

## **Planning for optimal performance – what happens before the taper?**

Karen. L. Johns<sup>1</sup>, Peter. M. Philipson<sup>2</sup> and Philip R. Hayes<sup>1</sup>

<sup>1</sup> Department of Sport, Exercise and Rehabilitation, Northumbria University, UK.

<sup>2</sup> Department of Mathematics, Physics and Electrical Engineering, Northumbria University, UK.

*Submission type:* Original manuscript.

*Abstract word count:* 200.

*Text-only word count:* 5,334.

*Number of tables:* 5.

*Number of figures:* 8.

*Pages:* 9 (excluding abstract, references, tables and figures).

Correspondence concerning this article should be addressed to: Karen Johns, Department of Sport, Exercise and Rehabilitation, Northumbria University, Newcastle upon Tyne, NE1 8ST, UK. Email: karen.johns@northumbria.ac.uk

1 **Abstract.**

2  
3 This study analysed contemporary performance data of middle distance athletes to determine  
4 a) the number of competitive performances prior to the season's fastest performance and b)  
5 the time frame between their first and fastest competitive performances of that season. Using  
6 a publicly available database, data on the number of races and days between athletes first  
7 and fastest races were extracted. The analysis utilised 4,800 observations from 1,166  
8 individual athletes for the period 2006 to 2017. Male 800 m athletes achieved their fastest  
9 performance in 8 races (IQR=4-12) distributed over 55 days (IQR=29-87). Female 800 m  
10 athletes also required 8 races (IQR=5-12), distributed over 63 days (IQR=34-91). In the 1500  
11 m event, male athletes, required 6 races (IQR=3-9) over 48 days (IQR=25-76), while female  
12 athletes, required 7 races (IQR=4-10) over 56 days (IQR=28-84). For both sexes, 1500 m  
13 athletes raced less, and over a shorter period than 800 m athletes before reaching their fastest  
14 performance. Female athletes had a longer time frame and number of races than male  
15 athletes. This study provides an evidence-based indicator of when a middle distance runner's  
16 fastest performance is likely to occur, providing benchmarks that could act as a guide for  
17 coaches when designing competition programmes, prior to any tapering process.

18  
19 **Keywords:** *track athletics, middle distance, fastest performance, competition, planning.*

## 1 Introduction.

2  
3 Sport performance occurs in many different domains ranging from participation to elite athletes,  
4 encompassing a diverse range of ages and disciplines. As the business of sport continues to grow,  
5 interest has increased in being able to maximise athletic performance<sup>1</sup>. Moreover, it has been  
6 recognised that winning gold medals at championship events requires not only outstanding athletic  
7 ability and the effective implementation of long-term training progressions<sup>1,2</sup>, but also the ability to be  
8 able to produce optimal performance at a pre-determined competition.<sup>1,3,4,5,6</sup>. An effective planning  
9 process facilitates the execution of optimum athlete performances in the designated competition.  
10 Periodisation has emerged as an important part of the planning process in aiding a coach's attempt to  
11 optimise their athlete's performance in the competition phase<sup>8</sup>. Periodisation describes the deliberate  
12 sequencing of training to enable an athlete to attain the physiological capabilities required to deliver  
13 timely optimum performance<sup>7</sup>. Despite the wide spread use of periodised plans, there is relatively little  
14 scientific underpinning regarding the content of periodisation<sup>8</sup>.

15 To support the delivery of optimum performance, previous research<sup>9,10,11,12,14</sup> has focused on  
16 the concept of tapering. Short-term training manipulations to achieve peaking for optimal sports  
17 performance have been investigated for more than 20 years<sup>1</sup>. Training variables such as volume,  
18 frequency and intensity distribution are important elements to support the maximization of athlete  
19 performance<sup>13</sup>. Therefore, a well-executed peaking phase can increase the odds of winning a gold  
20 medal at a championship event for an individual athlete with finalist potential<sup>1</sup>. A review by Pyne and  
21 colleagues (2009) highlighted several studies on the physiological<sup>9,15,16,17</sup> and performance aspects<sup>6,16</sup>  
22 of the taper. By contrast, there is a smaller amount of evidence<sup>1,18</sup> exploring what happens or should  
23 happen in the competition phase prior to the tapering process. The work of Hellard et al., (2013)  
24 examined training strategies both within the overload and taper period prior competition for elite  
25 swimmers, noting that the optimal training design for the pre-taper and taper periods gradually changed  
26 over the course of the athletes' careers. Whilst Tønnessen et al., (2014) provided observational  
27 evidence for pre-taper training strategies in elite athletes in cross country (XC) skiing concluding that  
28 during the competition phase, the XC skiers training became more sport-specific, and that the pre  
29 tapering strategy did not follow the suggested tapering practice with regard to rest. However, few  
30 studies have linked peaking strategies to annual training characteristics and the structure of the  
31 competitive season of athletes<sup>19</sup>. Earlier research that has examined performance and competition has  
32 focused on performance tracking<sup>20,21</sup>, the relationship between training and performance<sup>23</sup> and  
33 performance variability<sup>24,25</sup>.

34 Specific to the focus of this paper, performance variability in athletics has received some  
35 research focus, primarily looking at intra-subject variability of 5 km time-trial running<sup>26</sup>, variability of  
36 performance between laboratory conditions and those simulating a real competitive event<sup>27</sup>, and within-  
37 athlete variation in performance<sup>28,29</sup>. Featuring prominently is the work of Hopkins and colleagues and  
38 the concept of the *smallest worthwhile change* (SWC) (1999;2001; 2005;2014). Using real data and  
39 performance simulation focused on elite athletes in sports where the outcome is determined by a single  
40 score (e.g. time or distance) they examined the magnitude of performance change required to be  
41 practically meaningful. The SWC was considered 30% of the standard deviation (SWC = .30\*SD) in  
42 elite athletes,<sup>30,31</sup> which reflects winning one more medal per 10 competitions<sup>32</sup>. The SWC in  
43 performance is viewed as important when assessing athletes within a performance test to make  
44 decisions about meaningful changes in an individual or to research strategies that might affect  
45 performance<sup>30</sup>.

46 Yet the margins of victory in elite athletics, in many cases is less than the SWC. For many  
47 athletes the margin of victory, or the probability of medaling, is marginal; an enhancement of any kind  
48 could be important, possibly career changing. For example, at the Athens Olympics in 2004, 0.13  
49 seconds separated the first four finishers in the women's 800m, with 3<sup>rd</sup> and 4<sup>th</sup> separated by just 0.08  
50 of a second; well below the SWC. The SWC work is derived from data on elite athletes<sup>31</sup>, the extent  
51 to which this is applicable to lower level athletes is unknown. From an athlete's perspective, their focus  
52 is on absolute times (fastest time recorded) and even the smallest changes in performance are  
53 meaningful; whether that be winning medals or recording personal best performances.

54 Competitions are generally assumed to be part of the preparation of athletes and are frequently  
55 integrated into the peaking process in elite sports<sup>1</sup>, yet there appears to be scant information regarding  
56 the structure of an athlete's competition period (i.e. number of days or races) to support the timely  
57 achievement of their fastest performance. The design and management of the competition schedule  
58 appears to be an integral component in planning a taper. Guidance for coaches is reasonably limited,  
59 consisting of some criteria that a coach might consider in the design of a competition programme:  
60 athlete preference, age, training experience, the availability of relevant competitions<sup>4</sup>, the avoidance of

1 too many competitions and ensuring adequate rest time between competitions<sup>34</sup>. There is a suggestion  
2 of an optimum type and number of competitions ranging between seven and 16 competitions<sup>4,34</sup>.  
3 Perhaps it is no surprise that such a broad range of an optimal number of competitions are suggested.  
4 It is reasonable to suggest that the individuality of performance would inevitably mean that some  
5 athletes respond well to many competitions in a preparatory period, others less so. However, there is  
6 also a distinct lack of empirical evidence proposing the duration of a competition programme or the  
7 number, frequency and distribution of competitions to support the timely execution of an athlete's fastest  
8 performance and whether this is affected by the sex of the athlete. For example, the suggestion of 10  
9 to 16 races in a competitive season<sup>34</sup> raises questions regarding the distribution and frequency of these  
10 races, their time-course and the level of these races. In supporting the delivery of an athlete's  
11 performance, knowledge of how to plan a coherent competition phase would be beneficial to coaches.  
12 Understanding the duration of the competition phase, the type and number of competitions required  
13 would facilitate the coach's planning process. Currently, with most of research focusing on elite athletes  
14 there is no means of identifying best practice guidelines for coaches and athletes who are competing  
15 at sub elite performance levels.

## 16 **Purpose of the Study.**

17 The purpose of this study was to analyse contemporary United Kingdom (UK) performance  
18 data from middle distance runners, using a publicly available database, to determine a) the number of  
19 competitive performances prior to the season's fastest performance, b) the time frame between their  
20 first and fastest competitive performances of that season (in days), c) how this varied by event type and  
21 d) how this varied by sex, to support coaches to develop their planning practice.  
22  
23

## 24 **Method.**

### 25 **Subjects.**

26 United Kingdom (UK) athletes that were ranked in the UK top 100 athletes for the 800 m and  
27 1500 m athletics events during the period of 2006 to 2017 were the focus of this study. The initial  
28 sample consisted of 4,800 observations (n=2,400 male, n=2,400 female) over this period. In total,  
29 1,166 individual athletes contributed to these performances (n=604 male, n=562 female).  
30  
31

### 32 **Data extraction.**

33 The information on individual's races used in this study were extracted from a public database  
34 ([www.thepowerof10.info](http://www.thepowerof10.info)). Prior to data extraction, institutional ethical approval was gained. Using an  
35 observational research design, for the twelve years, for the 800 m and 1500 m events, the following  
36 data was extracted on individual athletes: athlete name, age group, date of birth (DoB), the fastest  
37 performance for the event in each season, date of the first outdoor track race in each season, date of  
38 fastest time in the event in each season, the number of races completed each season by each athlete  
39 prior to achieving their fastest performance, the total number of races to reach fastest performance (all  
40 track distances), the total number of event races (i.e. 800 m or 1500 m races) to reach the fastest  
41 performance, and the date of the final track race in each season. Subsequently the number of days  
42 between the first race and the fastest performance were calculated.  
43

### 44 **Performance selection criteria.**

45 All outdoor track performances were included irrespective of the level of the competition or the  
46 event distance covered. Competitions where the athlete started but did not finish were still counted in  
47 the analysis. This was on the basis that it was unlikely an athlete would have intentionally decided not  
48 to complete a race. Where an athlete's fastest performance occurred at a championships event, the  
49 results were scrutinised to ensure the performances were counted in the order in which they would have  
50 been completed (i.e. heats, semi-finals and final). For the purposes of this study, races within a  
51 championship context were counted as individual races, that is, where an athlete progressed through  
52 two qualifying rounds and then competed in the final; this was counted as three races. Where mid-race  
53 points were recorded (i.e. 1500 m point in a mile race), they were counted as one performance.

54 Performances were excluded for each year if they were achieved in any indoor track  
55 competitions. Indoor performances were discounted for this study as they are generally considered  
56 within athletics to be a separate competition phase. The indoor track season usually has a lower  
57 number of athletes opting to compete and is shorter in duration (i.e. January-March). In addition, any  
58 performances in an athlete's profile that were either non-track races (e.g. road racing,) or non-running  
59 (i.e. field events) were also discounted. Additionally, only those races that were completed within the

1 northern hemisphere's traditional outdoor track season (late March through to early September) were  
2 counted. For those athletes who competed in outdoor races in the southern hemisphere (e.g. Australia,  
3 South Africa) these races were discounted as they occurred outside what is generally accepted in  
4 athletics as the outdoor track season. Finally, athletes were not excluded from the study based on age.  
5

## 6 **Data Analysis.**

7 The data collected was subjected to a cleansing process to ensure the integrity of all extracted  
8 competitor performance data. The cleansing process subjected the individual performances to an  
9 assessment against pre-determined inclusion criteria (see above – performance selection criteria). If  
10 an athlete's performances did not meet the inclusion criteria those athletes were discounted from the  
11 list and replaced with the next suitable athlete in the rankings list. Within the complete dataset, 211  
12 individual athletes were removed (female, n=131, male, n=80). The number of athletes removed  
13 averaged 18 per year (range 8-40). Three years (2015, 2016 and 2017) had the most individual athletes  
14 removed from the data (n=40, 33 and 36 respectively). The number of individual athletes removed from  
15 the data set for the 800 m was 97 (female n=65: male, n=32). The number of individual athletes removed  
16 from the data set for the 1500 m was 114 (female n=66: male, n=48). Within the 800 m data, the  
17 individual athletes removed per year averaged 5 (range: 2-12) for females and 3 (range: 1-4) for males.  
18 The individual athletes removed per year in the 1500 m data averaged 6 (range: 0-14) for females and  
19 4 (range: 0-16) for males. Additionally, when analysing the data for the number of days and races  
20 between the first and fastest performance, the initial results suggested a large frequency of observations  
21 at zero, indicating that for a large number of athletes, their first run was also their fastest performance.  
22 If an athlete only completed one race in an event discipline in a season, then the athlete was discounted  
23 from the analysis. This was on the basis that for these athletes there was no competition profile. By  
24 contrast, an athlete who completed 3 races in a season with their first race as their fastest was still  
25 included in the analysis. Finally, for the purposes of this analysis, in calculating when athletes achieved  
26 their fastest performance, early season was defined as races completed pre June, mid-season as June  
27 to August and late season as post August.  
28

## 29 **Statistical analysis.**

30 The aim of the analysis was to determine a) the number of competitive performances prior to  
31 the season's fastest performance, b) the time frame between their first and fastest competitive  
32 performances of that season (in days), c) how this varied by event type and d) how this varied by  
33 sex. Within the data set, it was believed that the variance was unlikely to be constant; for example, as  
34 the numbers of both competitive performances and days between first and fastest race grow, the  
35 variability in the data would also grow. This was demonstrated through a greater spread around the  
36 higher numbers. Using a simple linear regression was deemed unsuitable as it allowed for the  
37 possibility that the analysis could result in predictions that had negative values and also assumes a  
38 constant variance of residuals. In this study, negative results could not be attained i.e. athletes cannot  
39 compete in minus 1 race. A negative binomial (NB) mixed effects model was used to handle the  
40 overdispersed count data (races and days) and to allow for non-constant variance of residuals. Mixed  
41 effects models were used to account for the repeated observations on athletes. The model also allowed  
42 the analysis to account for any differences between disciplines and athletes and that athletes might  
43 vary, be it physically, in terms of psychology or in terms of their training regime. Standard five-number  
44 summaries were calculated (minimum, lower quartile, median, upper quartile, maximum) along with the  
45 inter -quartile range (IQR), mean and standard deviation. The analysis was carried out in R using the  
46 glmmADMB package<sup>35,36,37</sup>. The reference lines and event dates appearing on some figures were  
47 sourced from public databases (<https://www.englandathletics.org> and <https://conac.org.uk>). A covariate  
48 called 'level' was also used within the analysis. The level of athlete in this study was determined using  
49 an athlete's overall fastest performance. Four broadly equal groups were defined using quantiles of  
50 their fastest performance; the groups are referred to as Q1 (reference), Q2, Q3 and Q4 in the following  
51 sections. For the purpose of this study, Q1 athletes are those individuals who have recorded the fastest  
52 race performances in terms of all-time personal best (PB). Conversely, Q4 athletes have the slowest  
53 all-time PB of the individuals included in this study. The cut-points for each sex and discipline are  
54 highlighted in table 1. The caterpillar plots displayed in the results section indicate the variability in  
55 athlete's competition programmes. The start of the line indicates when the first competition happened,  
56 the solid bullet indicates when the fastest performance of the season occurred, and the dashed line  
57 represents the duration of the competition programme for that season *after* the fastest performance.  
58 The reference lines indicate prominent competitions in the UK outdoor athletics calendar, including  
59 international events.

1 *\*\* Insert table 1 here \*\**

## 2 **Results.**

### 3 **Number of competitive performances prior to the season's fastest performance.**

4 The lower quartile, median and upper quartile data for the number of races completed prior to  
5 the achievement of the season's fastest performance by sex and discipline are shown in figure 1. The  
6 minimum value is 1 across both sexes and disciplines, the maximum values for female 800 m and 1500  
7 m was 39 and 31 races respectively. For male 800 m and 1500 m athletes the maximum values was  
8 35 and 23 races. There is a significant difference between the disciplines ( $P < 0.01$ ).

9 *\*\*Insert Figure 1 here \*\**

### 10 **Number of days between the first and fastest competitive performances of the season.**

11 Figure 2 highlights lower quartile, median and upper quartile data by sex and race discipline for  
12 the number of days between first and fastest race. The minimum value is zero across both sexes and  
13 disciplines, the maximum values for female 800 m and 1500 m was 165 and 161 days respectively. For  
14 male 800 m and 1500 m athletes the maximum values was 187 and 190 days. There was a significant  
15 difference ( $P < 0.01$ ) between the median number of days from the first to the fastest race for both sex  
16 and discipline.

17 *\*\*Insert figure 2 here \*\**

### 18 **800 m v 1500 m.**

19 800 m athletes had a longer time frame than 1500 m and greater number of competitive  
20 performances prior to achieving their fastest time of the season (Figure1). The number of races and  
21 days required for optimal 1500m performance was significant ( $P < 0.001$ ) for both sexes. Similarly,  
22 there was also a significant increase ( $P < 0.01$ ) between the number of races and days male athletes  
23 required for optimal 800m performance compared to that for 1500m.

24 *\*\* Insert figure 3 here \*\**

25 *\*\* Insert figure 4 here \*\**

### 26 **Male v Female athletes.**

27 Female athletes appear to require longer timeframes and more races prior to achieving the  
28 fastest performance compared to their male counterparts (figure 2). Both sexes athletes averaged 1  
29 race every 7 days, with SD of 4.0 and 4,5 respectively). There was no significant difference ( $P = 0.784$ )  
30 between male and females when examining the average number of days per race. Figures 1 and 2  
31 demonstrate that in 2016 there was considerable variability in both male and female athlete competition  
32 programmes regarding when fastest performance occurred; a finding that was consistent across all  
33 years of data considered in this work. Caterpillar plots are available for all years included in the analysis  
34 in the supplementary material.

### 35 **Level of athlete.**

36 Q1 male athletes (quickest in terms of all-time PB) ran the fewest races but were not  
37 significantly different from the Q2 and Q3 level male athletes; Q4 male athletes ran significantly more  
38 races ( $P < 0.01$ ). The Q4 athletes ran 12% more races than the Q1 athletes. There was no evidence  
39 of a difference in number of races across the levels of female athletes. The analysis indicated that the  
40 expected number of races is 5 for Q1 males running the 1500m. This increased to 6 races for Q1 males  
41 running 800m a difference that was significant ( $P < 0.001$ ). For female athletes, the expected number  
42 of all track races for the Q1 1500m women is 6 races increasing to 7 races for the 800m.

43 *\*\* Insert table 2 here \*\**

### 44 **Age group.**

45 Table 3 highlights the five number summaries for age group athletes by sex and discipline.  
46 Senior athletes appeared to have shorter timeframes and races compared to younger age groups with  
47 a smaller median number of races and number of days, with U20 athletes running the most races and  
48 across a longer timeframe. Figures 3-6 highlight the variability across the age groups regarding when  
49 the fastest performance occurred.

50 *\*\* Insert table 3 here \*\**

1 *\*\*Insert Figure 5 here \*\**  
2 *\*\*Insert Figure 6 here \*\**  
3 *\*\*Insert Figure 7 here \*\**  
4 *\*\*Insert Figure 8 here \*\**  
5

### 6 **Timing of the achievement of the fastest performance.**

7 When athletes achieved their fastest performance varied by age group. Athletes who achieved  
8 their fastest performance in the early part of the season (April and May), were 25% of senior athletes,  
9 28% of U23 athletes and 22% of U20 athletes. For athletes achieving their fastest performance in late  
10 season are 18% (Senior & U23), 23% (U20). Those who took > 120 days from first competition are 16%  
11 (Senior), 20% (U23) and 35% (U20). The analysis indicates that junior athletes run more and over a  
12 longer timeframe than their senior counterparts. For the Under 23 age group this was by 19% and 20%  
13 more races for female and male athletes respectively. Both sexes in the under 20 age group raced  
14 53% more than their senior counterparts. Both of these are statistically significant ( $P < 0.001$ ).  
15

16 *\*\* Insert table 4 here \*\**  
17 *\*\* Insert table 5 here \*\**  
18

### 19 **Discussion.**

20  
21 The purpose of this study was to analyse contemporary performance data in middle distance  
22 runners. The two main findings from the study indicate that 1) within discipline, female athletes required  
23 a greater number of days and races to achieve their fastest performance of the season, 2) 800 m  
24 athletes required a greater number of days and races to reach their fastest performance compared to  
25 1500 m. This was consistent across sex and takes into account between- and within-athlete variability.  
26 Notwithstanding these findings, there is a large amount of variability in the structure of competition  
27 programmes.  
28

### 29 **Number of competitive performances prior to the season's fastest performance.**

30 Within the time frame detailed in the results, the content of the competition programme should  
31 incorporate approximately six to eight races. Male and female athletes produced comparable results for  
32 the number of races required to achieve their fastest performance. It is not clear from the data, whether  
33 six to eight races are the actual number of races athletes require to achieve their fastest performance  
34 or rather an indication of the number of races that are possible within the period available. The number  
35 of times that an individual can race is generally determined by race availability and the available time  
36 frame in which to complete the races. For example, the more time that an athlete took to reach their  
37 fastest performance, generally the greater the number of races they competed in. Both sexes averaged  
38 approximately one race every seven days. Logically, this implies that the average days per race might  
39 be constrained by individual lifestyles, access to races or race availability. Conversely, it could also be  
40 an indication of a lack of planning of the competition programme and raises issues regarding the  
41 appropriateness of race selection. However, it is unclear from the data whether the principle information  
42 to aid the planning practices of a coach should be the time frame available or the number of races.  
43 Nonetheless, this information does provide guidelines to a coach regarding the period and volume of  
44 races that are more likely to support fastest performance.  
45

### 46 **Number of days between the first and fastest competitive performances of the season.**

47 The optimum time frame to produce the fastest performance is determined by event discipline  
48 and sex (figure 1). Females athletes appear to need a greater number of days than their male  
49 counterparts to achieve their fastest performance in both disciplines. It is not clear why females required  
50 a more days across both disciplines. The difference found between the sexes and discipline are  
51 discussed later in this paper. It would seem reasonable to suggest that there may be some element of  
52 cultural conditioning, regarding when the season traditionally begins for athletes. This could influence  
53 the number of days athletes are taking to reach their fastest performance. However, this is not  
54 necessarily an optimal way to support athletes to run their fastest. With a relatively stable competition  
55 calendar in the UK, an awareness of the approximate number of days between beginning the  
56 competition programme and achieving fastest performance should facilitate the competition planning  
57 process. The major national level competitions are commonly scheduled for late June into July,  
58 dictating that an athlete must be at their fastest within a small window of time. Knowing the parameters  
59 of days would allow coaches to manipulate training and competition schedules effectively to match

1 racing performance to an athlete's target competitions. In terms of planning an effective competition  
2 programme, the central considerations are a) time frame available and b) the number of races required.

#### 3 4 **800 m v 1500 m.**

5 For both sexes, 1500 m athletes raced less often and over a shorter time period than 800 m  
6 athletes before reaching their fastest performance. Traditionally, the structure of an athlete's training  
7 year employs a model that advocates athletes first build their aerobic capability (endurance training)  
8 during the winter period before transitioning to training increasingly focused on their anaerobic capacity  
9 (speed training)<sup>3, 21</sup>. The training to build the anaerobic capacity usually coincides with the start of the  
10 track season<sup>3, 21</sup>. An 800m race has a larger anaerobic contribution than the 1500 m<sup>41,42,43,44,45</sup>, the  
11 increase in days needed to achieve fastest performance in the 800 m could reflect the time needed for  
12 optimal anaerobic adaptations to occur. A tentative explanation for the increase in the number of 800  
13 m races could also indicate the possibility of athletes using racing as a training tool<sup>46</sup>. Anecdotal  
14 evidence from athletics suggests that coaches do use racing as a simulation tool to aid preparation.

#### 15 16 **Male v Female.**

17 Female athletes, on average, needed a longer time frame and number of races between the  
18 first and fastest race in the 800m and 1500m to reach fastest performance. The interquartile range  
19 (IQR) is similar across sex and discipline with regard to the number of races required to reach fastest  
20 performance. Across discipline the IQR indicated a difference between the sexes with regard to the  
21 number of days to achieve their fastest performance. There are more females requiring a longer time  
22 frame to reach their fastest performance. Why this difference between the sexes has occurred is  
23 uncertain. Although there is no conclusive evidence in the current literature, tentative suggestions  
24 include a possible time difference in female's adaptation to anaerobic training<sup>47</sup> or any effects of the  
25 female menstrual cycle in disrupting the completion of the training programme<sup>47</sup>. This latter point might  
26 provide a richer explanation because anecdotally<sup>48</sup> it is reported that many coaches employ a different  
27 approach when training male and female athletes. The differences in time frame between the sexes  
28 could be due to variations in training load. further research is required to determine the influence of  
29 recent training history on the achievement of fastest performance.

#### 30 31 **Variability in performance data by age and level.**

32 The variability demonstrated in figures 1 and 2 in achieving fastest performance is a strong indicator of  
33 the adoption of a variety of planning strategies. Yet what is unclear is how much of the planning is  
34 deliberate and purposeful; the variability is likely to have a multifactorial aetiology. The achievement of  
35 the fastest performance is not necessarily when the athlete was physically most capable. Variability in  
36 performance could be due to environmental conditions, such as temperature, wind and humidity.  
37 Additionally, the level of competition, the quality of track and the tactics deployed in any race, could also  
38 exert an influence on athlete performance. Furthermore, individual training responses, personal  
39 performance history, the level of athlete motivation on day of the competition, susceptibility to injury and  
40 illness, any variations in local race availability and the willingness to travel to races could all exert an  
41 influence on the achievement of the fastest performance.

42 Many athletes achieved their fastest performance outside of the major national level  
43 competitions (June & July). There is no clarity as to why these phenomena of early and late fastest  
44 performances have occurred. There was overall evidence of the phenomenon of many athletes  
45 running their fastest race as their first race but no evidence that this varied by discipline, but it did appear  
46 to vary by age group with both U23 and U20 athletes less likely to do so. The level of the athlete did  
47 not affect the chance of running fastest first time. The presentation of these phenomena and the large  
48 variability in the achievement of the fastest performance suggest that there are varying levels of  
49 competition planning being completed. Given the ridged competition calendar<sup>10</sup> and the implausibility  
50 an athlete intending to reduce their performance across the season, those achieving their fastest  
51 performance early in the season strongly indicates a lack of planning. What is less certain is whether  
52 longer time frames were the result of planning. For some athletes, injury could have increased the  
53 likelihood of peaking later in the season. Yet, this is unlikely to account for the whole sample. However,  
54 the constraints of the competition calendar would indicate that neither of these situations are optimal.  
55 The variation could be indicative of a lack of evidence based guiding principles for coaches, resulting  
56 in either ineffective planning or no planning.

57 Furthermore, whilst the variability might, in part, be attributed to a lack of effective planning,  
58 there is an element of uncertainty. Through incorporating the planning of the competition phase into  
59 coach education programmes, a coach whose athlete(s) appear(s) at either end of the ranges or who



1 has had a large seasonal variation in when they achieve their fastest performance, could be supported  
2 to change practice and plan more effectively. The large variation is an indication that there is a need  
3 to determine evidence based guiding principles. In the absence of any other empirical evidence, these  
4 results can provide a tentative framework within which a coach can plan and evaluate both current and  
5 future practice.

## 6 7 **Practical applications for athletes and coaches.**

8  
9 This study can aid those coaches who are planning for their athletes to achieve their fastest  
10 performance in a specified time frame or competition. Moreover, it offers a first step in providing an  
11 evidence based framework for parameters about when athletes are more likely to produce their fastest  
12 performance. This research has strong heuristic value for coaches regarding competition parameters  
13 associated with optimal athlete performance. This can support the general strategic considerations of  
14 the coach regarding the competition plan, whilst also helping coaches to determine an individual  
15 athlete's performance trends. It is recommended that coaches and coach education programmes follow  
16 our suggestions regarding the number of days and races. Initially a coach should use a value close to  
17 the median when constructing a competition programme. In subsequent years, they should undertake  
18 a backwards mapping process from the target competition to identify a suitable duration and number of  
19 competitions required for individual athletes. These guidelines would be particularly useful for novice  
20 or inexperienced coaches or those coaches who have experienced large seasonal variations in when  
21 their athletes achieve their fastest performance. There is a note of caution to the framework; coaches  
22 need to recognise the individuality required in the design of an effective competition program. There  
23 are other determinants that would also need consideration: athlete preference, age (biological and  
24 training ages), training history, event group, the athlete responses to competition, access to competition,  
25 single or double peak targets for example qualifying events for major championships and the status of  
26 the athlete (e.g. full time athletes, funded athletes or part time athletes with other professional  
27 occupations).

28 This analysis can only provide a partial answer to the design of effective competition  
29 programmes, and only provides an indication of the potential markers for a coach based on this sample  
30 group. The data captured from the Power of 10 does not capture the holistic nature of the athlete's  
31 competition profile. This analysis has only been able to provide evidence based benchmarks for the  
32 number days and races to fastest performance in middle distance track events. Additionally, the study  
33 was also unable to take account of when the athlete intended to reach their fastest performance, so the  
34 figures might not represent a fully accurate picture.

35 The recommendation is that future research should look to re-examine the data periodically to  
36 identify any changes in practice. To further aid the planning practice of the competition programme,  
37 future studies should look at individual athlete's event histories, the sequencing of an athlete's races  
38 within the competition period and the considerations that shape the decision-making process within a  
39 competition programme. This would help identify patterns in competition programmes and the  
40 implications for planning.

## 41 42 **Conclusions.**

43  
44 The exploration of a middle distance athlete's completion phase prior to the taper has revealed  
45 two main findings. Firstly within discipline, female athletes required a greater number of days and races  
46 than their male counterparts to achieve their fastest performance of the season, and secondly, 800 m  
47 athletes required a greater number of days and races to reach their fastest performance compared to  
48 1500 m athletes. This was consistent across sex and takes into account between- and within-athlete  
49 variability. The large inter-individual variability suggests that these general recommendations should  
50 be adopted so that a personal model can be constructed for each athlete, as advocated in most studies  
51 of the training- performance relationship (e.g. Hellard et al., 2013; 2005; Mujika et al., 1996a; 1996b;  
52 Stewart & Hopkins, 2000a; 2000b). These recommendations are the first step in providing evidenced  
53 based guidelines for middle distance athletics coaches regarding the average number of days and races  
54 to achieve fastest performance by sex and discipline respectively. The recommendations provide both  
55 a framework and parameters to aid middle distance coaches when planning an athlete's competition  
56 programme, with implications for coach education.

## References.

1. Tønnessen E, Sylta Ø, Haugen TA. et al. The Road to Gold: Training and Peaking Characteristics in the Year Prior to a Gold Medal Endurance Performance. *PLoS ONE*, 2014, 9(7): e101796. doi:10.1371/journal.pone.0101796.
2. Morton RH. The quantitative periodization of athletic training: A model study. *Sports medicine, training and rehabilitation: An international journal*. 2009, 3:1, 19-28.
3. Chamera T. The structure of the final preparation period and its effects on sport results of sailors taking part in the 2004 Olympic games. *Studies in physical, culture and tourism*. 2007, 14, 241-247.
4. Dick FW. *Sports training principles*. 3rd Edition. A&C Black, London. 2007
5. Le Meur Y, Hausswirth C. and Mujika I. Tapering for competition: A review. *Science & Sports*. 2012, 27, 77–87
6. Mujika I. and Padilla S. Scientific bases for pre-competition tapering strategies. *Medicine & Science in Sports & Exercise*, 2003, 35, 1182–1187.
7. Bompa T and Carrera M. *Periodization for sports training*. Human Kinetics. 2005
8. Kiely J. Periodization Paradigms in the 21st Century: Evidence-Led or Tradition-Driven? *International Journal of Sports Physiology and Performance* 2012, 7, pp242-250
9. Bosquet L, Montpetit J, Arvisais, D, et al. Effects of Tapering on Performance A Meta-Analysis. *Medicine & Science in sports and exercise*. *Journal of the American College of Sports Medicine*. 2007, pp1358-1365
10. Mujika I, Padilla S, and Pyne, D. Swimming performance changes during the final 3 weeks of training leading to the Sydney 2000 Olympic Games. *International Journal of Sports Medicine*, 2002, 23, 582–587.
11. Seiler S and Tønnessen E. Intervals, Thresholds, and Long Slow Distance: the Role of Intensity and Duration in Endurance Training. *Sportscience*, 2009, 13: 1–27.
12. Seiler S. What is Best Practice for Training Intensity and Duration Distribution in Endurance Athletes? *International Journal of Sports Physiology & Performance*, 2010, 5: 276–291.
13. Wenger HA and Bell GJ. The Interactions of Intensity, Frequency and Duration of Exercise Training in Altering Cardiorespiratory Fitness. *Sports Medicine*, 1986, 3: 346–356.
14. Pyne DB, Mujika I. and Reilly T. Peaking for optimal performance: research limitations and future directions. *Journal of Sports Science*. 2009, 27(3):195–202
15. Houmard, JA and Johns, RA. Effects of taper on swim performance: Practical implications. *Sports Medicine*, 1994, 17, 224– 232.
16. Mujika I, Padilla S, Pyne, D. et al. Physiological changes associated with the pre-event taper in athletes. *Sports Medicine*, 2004, 34, 891–927.
17. Mujika I, Goya A, Padilla S. et al. Physiological responses to a 6-d taper in middle-distance runners: influence of training intensity and volume. *Medicine & Science in Sports & Exercise*, 2000; 32(2):511–7.
18. Hellard P, Avalos M, Hausswirth C. et al. Identifying Optimal Overload and Taper in Elite Swimmers over Time. *Journal of Sports Science and Medicine*, 2012, 12, 668-678.
19. Mujika I, Chatard JC, Busso T. et al. Effects of training on performance in competitive swimming. *Canadian Journal of Applied Physiology*, 1995, 20: 395-406.
20. Costa MJ, Marinho DA, Reis VM. et al. Tracking the performance of world-ranked swimmers. *Journal of Sports Science and Medicine*. 2010, 9, 411-417
21. Trewin CB, Hopkins WG, and Pyne DB. Relationship between world-ranking and Olympic performance of swimmers. *Journal of Sports Sciences*, 2004, 22(4), 339-345.
22. Pyne DB, Trewin CB, and Hopkins WG. Progression and variability of competitive performance of Olympic swimmers. *Journal of Sports Sciences*, 2004, 22 (7), 613-620. DOI: 10.1080/02640410310001655822.
23. Stewart AM and Hopkins WG. Seasonal training and performance of competitive swimmers. *Journal of Sports Sciences*, 2000b, 18(11), 873-884.
24. Paton CD and Hopkins WG. Variation in performance of elite cyclists from race to race. *European Journal of Sports Sciences*, 2006, 6(01), 25-31.
25. Stewart AM and Hopkins WG. Consistency of swimming performance within and between competitions. *Medicine & Science in Sports & Exercise*, 2000a, 32(5), 997-1001.

26. Fisher J, Clark T, Newman-Judd K. et al. Intra-Subject Variability of 5 Km Time Trial Performance Completed by Competitive Trained Runners. *Journal of Human Kinetics*. 2017, volume 57, 139-146 DOI:10.1515/hukin-2017-0055 139.
27. Chryssanthopoulos C, Ziaras C, Zacharogiannis E. et al. Variability of performance during a 60-min running race. *Journal of Sports Sciences*, 2015, 33:19, 2051-2060, DOI: 10.1080/02640414.2015.1026379.
28. Malcata RM and Hopkins WG. Variability of Competitive Performance of Elite Athletes: A Systematic Review. *Sports medicine*. 2014, 44,12, pp 1763–1774
29. Hopkins WG and Hewson DJ. Variability of competitive performance of distance runners. *Medicine & Science in Sports & Exercise*, 2001, 33(9), 1588–1592.
30. Hopkins WG. Competitive Performance of Elite Track-and-Field Athletes: Variability and Smallest Worthwhile Enhancements. *Sportscience* 2005, 9, 17-20.
31. Kearney JT. Sport performance enhancement: design and analysis of research. Letter to editor. *Medicine & Science in Sports & Exercise*. 1999, 31(5):755-756.
32. Hopkins WG, Hawley JA and Burke LM. Design and analysis of research on sport performance enhancement. *Medicine & Science in Sports & Exercise*, 1999, 31:472–485.
33. Hollings SC, Hopkins WG and Hume PA. Environmental and venue-related factors affecting the performance of elite male track athletes. *European Journal of Sport Science*. 2012, 12 (3), 201-206.
34. Bompa TO and Haff GG. *Periodisation. Theory and methodology of training* (Fifth Edition ed. Human Kinetics. 2009.
35. R Core Team R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>. 2018
36. Fournier DA, Skaug HJ, Ancheta J. et al. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optimal Methods Software*, 2012, 27, 233-249.
37. Skaug H, Fournier D, Bolker B. et al. Generalized Linear Mixed Models using 'AD Model Builder'. *R package version 0.8.3.3*. 2018.
38. Duffield R, Dawson B and Goodman C. Energy system contribution to 400-metre and 800-metre track running, *Journal of Sports Sciences*, 2005, 23:3, 299-307, DOI: 10.1080/02640410410001730043.
39. Matveyev L. *Fundamentals of sports training*. Translated by Albert P. Zdornykh. Moscow, RU: Progress Publishers, 1991.
40. Duffield R, Dawson B and Goodman C. Energy system contribution to 1500- and 3000-metre track running, *Journal of Sports Sciences*, 2005, 23:10, 993-1002, DOI: 10.1080/02640410400021963.
41. Hill DW. Energy system contributions in middle-distance running events, *Journal of Sports Sciences*, 1999, 17:6, 477-483, DOI: 10.1080/026404199365786.
42. Gastin PB. Energy System Interaction and Relative Contribution During Maximal Exercise. *Sports Medicine*. 2001, 31 (10): 725-741.
43. Spencer MR, Gastin PB and Payne WR. Energy system contribution during 400 to 1500 metres running. *New Studies in Athletics*, 1996, 11, 59- 65.
44. Weyand P, Cureton K, Conley D. et al. Percentage anaerobic energy utilized during track running events. *Medicine & Science in Sports & Exercise*, 1993, 25, S105.
45. Spencer MR and Gastin PB. Energy system contribution during 200- to 1500-m running in highly trained athletes. *Medicine & Science in Sports & Exercise*, 2001, 33, 157 – 162.
46. Lydiard A. *Running to the top*. 1991.
47. Reilly T. The Menstrual Cycle and Human Performance: An Overview, *Biological Rhythm Research*, 2000. 31:1, 29-40.
48. Inside Track. 'Women on Track: Should males and females be coached differently?', [www.theinsidetrack.org.uk/womenontrack/](http://www.theinsidetrack.org.uk/womenontrack/) (2001, accessed 02 June 2017).

## Tables.

**Table 1:** Performance indicators used in determining an athlete's level of performance based on an individuals all-time personal best performance (PB) in the event.

<b>Sex</b>	<b>Discipline</b>	<b>Q1 athletes</b>	<b>Q2 athletes</b>	<b>Q3 athletes</b>	<b>Q4 athletes</b>
<b>M</b>	<b>800m</b>	1:43.8 – 1:48.1	1:48.1 – 1:49.4	1:49.4 – 1:50.6	1:50.6 – 1:52.8
<b>W</b>	<b>800m</b>	1:57.7 – 2:03.1	2:03.1 – 2:05.8	2:05.8 – 2:08.1	2:08.1 – 2:12.2
<b>M</b>	<b>1500m</b>	3:28.8 – 3:41.1	3:41.1 – 3:43.2	3:43.2 – 3:46.1	3:46.1 – 3:51.2
<b>W</b>	<b>1500m</b>	3:55.2 – 4:13.5	4:13.5 – 4:17.6	4:17.6 – 4:23.5	4:23.5 – 4:33.0

**Table 2:** Five number summaries (minimum, first quartile, median, upper quartile, maximum) race discipline, sex and level of athlete for number of days between first and fastest race and the number of races to achieve the fastest time.

Discipline	Sex	Level of athlete	Number of days from first to fastest race	Number of races to fastest race
800m	Female	Q1	0 - 35 - 66 - 91 - 147	1 - 4 - 6 - 11 - 23
		Q2	0 - 32 - 60 - 91 - 158	1 - 4 - 8 - 12 - 28
		Q3	0 - 32 - 63 - 91 - 165	1 - 4 - 7 - 12 - 27
		Q4	0 - 34 - 62 - 91 - 157	1 - 5 - 9 - 12 - 35
	Male	Q1	0 - 24 - 48 - 82 - 169	1 - 4 - 6 - 11 - 23
		Q2	0 - 31 - 55 - 88 - 150	1 - 4 - 8 - 12 - 28
		Q3	0 - 28 - 56 - 83 - 136	1 - 4 - 7 - 12 - 27
		Q4	0 - 38 - 64 - 89 - 187	1 - 5 - 9 - 12 - 35
1500m	Female	Q1	0 - 27 - 56 - 88 - 153	1 - 4 - 7 - 11 - 25
		Q2	0 - 28 - 56 - 85 - 154	1 - 4 - 7 - 10 - 22
		Q3	0 - 28 - 56 - 84 - 161	1 - 4 - 7 - 10 - 25
		Q4	0 - 31 - 56 - 78 - 142	1 - 4 - 7 - 10 - 31
	Male	Q1	0 - 21 - 47 - 76 - 190	1 - 3 - 5 - 9 - 19
		Q2	0 - 25 - 45 - 75 - 142	1 - 4 - 6 - 9 - 20
		Q3	0 - 22 - 46 - 70 - 154	1 - 3 - 6 - 9 - 20
		Q4	0 - 28 - 52 - 81 - 156	1 - 4 - 7 - 10 - 23

**Table 3:** Five number summaries (minimum, first quartile, median, upper quartile, maximum) by sex, race discipline and age group for number of days between first and fastest race and the number of races to achieve the fastest time.

Gender	Discipline	Athlete Age group	Number of days from first to fastest race	Number of races to fastest race
Male	800m	Senior	0 - 25 - 52 - 84 - 187	1 - 4 - 6 - 11 - 27
		U23	0 - 29 - 55 - 81 - 137	1 - 5 - 8 - 12 - 21
		U20	0 - 39 - 66 - 93 - 150	1 - 6 - 9 - 14 - 35
	1500m	Senior	0 - 21 - 42 - 72 - 190	1 - 3 - 5 - 8 - 22
		U23	0 - 28 - 49 - 77 - 154	1 - 4 - 7 - 10 - 22
		U20	0 - 39 - 57 - 83 - 156	1 - 6 - 8 - 12 - 23
Female	800m	Senior	0 - 28 - 55 - 84 - 158	1 - 4 - 7 - 11 - 31
		U23	0 - 34 - 62 - 87 - 143	1 - 5 - 8 - 11 - 26
		U20	0 - 42 - 73 - 103 - 165	1 - 6 - 11 - 15 - 39
	1500m	Senior	0 - 24 - 48 - 76 - 161	1 - 3 - 6 - 9 - 31
		U23	0 - 29 - 56 - 90 - 143	1 - 4 - 8 - 11 - 24
		U20	0 - 42 - 66 - 88 - 150	1 - 6 - 9 - 13 - 28

**Table 4:** When athletes achieved their fastest performance in the season.

	<b>Apr-May</b>	<b>Post Aug</b>	<b>&gt;120days from first race</b>
<b>Age group</b>	<b>% of athletes</b>		
<b>Senior</b>	25	18	16
<b>Under 23</b>	28	18	20
<b>Under 20</b>	22	23	35

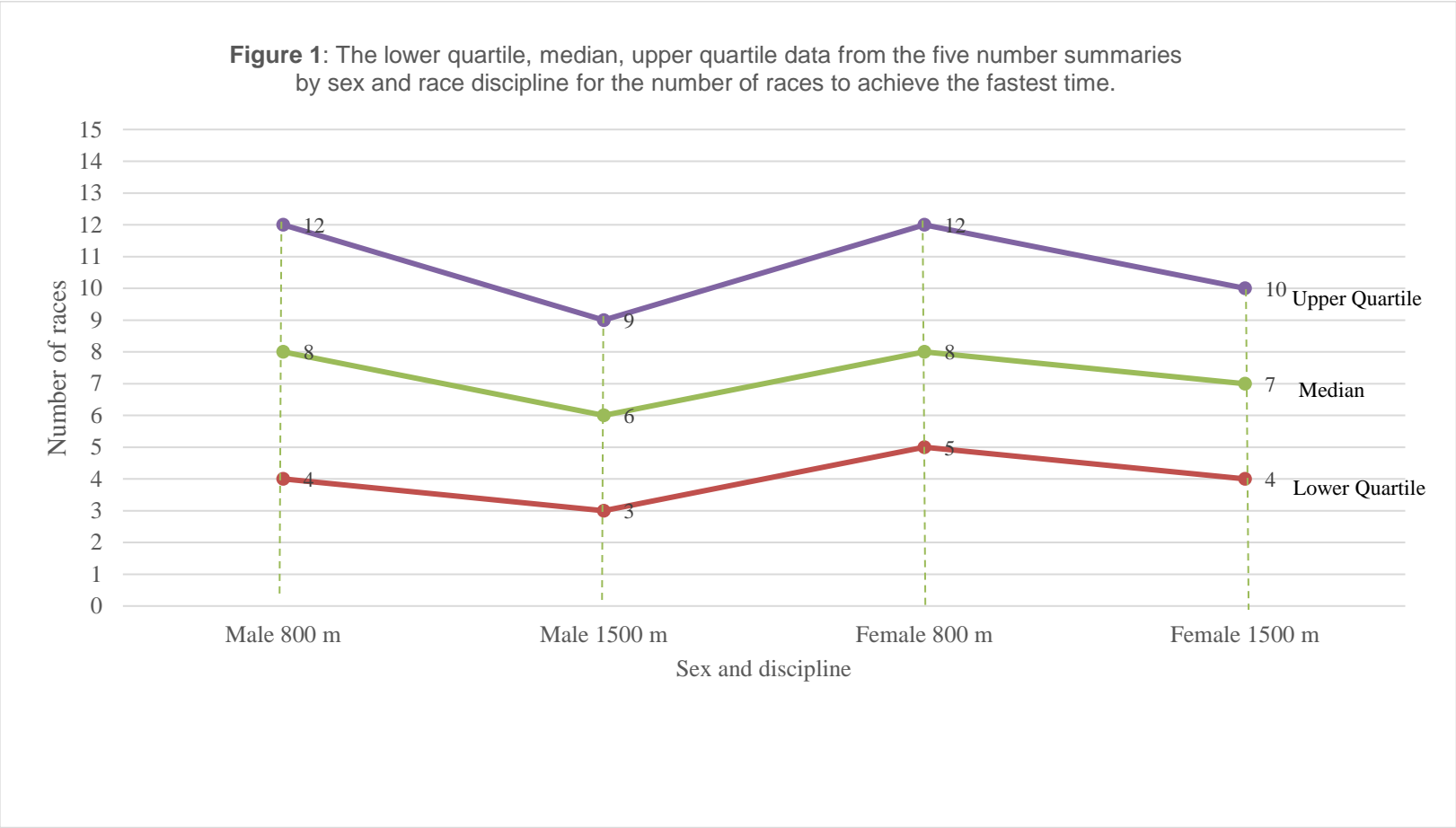
**Table 5:** When athletes achieved their fastest performance in the season by sex and age group (percentage of athletes).

Age group	Apr-May		Post Aug		>120days from first race	
	Male	Female	Male	Female	Male	Female
Senior	26	23	16	21	16	15
Under 23	30	26	17	20	16	25
Under 20	26	20	21	24	30	38

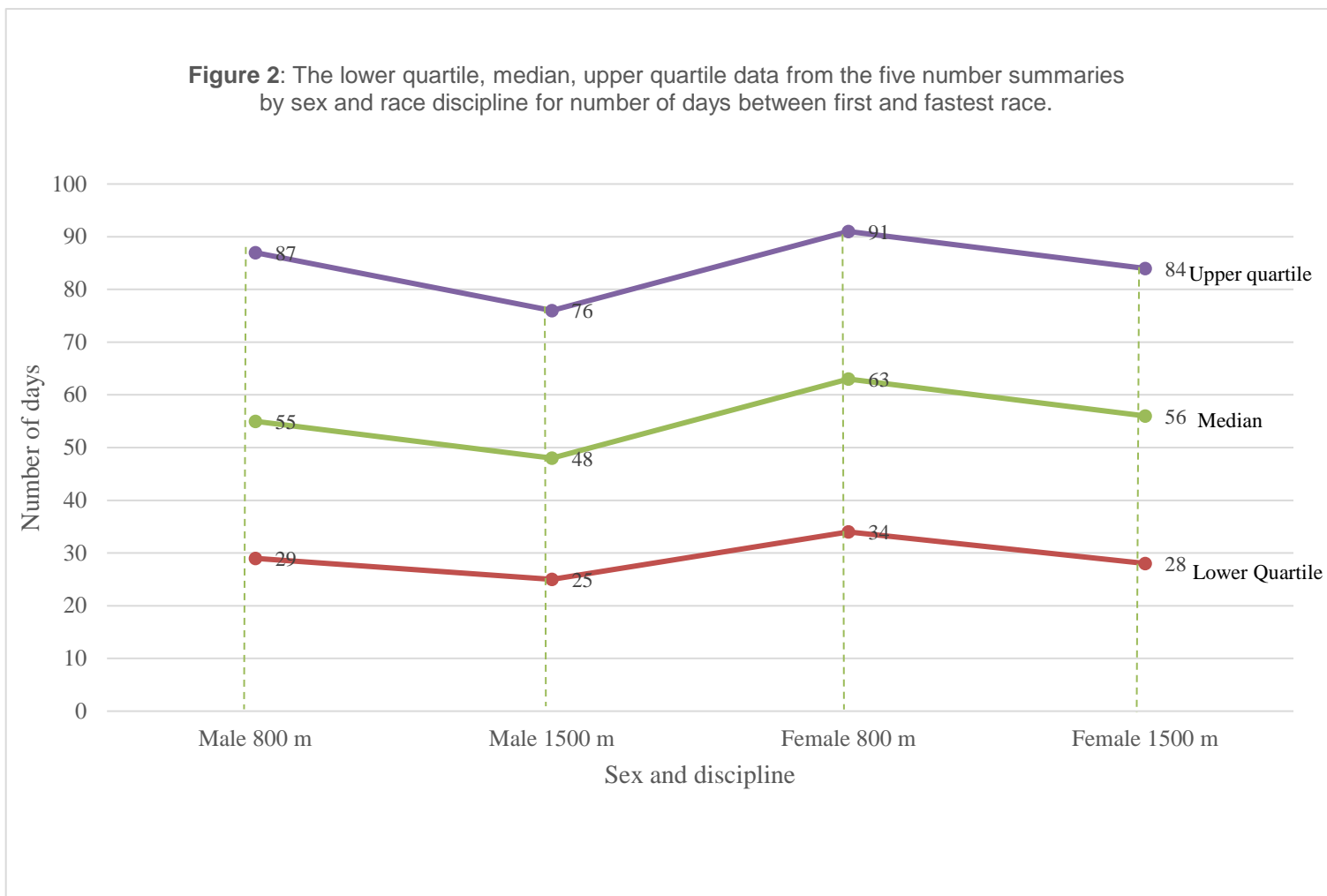


**Figures.**

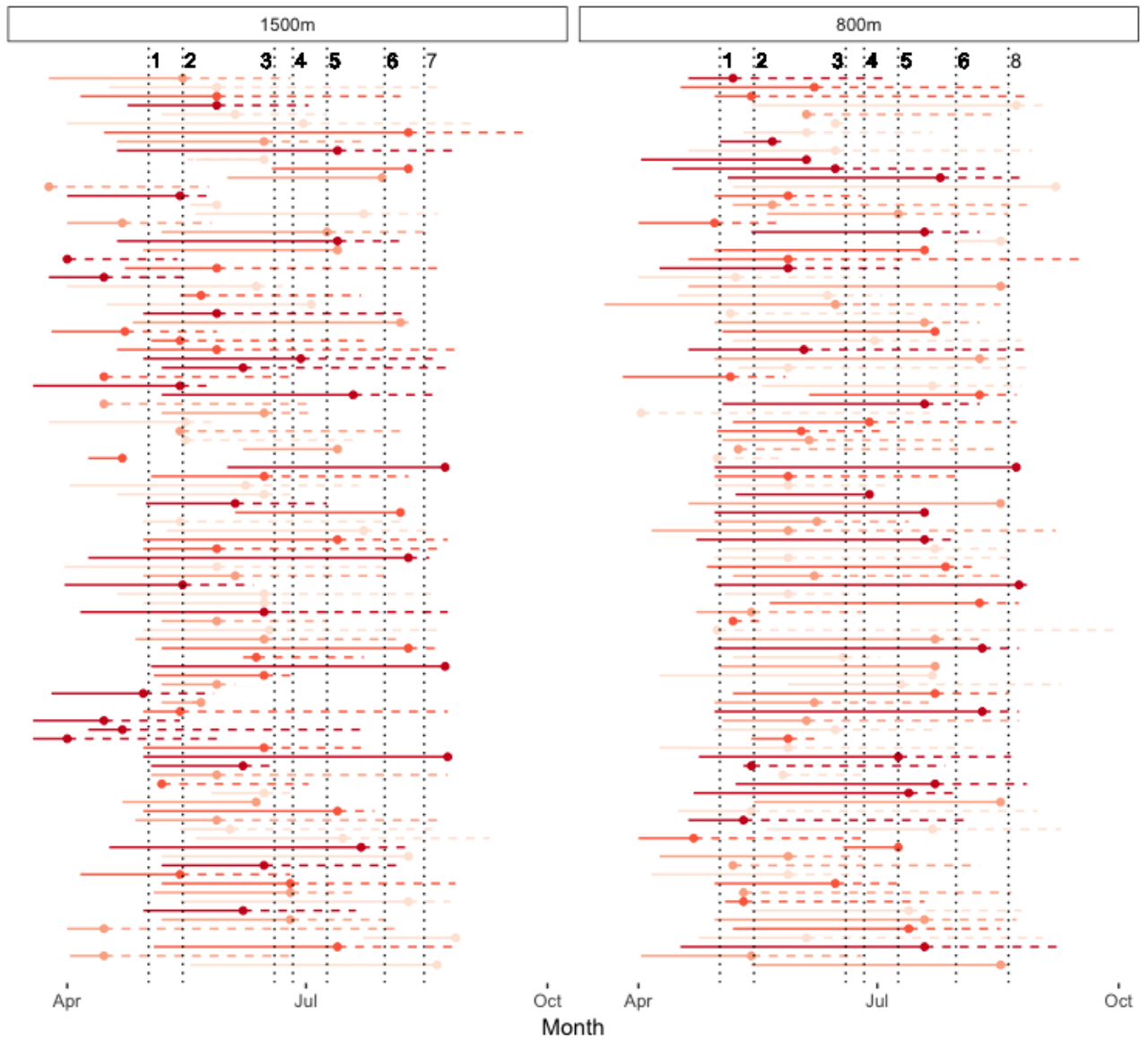
**Figure 1:** The lower quartile, median, upper quartile data from the five number summaries by sex and race discipline for the number of races to achieve the fastest time.



**Figure 2:** The lower quartile, median, upper quartile data from the five number summaries by sex and race discipline for number of days between first and fastest race.

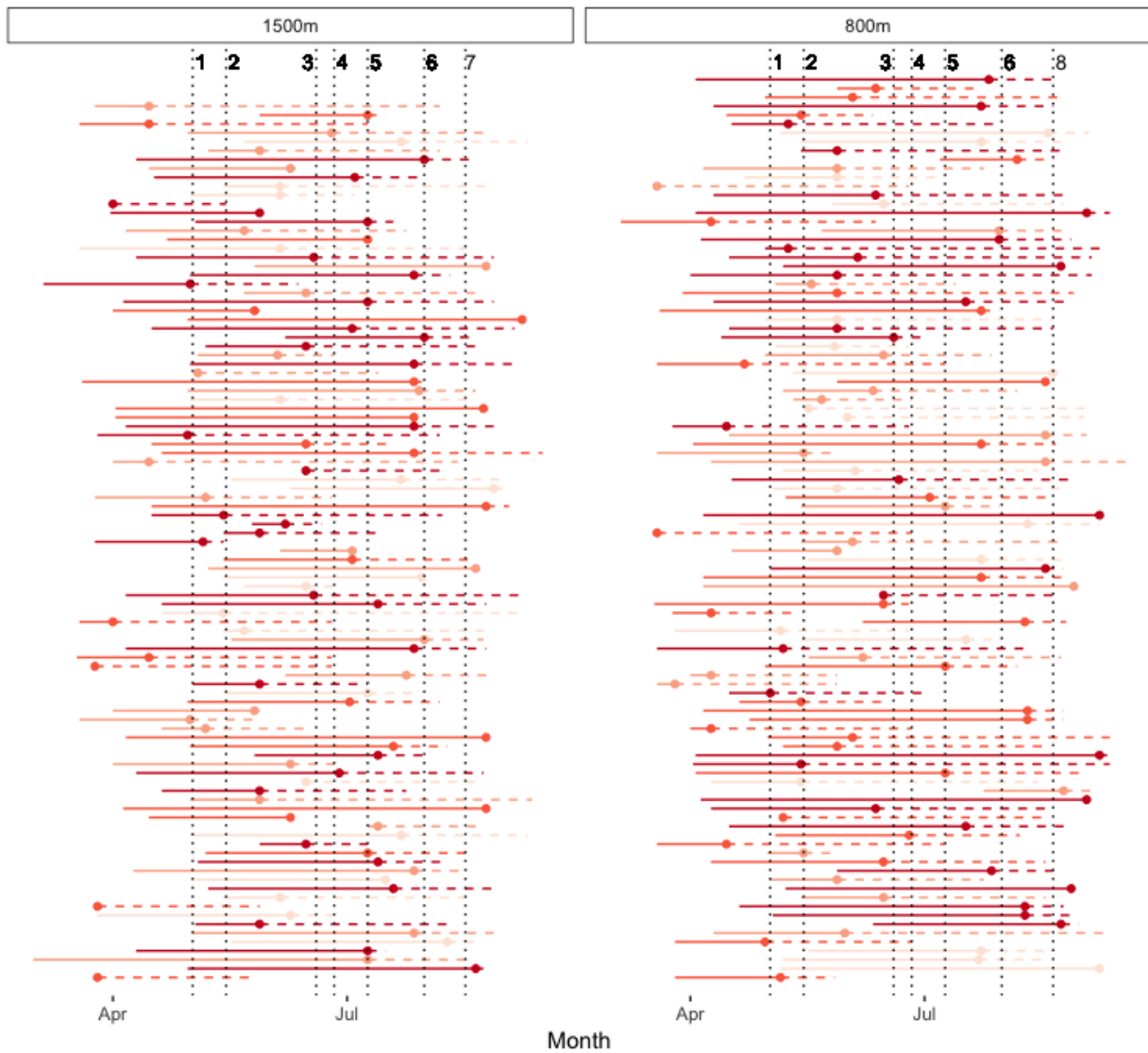


**Figure 3:** Caterpillar plots showing the variability in male athlete competition programmes for 2016 by discipline against where the important competitions occurred.



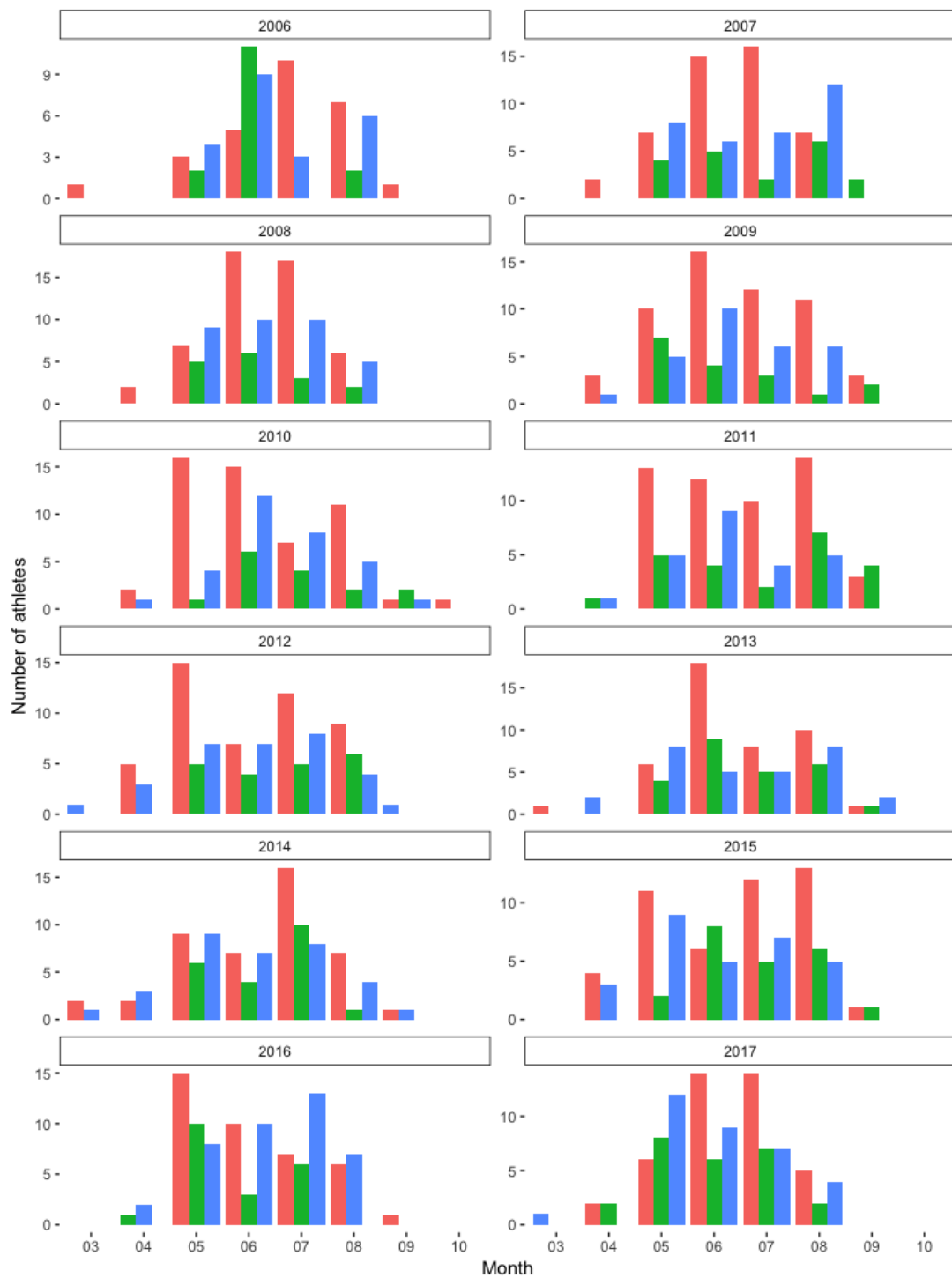
Legend Reference lines: 1 – County Championships; 2 – BUCS; 3 – AAA U20 & U23 Championships; 4 – British Athletics National Championships; 5 – ESAA Championships; 6 – AAA Senior Championships; 7 – Olympics 1500m final; 8 – Olympics 800m final

**Figure 4:** Caterpillar plots showing the variability in female athlete competition programmes for 2016 by discipline against where the important competitions occurred.



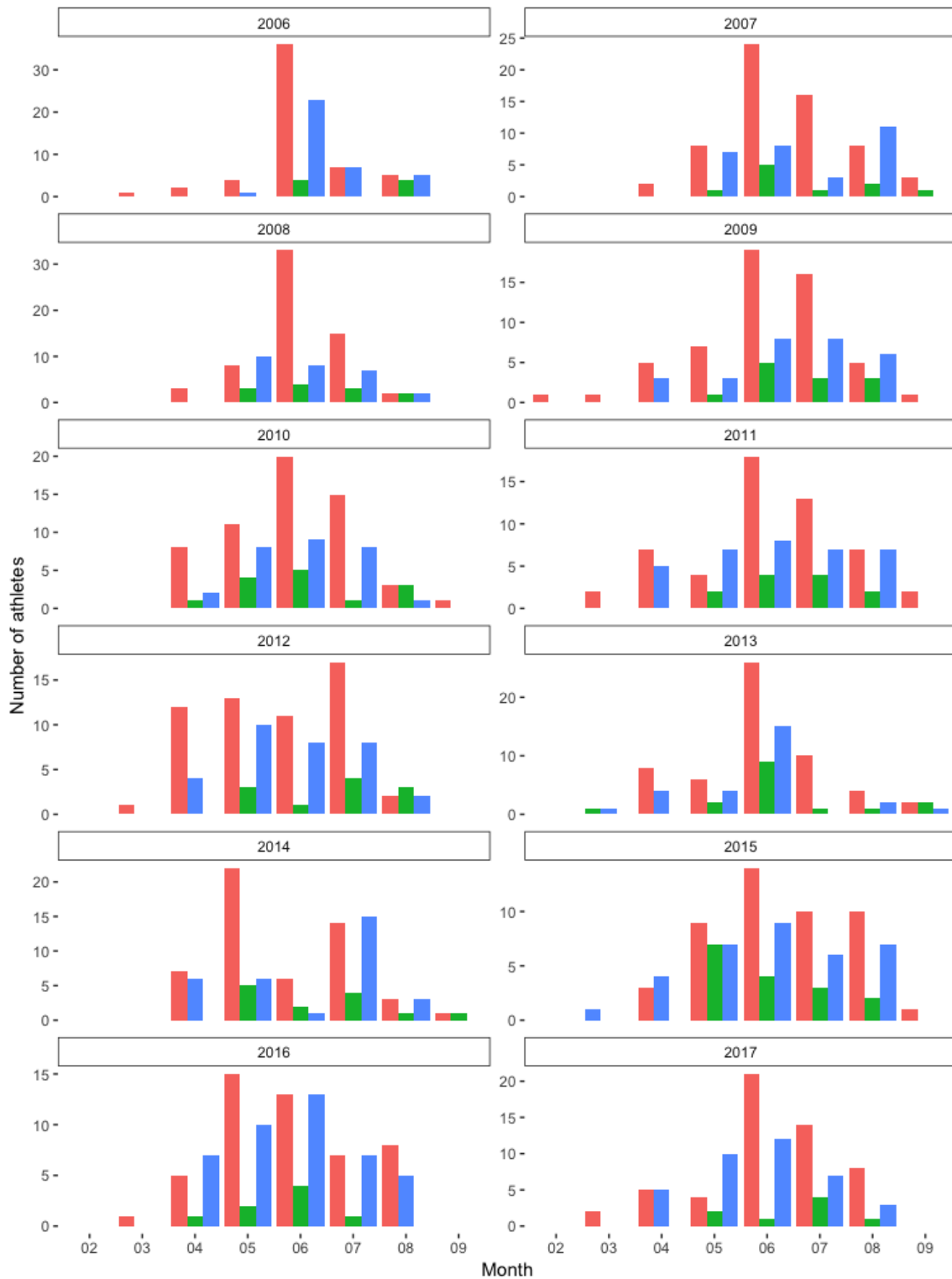
Legend Reference lines: 1 – County Championships; 2 – BUCS; 3 – AAA U20 & U23 Championships; 4 – British Athletics National Championships; 5 – ESAA Championships; 6 – AAA Senior Championships; 7 – Olympics 1500m final; 8 – Olympics 800m final

**Figure 5:** Frequency plots by age group and discipline, indicating which month male 800m athlete's fastest performance occurred.



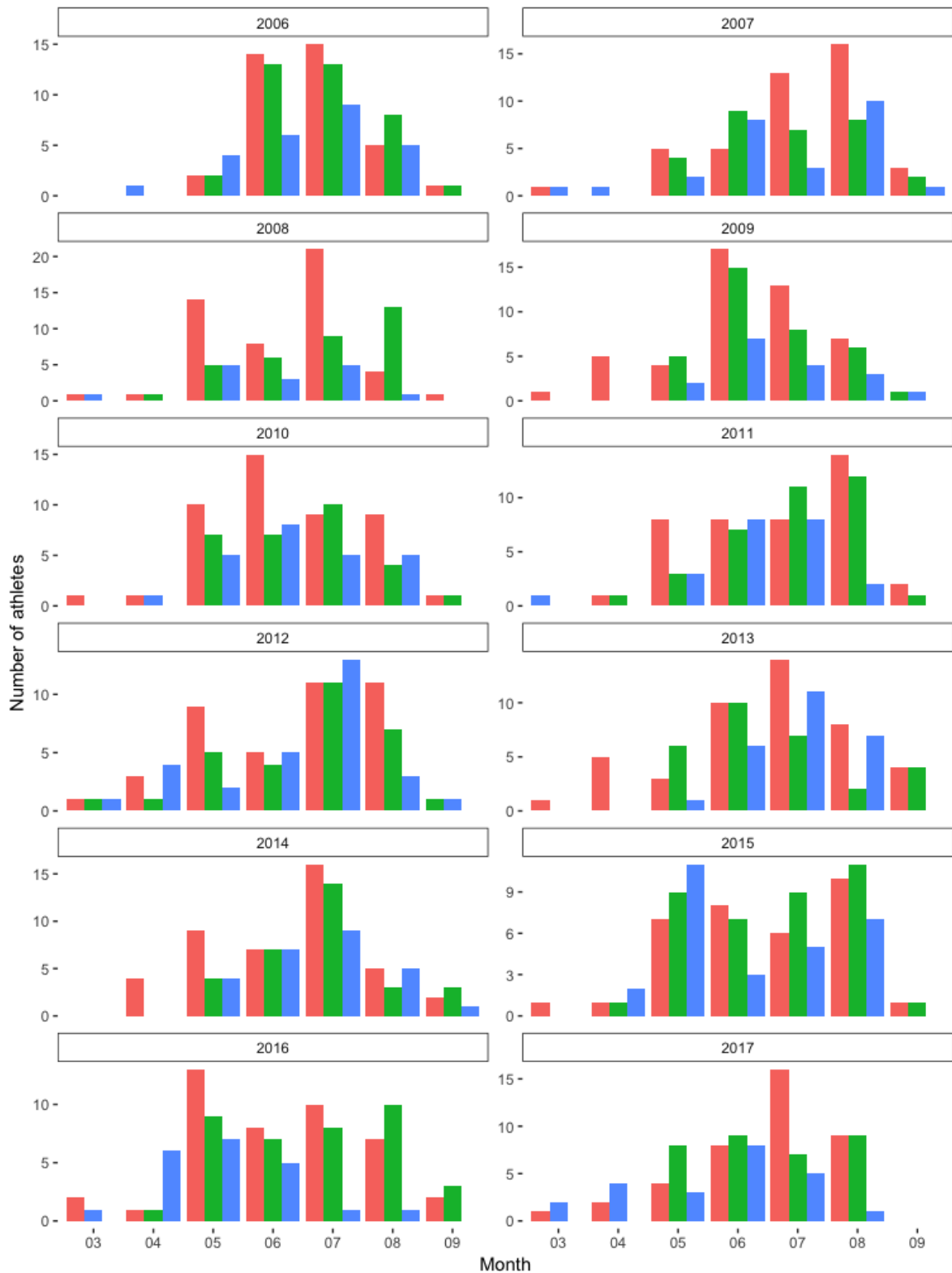
Age group legend: Red is 'Senior', 'Blue is U23', 'Green is U20'.

**Figure 6:** Frequency plots by age group and discipline, indicating which month male 1500m athlete's fastest performance occurred



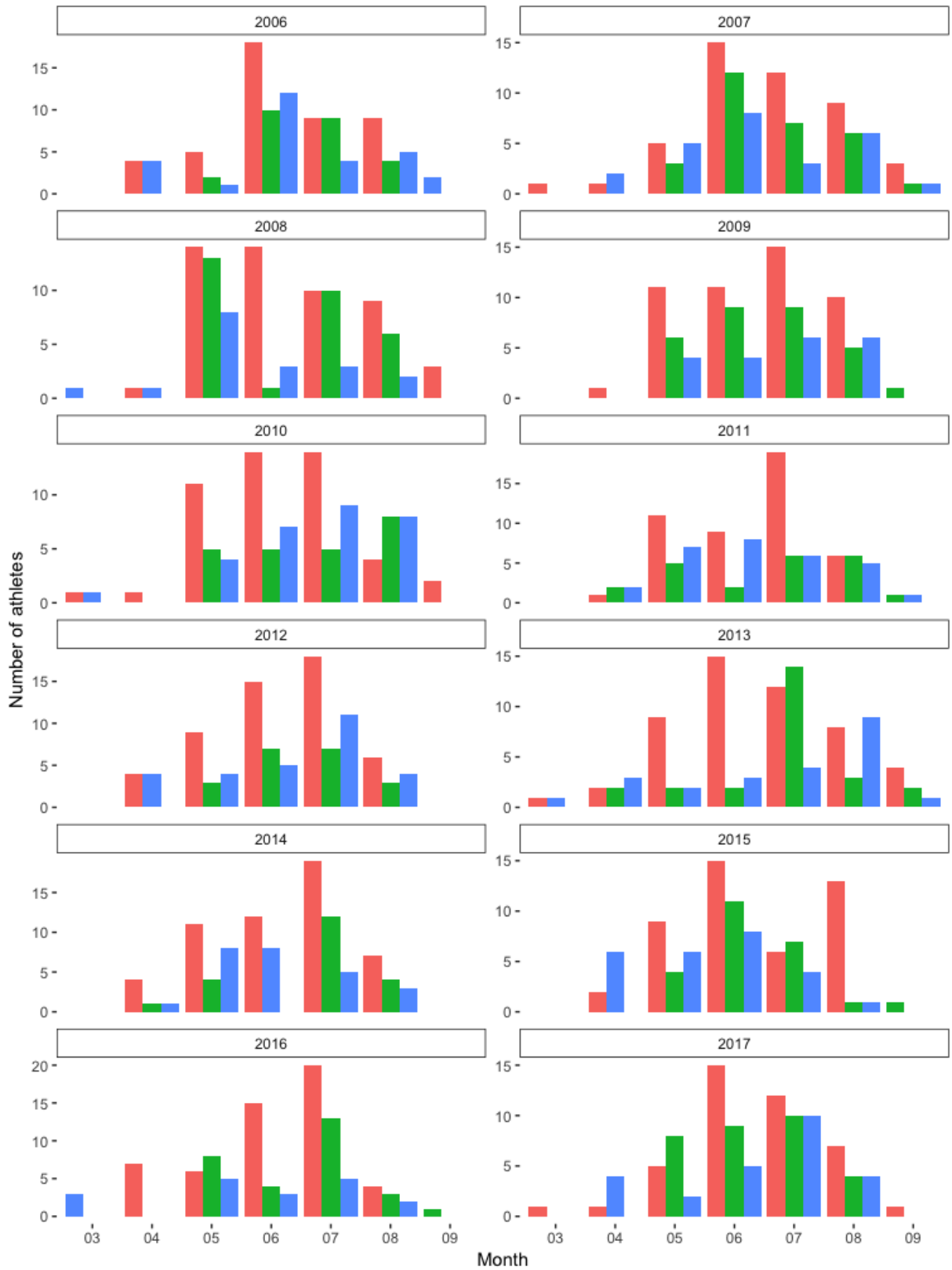
Age group legend: Red is 'Senior', 'Blue is U23', 'Green is U20'.

**Figure 7:** Frequency plots by age group and discipline, indicating which month female 800m athlete's fastest performance occurred



Age group legend: Red is 'Senior', 'Blue is U23', 'Green is U20'.

**Figure 8:** Frequency plots by age group and discipline, indicating which month female 1500m athlete's fastest performance occurred.



Age group legend: Red is 'Senior', 'Blue is U23', 'Green is U20'