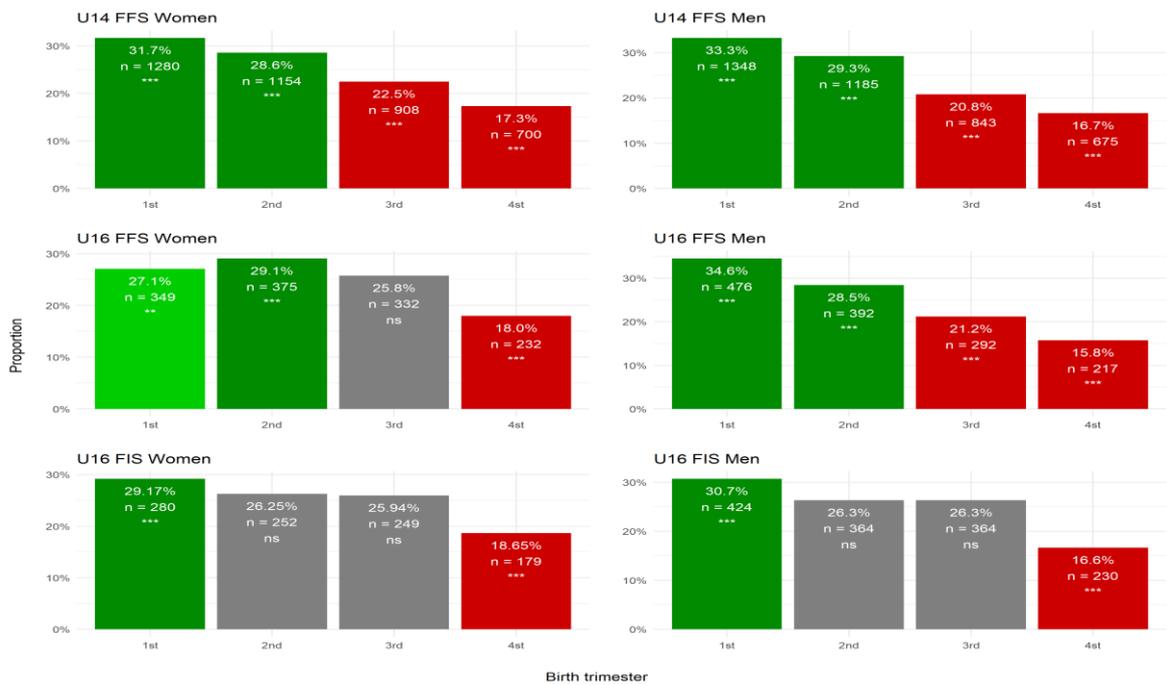
504 Smith, Kristy L., Patricia L. Weir, Kevin Till, Michael Romann, and Stephen Copley.  
505 2018. "Relative Age Effects Across and Within Female Sport Contexts: A Systematic  
506 Review and Meta-Analysis." *Sports Medicine (Auckland, N.Z.)* 48 (6): 1451–78.  
507 <https://doi.org/10.1007/s40279-018-0890-8>.

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- 508 Steidl-Müller, Lisa, Erich Müller, Carolin Hildebrandt, and Christian Raschner. 2019.  
509 “Did the Relative Age Effect Change over a Decade in Elite Youth Ski Racing?”  
510 *Frontiers in Sports and Active Living* 1: 55. <https://doi.org/10.3389/fspor.2019.00055>.  
511 Till, K., S. Cobley, J. O’ Hara, C. Cooke, and C. Chapman. 2014. “Considering  
512 Maturation Status and Relative Age in the Longitudinal Evaluation of Junior Rugby  
513 League Players.” *Scandinavian Journal of Medicine & Science in Sports* 24 (3): 569–76.  
514 <https://doi.org/10.1111/sms.12033>.  
515 Tribolet, Rhys, Kyle J. M. Bennett, Mark L. Watsford, and Job Fransen. 2018. “A  
516 Multidimensional Approach to Talent Identification and Selection in High-Level Youth  
517 Australian Football Players.” *Journal of Sports Sciences* 36 (22): 2537–43.  
518 <https://doi.org/10.1080/02640414.2018.1468301>.  
519 Votteler, Andreas, and Oliver Höner. 2017. “Cross-Sectional and Longitudinal Analyses  
520 of the Relative Age Effect in German Youth Football.” *German Journal of Exercise and  
521 Sport Research* 47 (3): 194–204. <https://doi.org/10.1007/s12662-017-0457-0>.  
522 Webdale, Kelly, Joseph Baker, Jörg Schorer, and Nick Wattie. 2020. “Solving Sport’s  
523 ‘Relative Age’ Problem: A Systematic Review of Proposed Solutions.” *International  
524 Review of Sport and Exercise Psychology* 13 (1): 187–204.  
525 <https://doi.org/10.1080/1750984X.2019.1675083>.

45 **Tables**

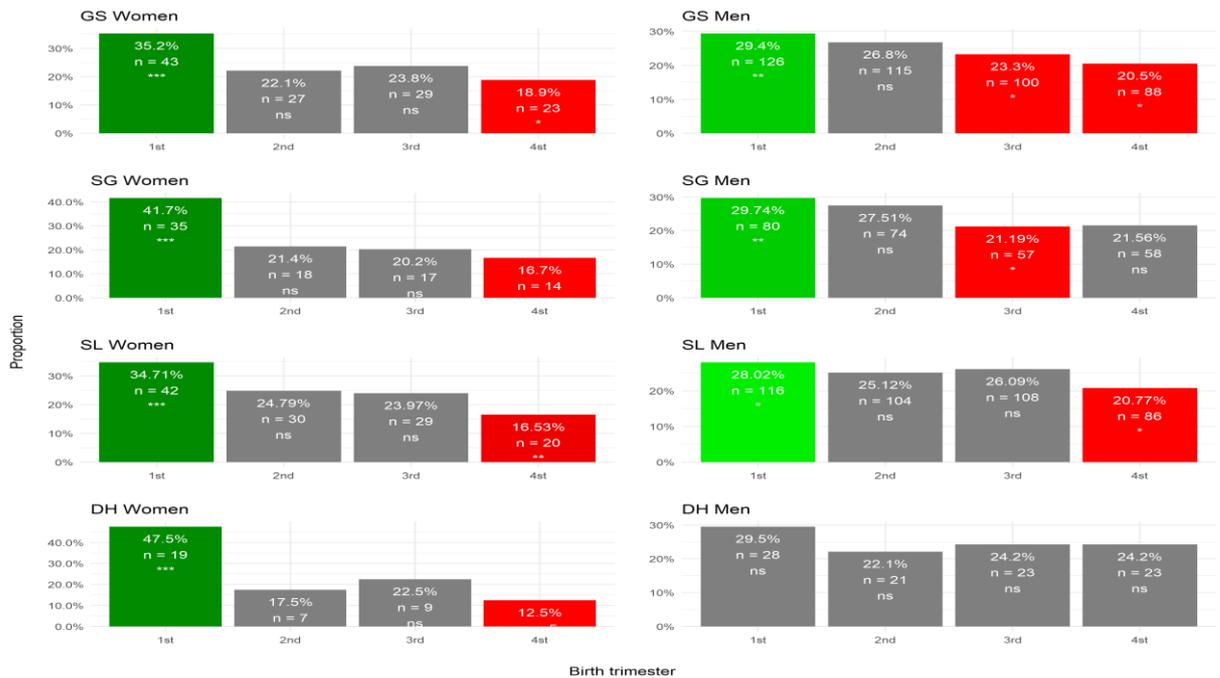
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528 **Figures**



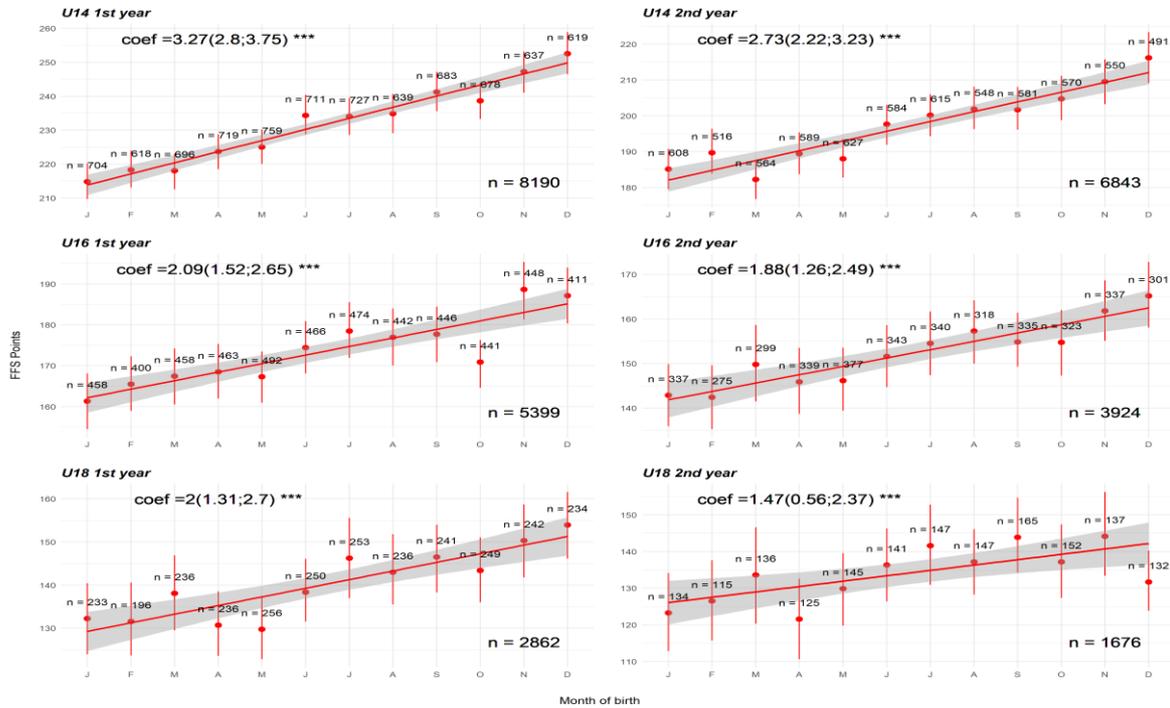
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530 Figure 1: Distribution of proportions of female and male skiers according to their  
 531 trimester of birth in French elite youth skiing competitions (U14 FFS, U16 FFS, U16  
 532 FIS). The stars indicate the level of significance level of the over or under representation  
 533 of the corresponding trimester ( \* :0.1; \*\* :0.05, \*\*\* :0.01)

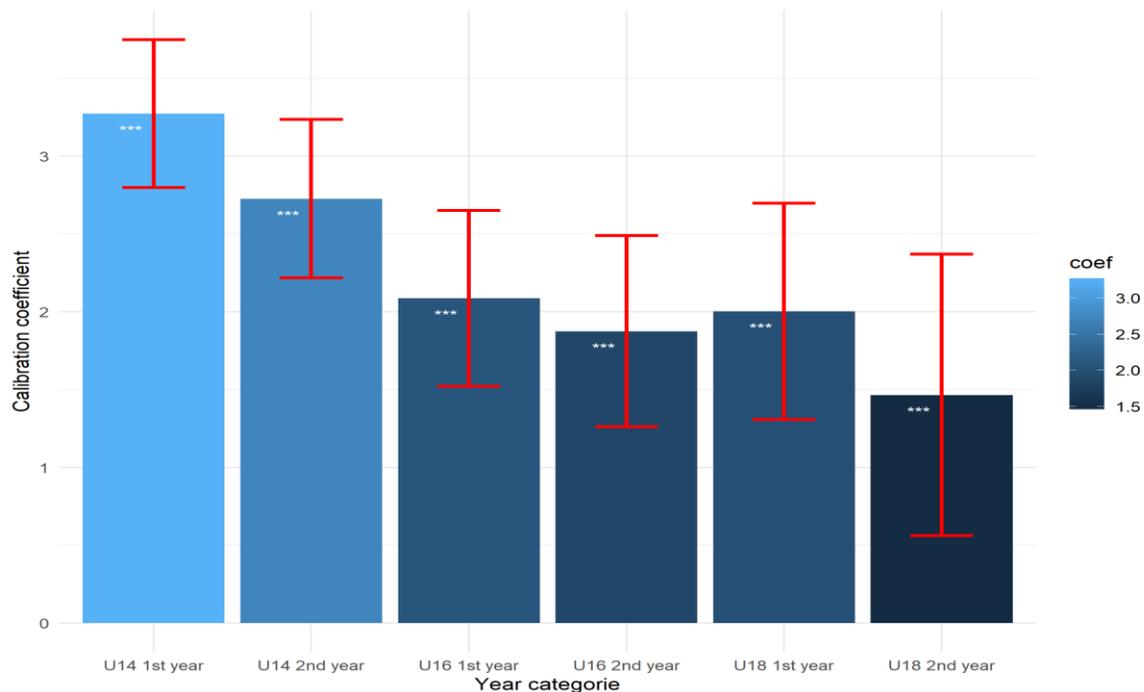


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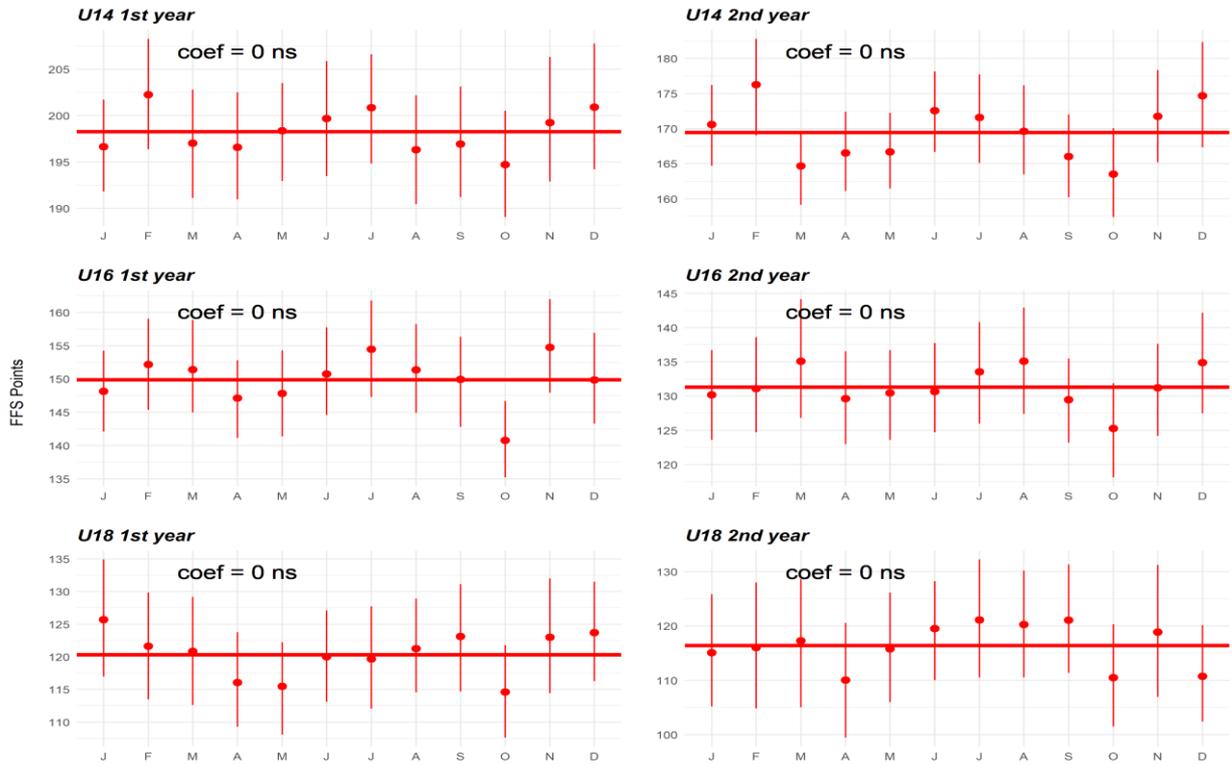
535 Figure 2: distribution of the birth trimester of participants in international competitions  
 536 (FIS) in the senior category (U30). The stars indicate the level of significance level of the  
 537 over or under representation of the corresponding trimester ( \* :0.1; \*\* :0.05, \*\*\* :0.01)



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 539 Figure 3: Performance (FFS points) according the month of birth and calibration  
 540 coefficient (coef) at each age in male Giant Slalom.

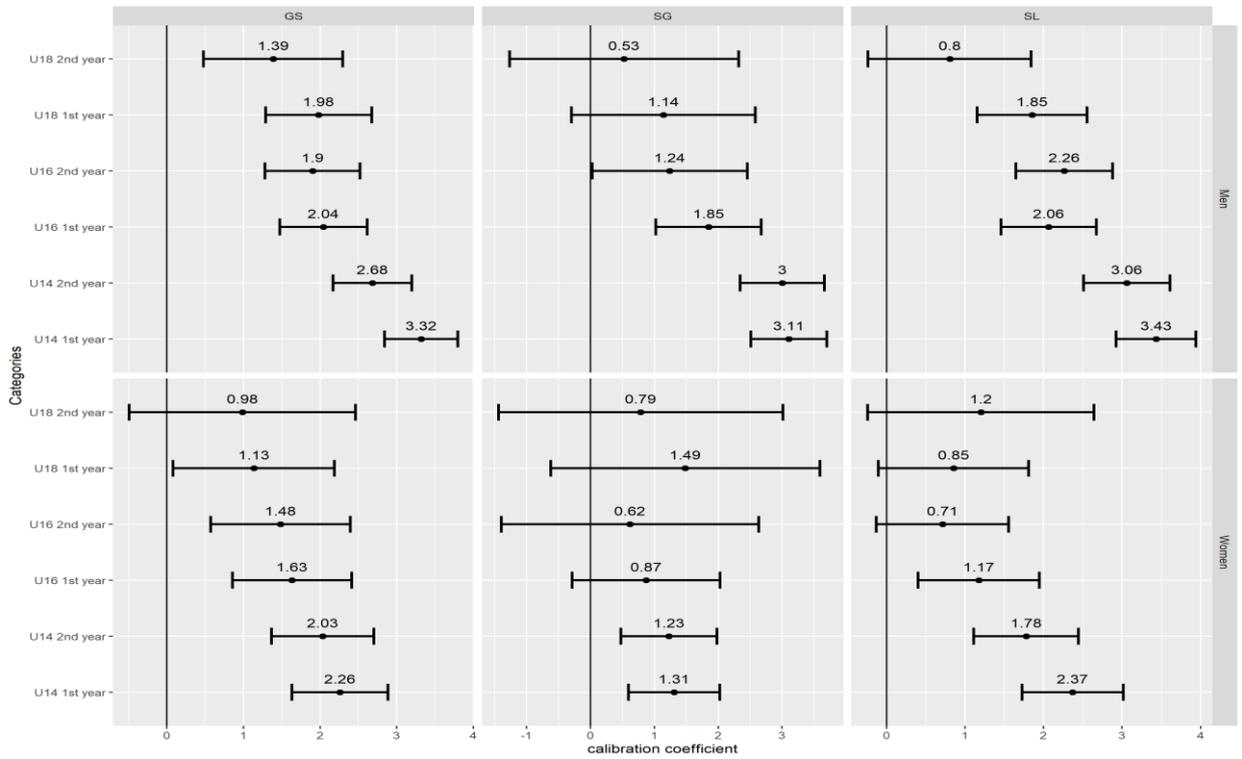


542 Figure 4: Calibration coefficient at each age in male Giant Slalom. The lighter the color,  
 543 the higher the coefficient and the higher the relationship between month of birth and  
 544 performance. The 95% confidence interval of the coefficients is delimited by the errors  
 545 bar.  
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 548 Figure 5: Performance (FFS points) according to the month of birth and calibration  
 549 coefficient at each age in male Giant Slalom after performance correction  
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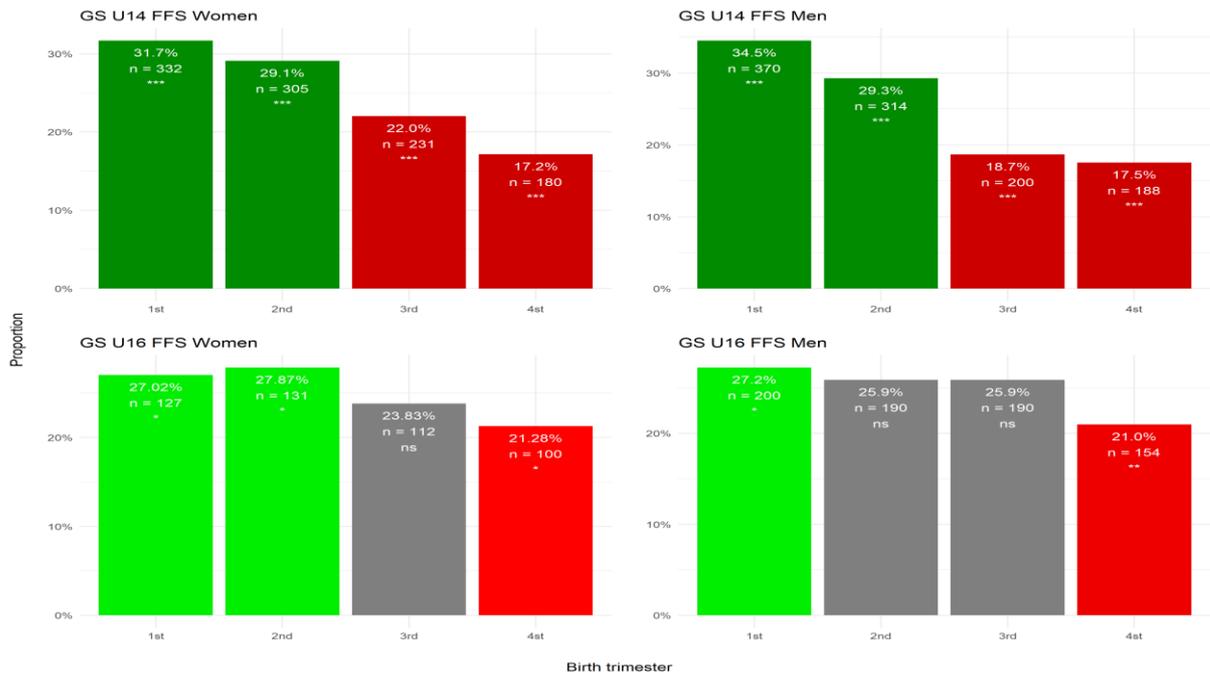


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553 Figure 6: Calibration coefficient for all categories (in column) and for each gender (in  
 554 line) in each category year. The horizontal axis is the calibration coefficient and the  
 555 vertical axis is the year category. If the confidence interval (determined by the two  
 556 horizontal bars) includes the value 0, the coefficient is not significantly different from 0

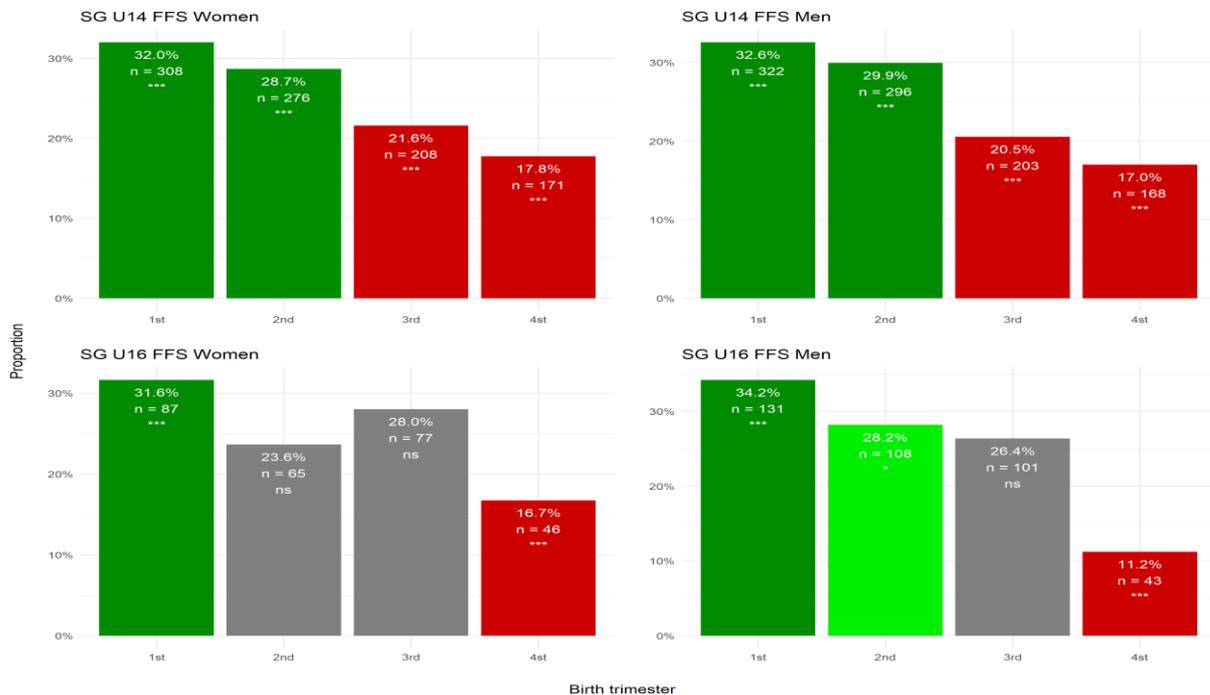
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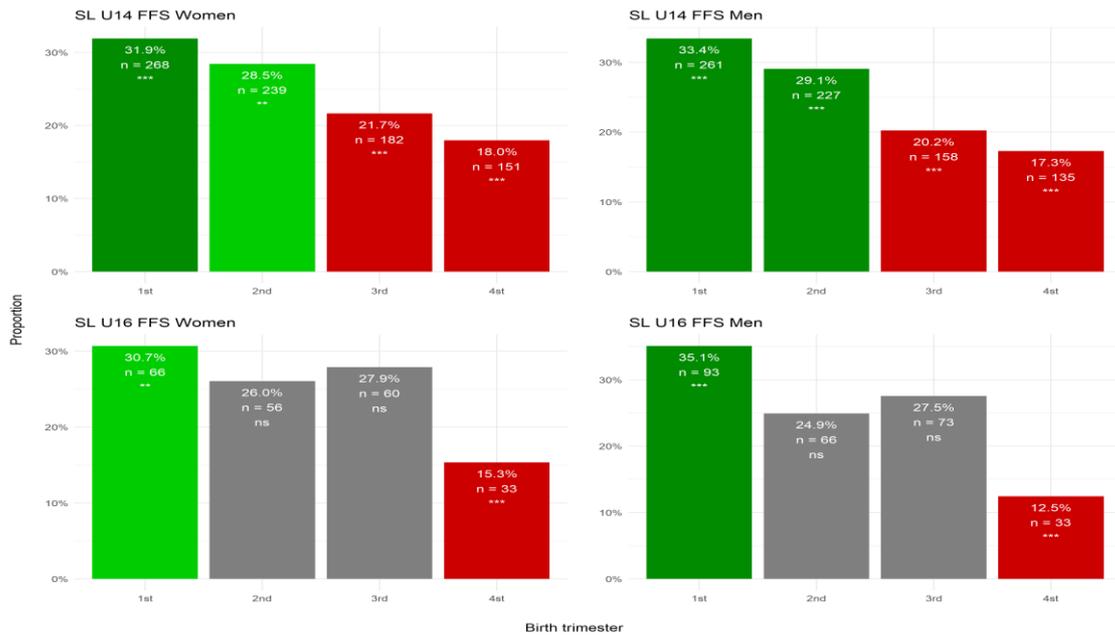
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559 Figure 7: Distribution of terms of birth by category for elite youth competitions (FFS U14  
 560 above and FFS U16 below) and each gender (male on the right and female on the left) in  
 561 GS



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563 Figure 8: Distribution of terms of birth by category for elite youth competitions (FFS U14  
 564 above and FFS U16 below) and each gender (male on the right and female on the left) in  
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567 Figure 9: Distribution of terms of birth by category for elite youth competitions (FFS U14  
 568 above and FFS U16 below) and each gender (male on the right and female on the left) in  
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