# Performance progression of elite jumpers: Early performances do not predict later success



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**Title: Performance progression of elite jumpers: early performances do not predict later success**

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**Abstract**

This study aimed 1) to estimate the transition rate for top 50 ranked track and field jumpers 2) to compare the performance progression of top 50 ranked senior jumpers (*top50 senior*) to those who failed to be top 50 ranked in the senior category despite being top 50 ranked in the under 18 category (*only U18*) and 3) to verify if relative age effect may at least partially explain the differences in the two above-mentioned subgroups.

The career performance trajectories of 5981 athletes (2837 females) competing in jump events from 2000 to 2019 were extracted from the World Athletics database. The all-time top 50 ranked athletes for each age from 16 yrs to senior category were identified. Performance progression characteristics were compared using linear mixed-effects model.

Only 8% of males and 16% of females top 50 ranked at the age of 16 yrs managed to be included among the *top50 senior*. Only U18 subgroup made the first appearance in the database (at 15-16 yrs) and reached the peak performance (at 20 yrs) earlier than *top50 senior* (17-18 and 26-27 yrs respectively). The relative age effect was largely present in Only U18 but not in *top50 senior* subgroups.

Most of the early-successful U18 world-class jumpers did not manage to maintain the same level of competitiveness in adulthood since they experienced a plateau in performance from 20 yrs of age. Conversely, top 50 ranked senior jumpers continued to produce consistent performance improvement up to 26-27 yrs of age.

**Keywords:**

Talent identification; conversion rate; junior to senior transition; career trajectories; long jump; high jump; triple jump; pole vault.

## Introduction

The international arena of track and field has become so popular and competitive that governing bodies do their best to achieve success on the international stage to at least some of their junior talented athletes [1,2]. Numerous talent identification programs aimed at selecting and developing sports talent have been proposed over recent years [3-6]. While it is clear that talent is multidimensional in nature, a comprehensive and accepted definition of sports talent is lacking [2,7,8]. However, many authors agree that talent in sports relates to the presence of particular skills at an early age that predicts future performance [7,9]. Consequently, a talented athlete is an individual whose athletic performances are superior to his/her peer group at any given time and has the potential to reach elite-level performances in adulthood.

Because of the volatile nature of performance progressions, talent selection based on early age performances has been suggested to be unreliable [10,11]. While the general trends for athletics performance development across the adolescence [12] and throughout the lifespan [13] are known, the individual trajectories are less predictable. Genetics is known to determine the performance potential in running, jumping and throwing skills [14]. Nevertheless, psychological characteristics, despite being sometimes underrated and overlooked, can also largely affect long term achievement [8]. The prediction of future performances is now a sought after strategy to be able to make the best return in talent investment. However, the complex development of technical and acrobatic (for high jump and pole vault) skills required in some athletic disciplines makes the prediction of future performances difficult [15]. Also, the occurrence of musculoskeletal injuries at an early stage of the athletic career [16], particularly in correspondence of specific growth phases [17], makes the path to adult career even more challenging. For all the above-mentioned reasons, the chances of achieving elite senior performance in athletics are unpredictable also for young athletes that outperformed their peers at young ages.

The transition rate, which represents the chance for an elite junior athlete to become an elite senior athlete, is remarkably low in track and field. At the national level, the transition rates reported in the literature are not encouraging: in fact, less than 30% of elite young track and field athletes maintain their elite status in adulthood [15,18,19]. At the international level, the data are more scarce and mostly limited to sprint [20,21] and middle distance events [22]. We recently reported that only ~ 20% of 17-year-old top 50 ranked world-class sprinters reached the top 50 rankings in the senior category [23]. At the moment, there is no clear information on typical transition rates for world-class jumpers [24]. The only way to analyse this aspect would be to assess the performances of a large sample of world-class athletes and track their development across their whole sporting career.

One of the most noticeable confounding factor related to talent selection is the relative age effect (RAE) [25,26]. This phenomenon has been described previously in many sports [27]. Many authors also reported that jumpers born close to the date of selection (i.e. the 1st January in many nations) are more likely to reach national-level achievements in junior categories [28-31]. At the international level, jumpers born in the first part of the year were more likely to reach the finals at IAAF World U18 and U20 Championships [32] and to be included the top 100 U18 and U20 rankings compared to their counterparts [33]. In the senior category, the RAE for jumpers was not confirmed [33] suggesting that being born in the first part of the year might provide an advantage for early selection but not for adult success. Only a longitudinal approach, consisting of tracking the performances across the whole athletes' career, would be able to investigate if the RAE would confound the talent selection of world-class jumpers in the long term.

Therefore, this study aimed 1) to provide the transition rate for top 50 ranked (world-level) track and field jumpers; 2) to compare the performance progression of those who achieved and those who did not achieve the top 50 ranking in adulthood, despite being top 50 ranked in the youth; 3) verify if RAE may at least partially explain the differences in the two above-mentioned group of performers.

## Materials and Methods

Performance data of jumping disciplines (i.e., High Jump, Long Jump, Triple Jump and Pole Vault) were collected from the public databases of the International Association of Athletics Federations (IAAF – now called World Athletics; https://www.iaaf.org/home), the IAAF World U18 Championships (https://www.iaaf.org/competitions/iaaf-world-u18-championships) and the IAAF World U20 Championship (https://www.iaaf.org/competitions/iaaf-world-u20-championships). The names of top 100 athletes in each season from 2000 to 2019 were extracted from the first database, while the list of participants' names in the IAAF World U20 and World U18 competition in each season from 1998 to 2015 were extracted in the remaining two databases.

After removal of duplicate entries in the list of participants' names, seasonal best performances (SBPs) obtained by each athlete in outdoor competitions and with legal wind speed (i.e., $\leq$ 2 m/s) were recorded in the dataset. The SBPs were collected from the first to the last appearance in the IAAF database, or up to December 31, 2019, if the athlete was still competing. Athletes disqualified for doping offences (n=36; 27.8 % female) were excluded from the analysis. The study was conducted according to the declaration of Helsinki. Since the data were based on publicly available resources, no informed consent was obtained. This study was approved by the local ethics committee of the University of Torino.

Separate analyses were performed for each discipline and gender. Athletes were included only if the SBP was presented for a minimum of three years, also non-consecutively [18,23]. Since the

SBPs were recorded across a large range of time (from 1985 to 2019) and thus for different generations of athletes, SBPs were normalised according to the prevailing world record (WR). Specifically, the following formula was used:

$$\text{rSBT} = \left(\frac{SBT}{WR}\right) \times 100$$

where rSBT indicated the normalised SBP.

Thus, a value of 100 was corresponding to the best performance of that relative year. Subsequently, according to their age, all the athletes were ranked according to their rSBT. Specifically, different rankings have been calculated for each year considered i.e. 16, 17, 18, 19, ≥20 yrs (e.g., Senior category).

Then, the all-time top 50 ranked athletes at 16 yrs, 17 yrs, 18 yrs, 19 yrs and Senior category were identified. The transition rates, i.e. the proportion of athletes that were top 50 ranked across different ages were calculated. This was calculated with prospective and retrospective approaches. Prospectively, we counted how many jumpers top 50 ranked at 16 yrs old managed to become top 50 ranked in the following stage of their career. Retrospectively we counted how many top 50 ranked Senior jumpers were already top 50 ranked at younger ages. We arbitrarily selected the threshold of the top 50 athletes according to our previous study [23]. Using the same approach but selecting the first top 100 ranked athletes the proportion did not change so for conciseness, we decided to discuss and present only the results of the top 50.

To address the second and third aim of the study, two subgroups of athletes were defined:

(1) *Only U18:* athletes who have been included in the top 50 rankings at Under 18 (U18, either at 16 and/or 17 yrs), but did not reach the top 50 rankings in the senior category;

(2) *Top50 senior*: athletes who have been top 50 ranked in the senior category, independently from being top 50 ranked in the U18 category or not.

To characterise the career of athletes the age of the first and last appearance in the IAAF database were identified. Subsequently, individual trends were generated by fitting a quadratic curve separately to each athlete's performance [23,34]. From the quadratic curve the peak performance and age of peak performance were calculated. Finally, the month from the date of birth was recorded for each athlete in *only U18* and *top 50 senior* subgroups.

**Statistical analysis**

To compare the career progressions between *only U18* and *top50 senior* subgroups a series of independent t-test was carried out for the age of first and last appearance in the IAAF database, peak performance, and age of peak performance. When the homogeneity of variances was violated, as assessed by Levene's Test of Homogeneity of Variance (all P values<0.05), a correction was used.

The difference in performance progression between *only U18* and *top50 Senior* was investigated using linear mixed models with the seasonal best performance from 16 to 24 yrs of age as a dependent variable. Group and age were considered as fixed effects, while subjects were included as a random effect. Post-hoc pairwise comparisons were performed using Tukey correction.

To investigate the RAE month birth-date were split into the four following quartiles: January to March 1$^{st}$ quartile (Q1), April to June 2$^{nd}$ quartile (Q2), July to September 3$^{rd}$ quartile (Q3), October to December 4$^{th}$ quartile (Q4). The difference between observed and expected subgroups' quartile distributions was investigated using Chi-square ($\chi^2$). Odds ratios (ORs) and 95% confidence intervals [95% CIs] were calculated for the first and the last quartile (i.e., Q1 vs. Q4) and the first and the second semester of the year (Q1+Q2 vs. Q3+Q4). A uniform distribution (i.e., 25% for each quartile) was adopted as expected distribution [33,35]. For the RAE analysis, all disciplines were merged to increase the sample size. All data were analysed with custom-written software in MATLAB R2019b (Mathworks, Natick, Massachusetts). The graphs were prepared with GraphPad Prism 8 (San Diego: CA, USA). The level of significance was set at $p \leq 0.05$.

**Results**

After removal of missing data and duplicates, the career of a total of 5981 athletes was analysed. Specifically, 1441 athletes were high jumpers (female: n=681, 47.3%), 1587 athletes were long jumpers (female: n=719, 45.3%), 1448 athletes were triple jumpers (female: n=693, 47.9%), and 1505 athletes were pole vaulters (female: n=744, 49.4%).

When transition rate was analysed, only 8% of male jumpers (and 16% of female jumpers) top-50 ranked at 16 yrs old managed to become top 50-ranked in the senior category (Figure 1a). Similarly, only 8% of male jumpers (and 16% of female jumpers) top-50 ranked in the senior category were top 50 ranked already at 16 yrs old (Figure 1 b).

<Figure 1 about here>

<Table 1 about here>

Table 1 shows the characterisation of the career path of *only U18* and *top50 senior* subgroups. In all disciplines, the age of entering the database, age of the last appearance in the database, the age of personal peak performance was lower for *only U18* than for *top 50 senior* subgroup. The *top 50 Senior* subgroup showed better peak performances in all disciplines (Table 1).

Considering performance progression, significant group x time interactions were observed for both gender in High Jump (Male: F=39.0, P<0.001; Female: F=39.3; P<0.001), Long Jump (Male: F=31.6, P<0.001; Female: F=19.9; P<0.001), Triple Jump (Male: F=35.2, P<0.001; Female: F=47.1; P<0.001), and Pole Vault (Male: F=33.7, P<0.001; Female: F=51.0; P<0.001). The post-hoc analysis reported in Figure 2, represents the statistical difference between *only U18* and *top 50 Senior* for each age year .

<Figure 2 about here>

Finally, large RAE was observed only for *only U18* subgroup in both gender distribution (men: $\chi^2$=38.72, p<0.001, Cramer's V=0.27; women: $\chi^2$=19.05, p<0.001, Cramer's V=0.20 respectively) but not for *top 50 senior* subgroup (men: $\chi^2$=3.86; p=0.276, Cramer's V=0.10; women: $\chi^2$=1.70, p=0.063, Cramer's V=0.06 respectively). The ORs showed that the likelihood of being included in the *only U18* subgroup is higher for an athlete born in the Q1 rather than in Q4 (OR Q1/Q4=4.4, 95%CI (2.5,7.7) and 3.1, 95%CI (1.8, 5.3) for male and female respectively) but not in *top 50 senior* subgroup (OR Q1/Q4=1.2, 95%CI (0.7, 2.1) and 0.9, 95%CI (0.5, 1.6). See Figure 3 for more details. The ORs for the first vs the second part of the year, i.e. (Q1+Q2)/(Q3+Q4) were: 3.0 (95%CI 2.1,4.3) for *only U18* male, 2.1 (95%CI 1.4, 3.1) for only U18 females, 1.2 (95%CI: 0.6, 2.2) for *top 50 senior* males, 1.1 (95%CI 0.8, 1.7) for *top 50 senior* females.

<Figure 3 about here>

**Discussion**

The present study aimed to provide robust junior-to-senior transition rate for world-class track and field jumpers and to identify differences between the pathway of early- compared to later-successful jumpers. For this scope, the performance progression of ~ 6000 international level athletes was tracked across their whole competitive lifespan. The main findings of the study were the followings: 1) the junior to senior transition rate for athletes top 50 ranked at the age of 16 yrs was 8% for males and 16% for females; 2) top50 senior athletes appeared in IAAF database (17-18 yrs) and reached the peak performance (26-27 yrs) later compared to those who were top 50 ranked only in U18 (15-16 and 20 yrs, respectively); 3) the group of athletes top 50 ranked only in U18 showed a large relative age effect.

Most early-successful jumpers did not maintain the same level of success later in their career. Indeed, only 8% of the top 50 ranked male athletes at the age of 16 yrs managed to be top 50 ranked in the senior category (Figure 1a). The transition rate in females was larger than in males (16%) but still low (Figure 1a). These percentages were calculated adopting all-time rankings across more than 30 years of competitions and therefore are likely to provide a robust estimate of transition rate for world-class jumpers. These indices are in line with those we reported for world-class sprinters adopting a similar methodological approach [23]. When analysing national-level elite groups, the reported transition rates for jumpers were slightly larger (ranging from 20 to 30%), possibly because of lower competitiveness at the senior national level in any given country. However, in this study, 84 to 92% of top 50 ranked athletes did not maintain the top 50 positions in the ranking in the adulthood, and most of them lost the first 50 ranks already at 19 yrs of age (Figure 1). Consequently, a talent identification procedure based on early performance does not seem to be an effective strategy to select future elite athletes and might miss some later developing athletes. Furthermore, when adopting a retrospective approach, our results show that only 40% of the top 50 ranked senior athletes were already top 50 ranked at 19 yrs of age (Figure 1b). This means that selecting athletes at 19 yrs of age may not guarantee a successful selection since more than half of 19 yrs top performers would have not reached the top level in the senior category. To be clear, we are not saying that *all* top 50 ranked athletes in U18 and U20 categories would not be able to reach the top 50 ranking in the senior category. We are just highlighting that trying to predict future success based on performances in the U18 and U20 category may not be a smart approach. These findings thus corroborate previous evidence suggesting that talent identification and selection at young ages can be biased and does not guarantee the ability to identify senior performers in athletics [19,23,24,36]. Also, as already observed in sprinter athletes [37], young jumpers that reach a high performance level without excessive specialisation may have a better development towards senior success.

The performances of *only U18* and *top50 senior* subgroups were largely indistinguishable up to 19 yrs of age (Figure 2). This further supported the notion that before 19 yrs of age it would be hard to identify those who will reach top50 senior ranking. The career pattern of these two subgroups of athletes started to significantly differentiate from the age of 20-21 yrs. Gullich [38] recently suggested that the athletes who showed greater performance enhancement at a later age were those who experienced more multiport practice in their adolescent years. However, from 20-21 years on, the top 50 ranked senior jumpers continued to increase their performance while the early successful athletes seemed to plateau [24] [see Figure 2]. This data corroborated previous findings suggesting the consistent performance improvement in the years before the peak performance as the fundamental factor that distinguishes athletes that reach the top-level compared to those who don't [39].

Pole vault represented an extreme case in terms of performance progression: at 17 yrs of age, only the U18 subgroup of pole vaulters had significantly higher performances compared to the athletes that reached top 50 as seniors. This phenomenon was even more evident in female athletes. This suggests that selecting top pole vaulters in the U18 category (or earlier) can be completely misleading in the long-term. Pole vault performance is not only relying on muscle strength and power, but it is also determined by remarkable acrobatic skills. It is therefore likely that athletes with previous experience from other acrobatic sports, such as gymnastics, and/or athletes who have completed growth earlier may be performing better at a young age. However, in the long term, the continuous development of pole vault specific skills may be the key to reach senior success.

Early successful athletes that did not maintain their status in adulthood (*only U18*) entered the database and reached peak performance earlier than their counterpart (*i.e. top50 senior*, see Table 1). While the age of the first appearance in the database cannot be defined as an accurate estimate of the age of entering a competitive career, this finding suggested that *only U18* reached a performance level good enough for entering international competitions earlier compared to their counterpart. In line with a previous study [24], we found that *only U18* reached their personal best earlier than *top50 senior* and this was associated to lower personal best performances (Table 1). Together, the results of this study suggest that it is likely that entering world-class performances earlier might somehow reduce the rate of improvement in performance leading to an earlier personal best and lack of progression later on in the career. The anticipated career pattern of *only U18* subgroup can be attributable to multiple factors such as early maturation [40] and early specialisation [37,38,41]. While these factors cannot be investigated using the current database, the analysis of RAE may partially explain the differences between the two subgroups.

RAE was evident in athletes that enjoyed early success (Figure 3). In males, the number of athletes born in the first half of the calendar year was three-times larger than those born in the second half. In females, this number was lower than in males but still high (i.e. two-times larger). Being relatively older compared to their peers had possibly increased the chance of these athletes to outperform their peers at under18 level. The relatively older athletes have been demonstrated to be advantaged in the early phase of the career [25,32] because of a multitude of biopsychosocial factors related to maturation [40]. However, our data show that such advantage disappears later in their career.

Despite the large dataset employed in the study, it is important to highlight some limitations. The first limitation is represented by the determination of the career path using only the IAAF database. Many athletes likely started their career before even appearing in the IAAF database possibly competing in lower level (national) competitions. Additionally, we performed separated analysis for each jump events and we did not consider the influence of performing in difference jumping events and/or other athletics events (for example in sprints). Finally, even if we removed from the database athletes disqualified for doping offences, it may be possible that some may have adopted undetected performance-enhancing strategies.

To summarise, most of the early-successful U18 world-class jumpers did not manage to maintain the same level of competitiveness during adulthood. On average, this group of jumpers experienced a plateau in performance around 20 yrs of age, while the top 50 ranked senior jumpers continued to produce consistent performance improvement up to 26-27 yrs of age. Therefore, trying to predict future performances from the results in competitions in the U18 category or earlier does not seem a viable strategy for talent identification.

## Perspective

The present findings provide strong arguments against talent identification/selection strategies based on performances at U18 level in jumping events. The unpredictability of performance progression in late adolescence and early adulthood requires caution in talent selection. Our analysis suggests that performance development is a better indicator of athlete potential and we believe the present findings can serve as a useful reference tool for coaches, sports institutions and sports governing bodies to benchmark their talent selection and development strategies.

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**Table 1. Descriptive data and ANOVA outcome of variables characterising the career of athletes' subgroups according to discipline and gender**

| | **High Jump** | | **Long Jump** | | **Triple Jump** | | **Pole Vault** | |
|---|---|---|---|---|---|---|---|---|
| | *Only U18* | *Top50 senior* | *Only U18* | *Top50 senior* | *Only U18* | *Top50 senior* | *Only U18* | *Top 50 senior* |
| **Men** | M (90% CI) | M (90% CI) | M (90% CI) | M (90% CI) | M (90% CI) | M (90% CI) | M (90% CI) | M (90% CI) |
| Age of entering in database | 15.72 (15.54, 15.90) | 17.91 (17.54, 18.28) $^{***}$ | 15.92 (15.76, 16.07) | 18.74 (18.15, 19.32) $^{***}$ | 15.80 (15.64, 15.96) | 17.9 (17.44, 18.36) $^{***}$ | 15.76 (15.57, 15.95) | 18.22 (17.74, 18.7) $^{***}$ |
| Age of exit in database | 23.94 (23.16, 24.72) | 31.09 (30.10, 32.09) $^{***}$ | 22.92 (22.25, 23.59) | 30.28 (29.12, 31.45) $^{***}$ | 23.70 (22.90, 24.50) | 32.36 (31.11, 33.61) $^{***}$ | 24.3 (23.43, 25.17) | 31.86 (30.65, 33.07) $^{***}$ |
| Peak Performance | 2.22 (2.21, 2.23) | 2.32 (2.32, 2.33) $^{***}$ | 7.82 (7.77, 7.87) | 8.30 (8.25, 8.34) $^{***}$ | 16.45 (16.34, 16.57) | 17.29 (17.21, 17.37) $^{***}$ | 5.53 (5.49, 5.56) | 5.82 (5.80, 5.85) $^{***}$ |
| Age of Peak Performance | 20.49 (19.87, 21.10) | 25.83 (25.14, 26.51) $^{***}$ | 19.76 (19.25, 20.28) | 25.02 (24.29, 25.75) $^{***}$ | 20.40 (19.88, 20.92) | 25.81 (25.13, 26.5) $^{***}$ | 21.52 (21.05, 21.99) | 26.03 (25.3, 26.75) $^{***}$ |
| **Women** | | | | | | | | |
| Age of entering in database | 15.28 (15.05, 15.52) | 17.29 (16.74, 17.84) $^{***}$ | 15.64 (15.46, 15.83) | 18.73 (18.09, 19.36) $^{***}$ | 15.72 (15.53, 15.92) | 17.90 (17.29, 18.51) $^{***}$ | 14.79 (14.54, 15.03) | 17.33 (16.72, 17.94) $^{***}$ |
| Age of exit in database | 24.57 (23.56, 25.57) | 32.33 (31.14, 33.53) $^{***}$ | 25.33 (24.52, 26.14) | 32.08 (31.02, 33.14) $^{***}$ | 24.05 (23.25, 24.86) | 31.78 (30.74, 32.82) $^{***}$ | 22.95 (22.10, 23.80) | 30.37 (29.36, 31.38) $^{***}$ |
| Peak Performance | 1.89 (1.88, 1.90) | 1.97 (1.96, 1.98) $^{***}$ | 6.52 (6.48, 6.57) | 6.82 (6.77, 6.88) $^{***}$ | 13.81 (13.73, 13.89) | 14.58 (14.51, 14.65) $^{***}$ | 4.32 (4.29, 4.35) | 4.69 (4.66, 4.73) $^{***}$ |
| Age of Peak Performance | 20 (19.23, 20.76) | 26.27 (25.51, 27.03) $^{***}$ | 21.30 (20.65, 21.96) | 26.75 (25.96, 27.54) $^{***}$ | 20.72 (20.14, 21.3) | 26.29 (25.55, 27.04) $^{***}$ | 20.44 (19.8, 21.08) | 27.06 (26.31, 27.81) $^{***}$ |

*Notes: statistical significant difference between Top50 Senior and Only U18 are reported as follow:* $^{*}$ *$P<0.05$;* $^{**}$ *$P<0.01$;* $^{***}$ *$P<0.001$*

Captions

Figure 1

The transition rates (merged across disciplines) of the top 50 ranked jumpers are reported for the prospective (a) and retrospective (b) approach. Panel a) shows how many jumpers top-50 ranked at 16 yrs old managed to become top 50 ranked in the following stage of their career. Panel b) shows how many top 50 ranked Senior jumpers were already top 50 ranked at younger ages.

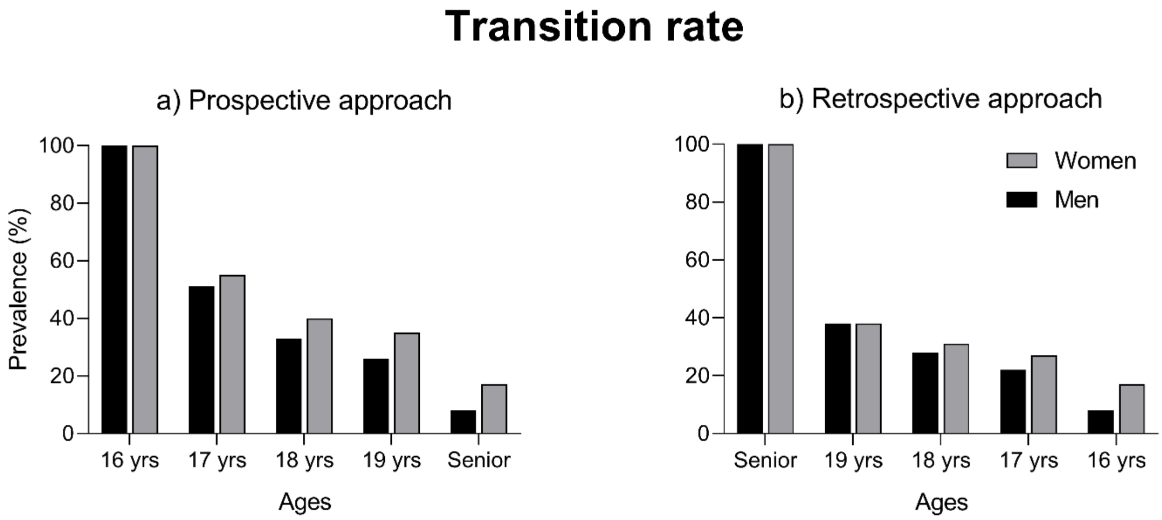


Figure 2

Performance progressions for males (upper panels) and females (lower panels) in two subgroups of athletes: *Only U18*, i.e. those who have been included in the top 50 rankings at Under 18 but did not reach the top 50 rankings in the senior category; *Top50 senior*, i.e. those who have been top 50 ranked in the senior category, independently from being top 50 ranked in the U18 category or not. Post hoc analysis: * P<0.05; ** P<0.05; *** P<0.05.

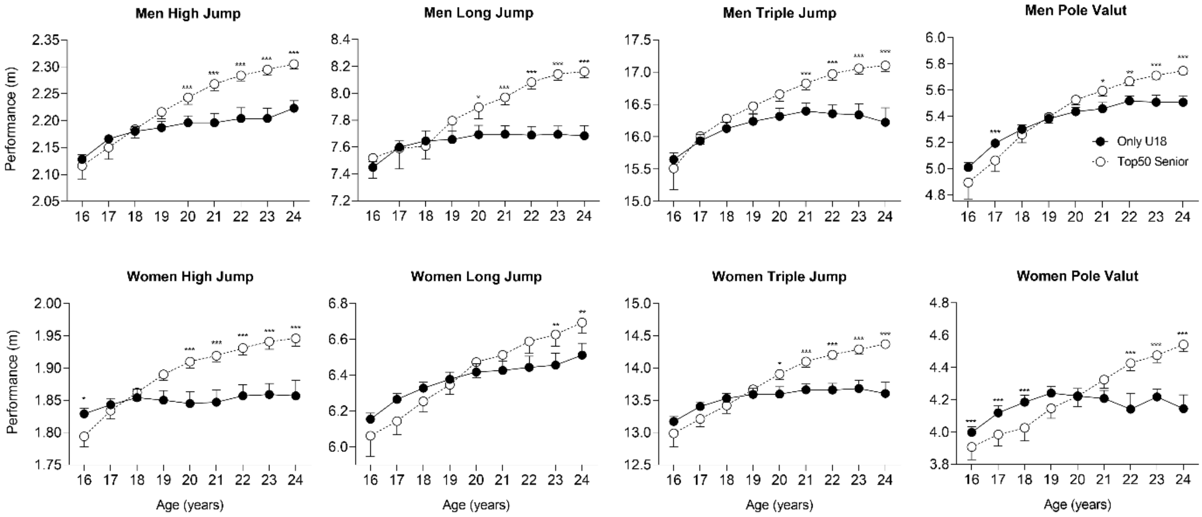


Figure 3

Quartile birth month distribution for male (left panel) ad females (right panel) athletes. *Only U18*, those who have been included in the top 50 rankings at Under 18 but did not reach the top 50 rankings in the senior category. *Top50 senior*, i.e. those who have been top 50 ranked in the senior category, independently from being top 50 ranked in the U18 category or not. Data are merged across disciplines.