Planning for optimal performance – what happens before the taper?

Karen. L. Johns[1], Peter. M. Philipson[2] and Philip R. Hayes[1]

[1] Department of Sport, Exercise and Rehabilitation, Northumbria University, UK.

[2] Department of Mathematics, Physics and Electrical Engineering, Northumbria University, UK.

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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

Abstract.

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

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

Introduction.

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

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

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

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

Competitions are generally assumed to be part of the preparation of athletes and are frequently integrated into the peaking process in elite sports[1], yet there appears to be scant information regarding the structure of an athlete's competition period (i.e. number of days or races) to support the timely achievement of their fastest performance. The design and management of the competition schedule appears to be an integral component in planning a taper. Guidance for coaches is reasonably limited, consisting of some criteria that a coach might consider in the design of a competition programme: athlete preference, age, training experience, the availability of relevant competitions[4], the avoidance of too many competitions and ensuring adequate rest time between competitions [34]. There is a suggestion of an optimum type and number of competitions ranging between seven and 16 competitions [4,34]. Perhaps it is no surprise that such a broad range of an optimal number of competitions are suggested. It is reasonable to suggest that the individuality of performance would inevitably mean that some athletes respond well to many competitions in a preparatory period, others less so. However, there is also a distinct lack of empirical evidence proposing the duration of a competition programme or the number, frequency and distribution of competitions to support the timely execution of an athlete's fastest performance and whether this is affected by the sex of the athlete. For example, the suggestion of 10 to16 races in a competitive season [34] raises questions regarding the distribution and frequency of these races, their time-course and the level of these races. In supporting the delivery of an athlete's performance, knowledge of how to plan a coherent competition phase would be beneficial to coaches. Understanding the duration of the competition phase, the type and number of competitions required would facilitate the coach's planning process. Currently, with most of research focusing on elite athletes there is no means of identifying best practice guidelines for coaches and athletes who are competing at sub elite performance levels.

Purpose of the Study.

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

Method.

Subjects.

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

Data extraction.

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

Performance selection criteria.

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

Performances were excluded for each year if they were achieved in any indoor track competitions. Indoor performances were discounted for this study as they are generally considered within athletics to be a separate competition phase. The indoor track season usually has a lower number of athletes opting to compete and is shorter in duration (i.e. January-March). In addition, any performances in an athlete's profile that were either non-track races (e.g. road racing,) or non-running (i.e. field events) were also discounted. Additionally, only those races that were completed within the northern hemisphere's traditional outdoor track season (late March through to early September) were counted. For those athletes who competed in outdoor races in the southern hemisphere (e.g. Australia, South Africa) these races were discounted as they occurred outside what is generally accepted in athletics as the outdoor track season. Finally, athletes were not excluded from the study based on age.

Data Analysis.

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

Statistical analysis.

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

*** Insert table 1 here ***

Results.

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

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

***Insert Figure 1 here ***

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

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

***Insert figure 2 here ***

800 m v 1500 m.

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

*** Insert figure 3 here ***
*** Insert figure 4 here ***

Male v Female athletes.

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

Level of athlete.

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

*** Insert table 2 here ***

Age group.

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

*** Insert table 3 here ***

***Insert Figure 5 here ***

***Insert Figure 6 here ***

***Insert Figure 7 here ***

***Insert Figure 8 here ***

Timing of the achievement of the fastest performance.

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

*** Insert table 4 here ***

*** Insert table 5 here ***

Discussion.

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

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

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

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

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

800 m v 1500 m.

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

Male v Female.

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

Variability in performance data by age and level.

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

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

Furthermore, whilst the variability might, in part, be attributed to a lack of effective planning, there is an element of uncertainty. Through incorporating the planning of the competition phase into coach education programmes, a coach whose athlete(s) appear(s) at either end of the ranges or who has had a large seasonal variation in when they achieve their fastest performance, could be supported to change practice and plan more effectively. The large variation is an indication that there is a need to determine evidence based guiding principles. In the absence of any other empirical evidence, these results can provide a tentative framework within which a coach can plan and evaluate both current and future practice.

Practical applications for athletes and coaches.

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

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

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

Conclusions.

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

Sex	Discipline	Q1 athletes	Q2 athletes	Q3 athletes	Q4 athletes
M	**800m**	1:43.8 – 1:48.1	1:48.1 – 1:49.4	1:49.4 – 1:50.6	1:50.6 – 1.52.8
W	**800m**	1:57.7 – 2:03.1	2:03.1 – 2:05.8	2:05.8 – 2:08.1	2:08.1 – 2.12.2
M	**1500m**	3:28.8 – 3:41.1	3:41.1 – 3:43.2	3:43.2 – 3:46.1	3:46.1 – 3:51.2
W	**1500m**	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.

	Apr-May	Post Aug	>120days from first race
Age group	**% of athletes**		
Senior	25	18	16
Under 23	28	18	20
Under 20	22	23	35

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

	Apr-May		Post Aug		>120days from first race	
Age group	**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.

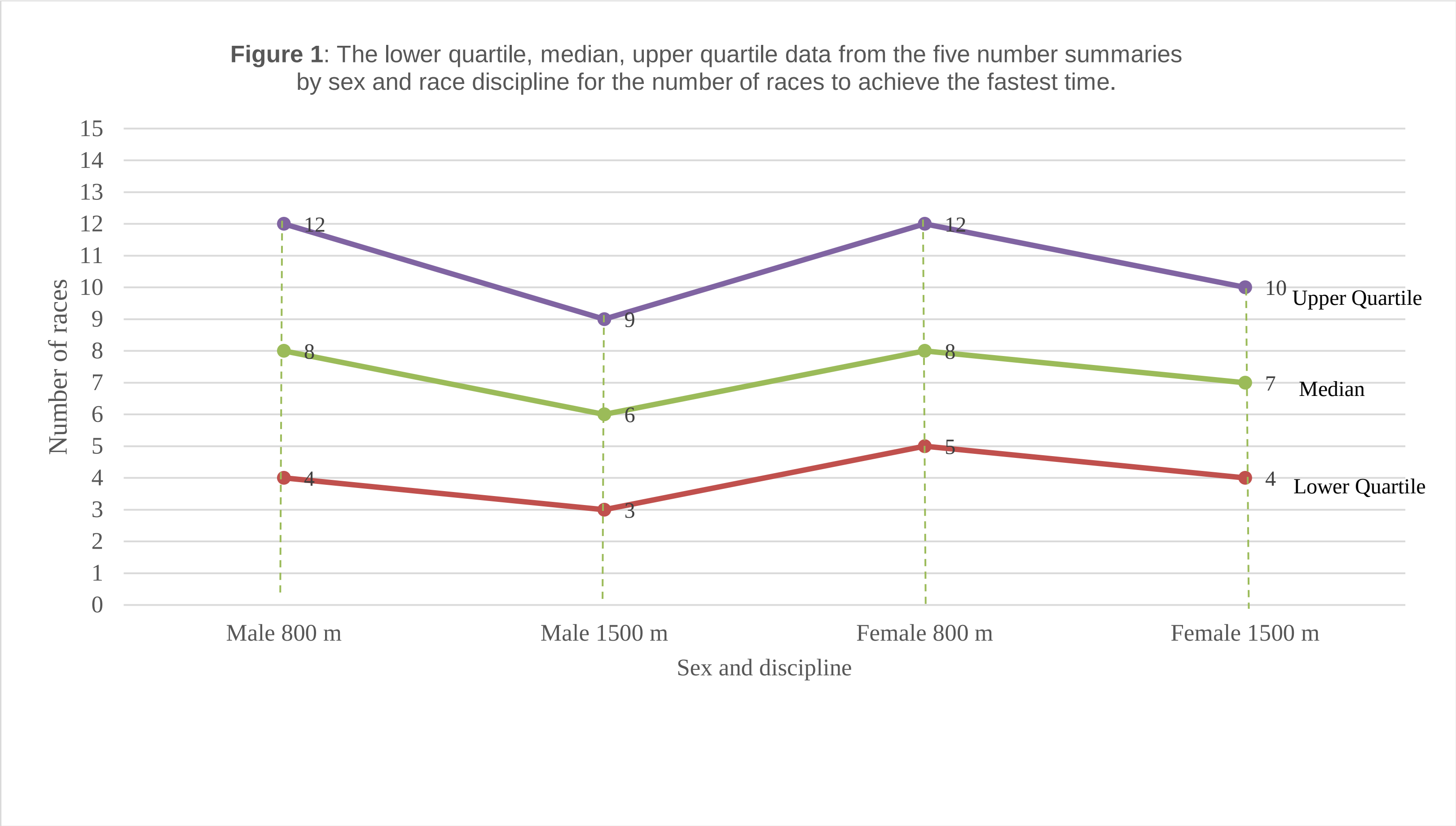


Figure 2: The lower quartile, median, upper quartile data from the five number summaries by sex and race discipline for number of days between first and fastest race.

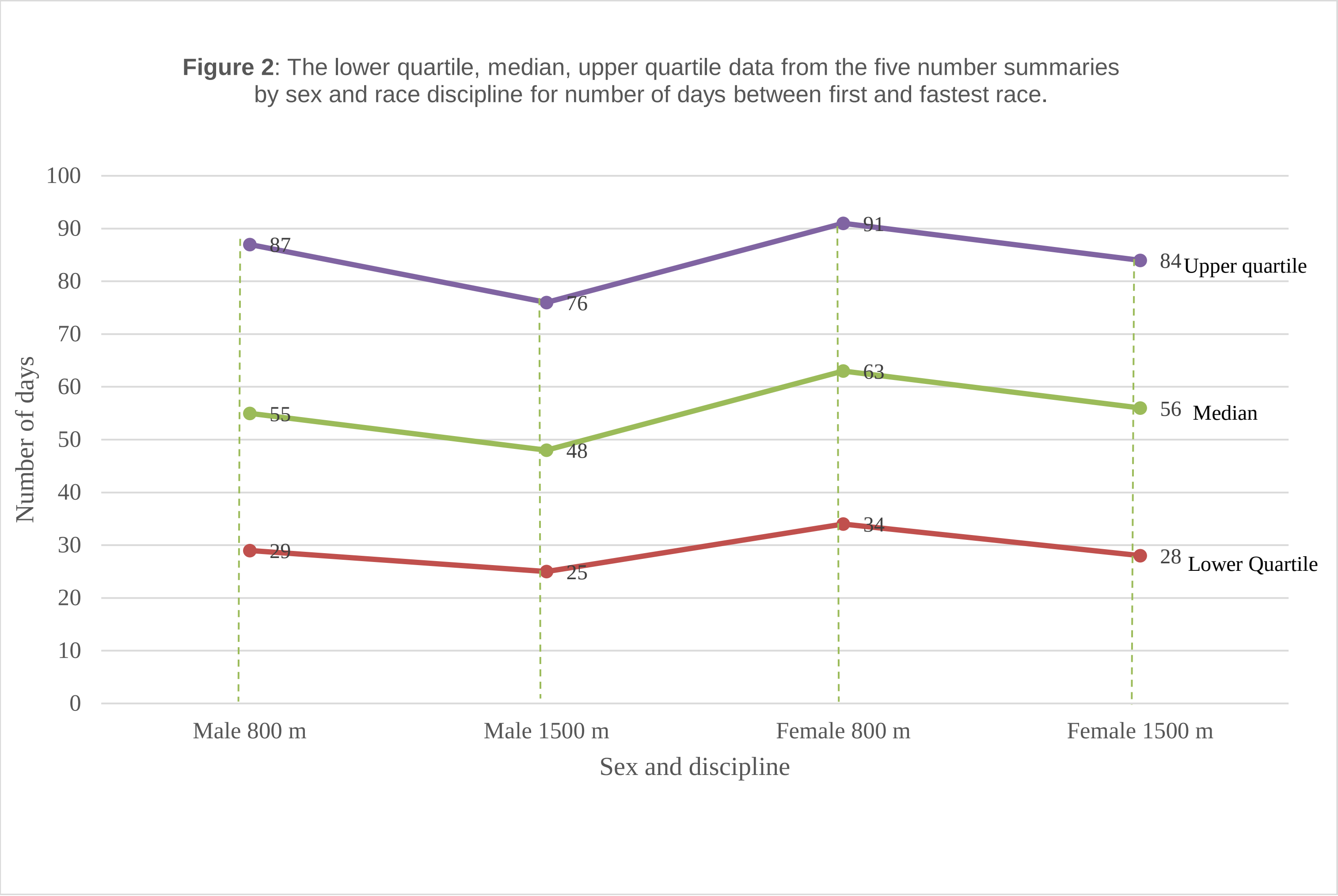
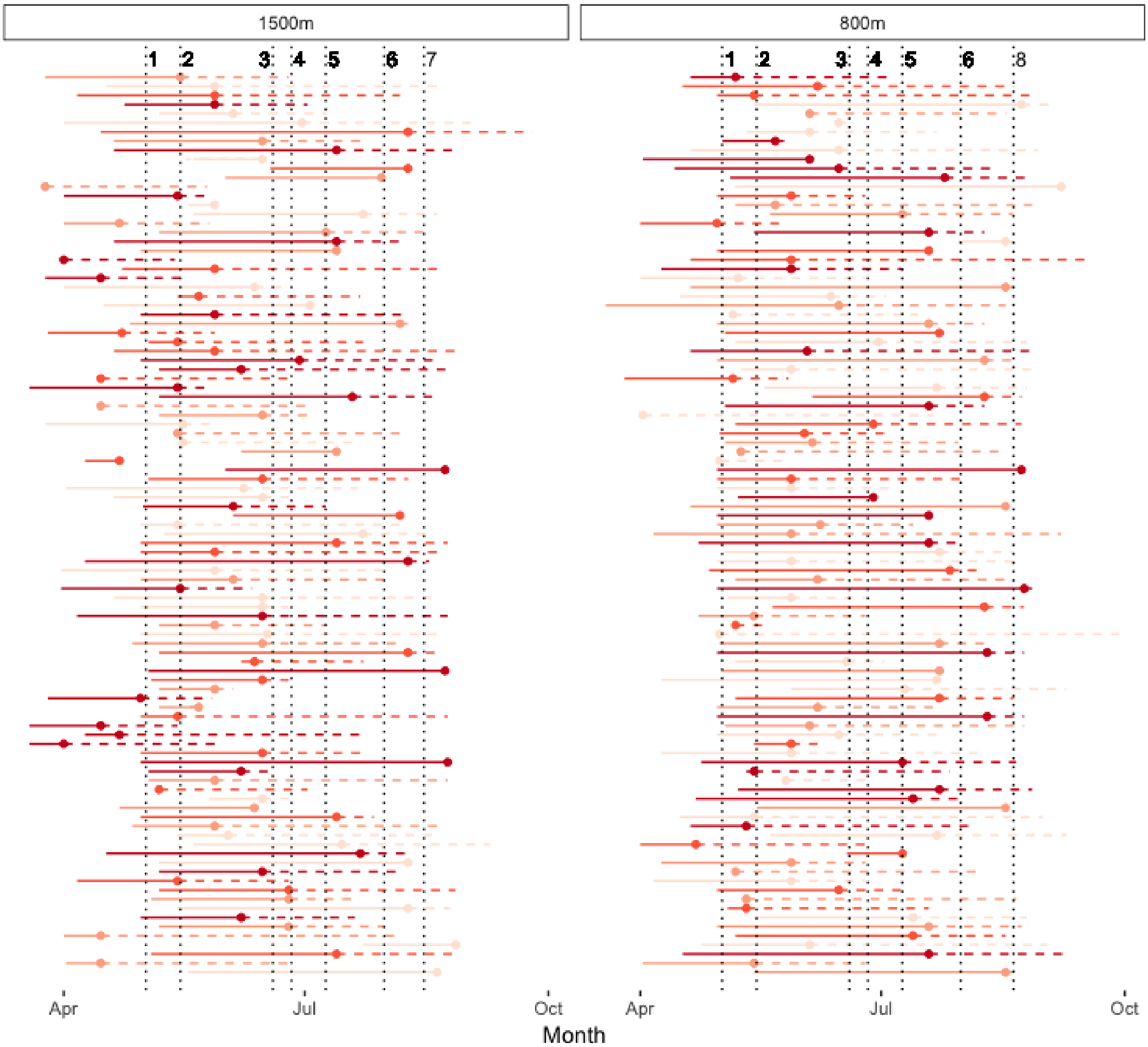
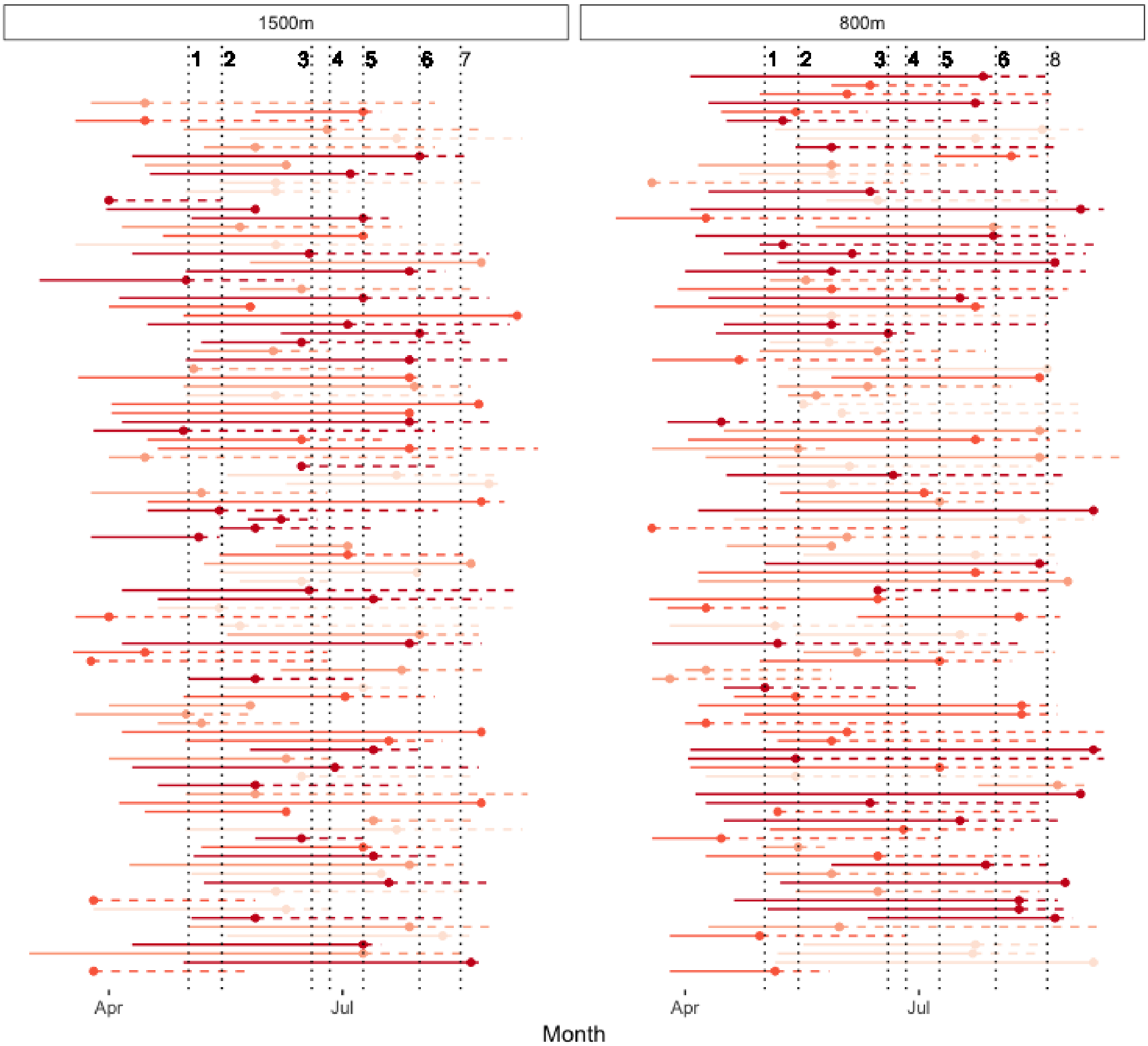


Figure 3: Caterpillar plots showing the variability in male athlete competition programmes for 2016 by discipline against where the important competitions occurred.



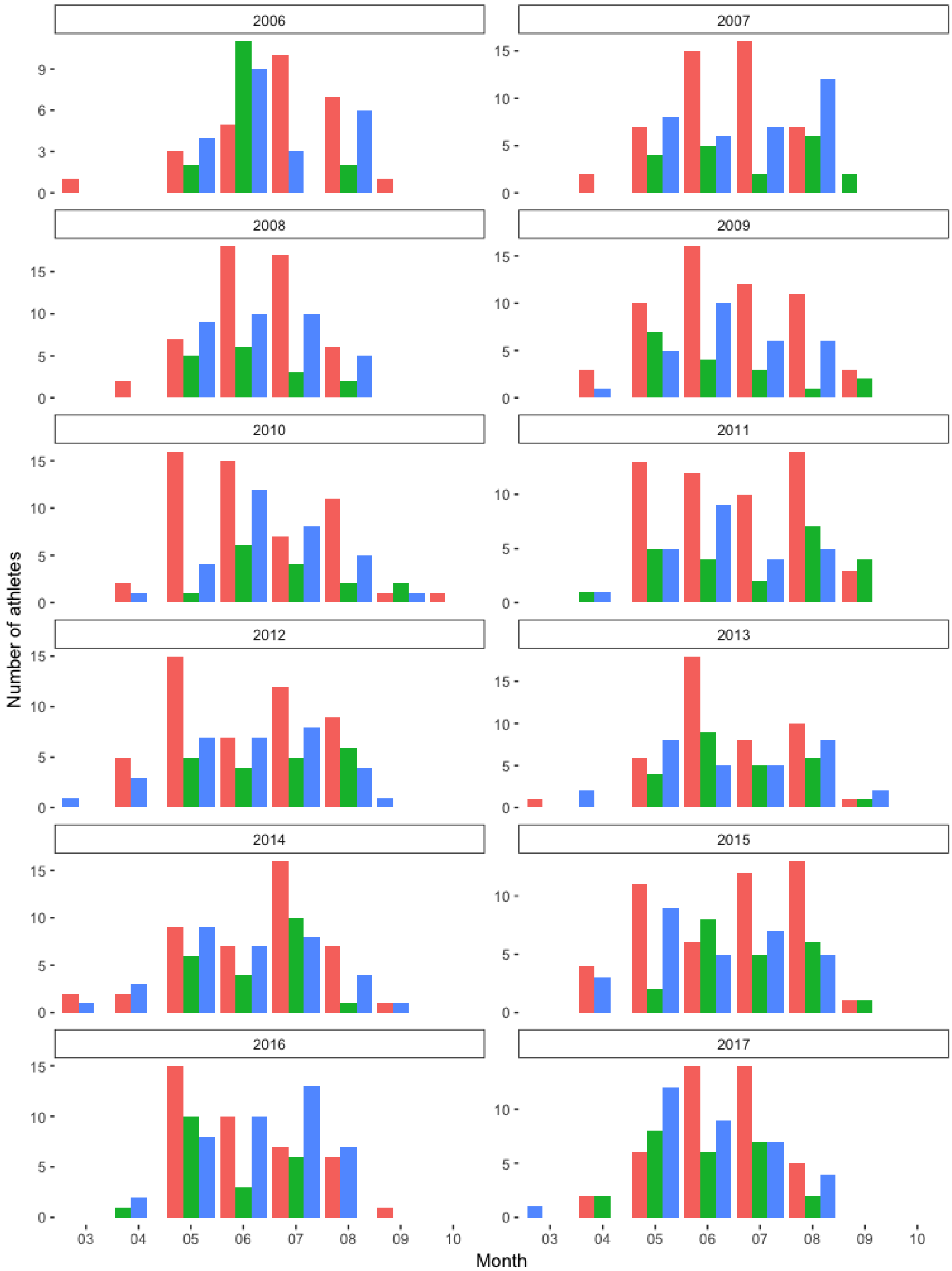
Legend Reference lines: 1 – County Championships; 2 – BUCS; 3 – AAA U20 & U23 Championships; 4 – British Athletics National Championships; 5 – ESAA Championships; 6 – AAA Senior Championships; 7 – Olympics 1500m final; 8 – Olympics 800m final

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



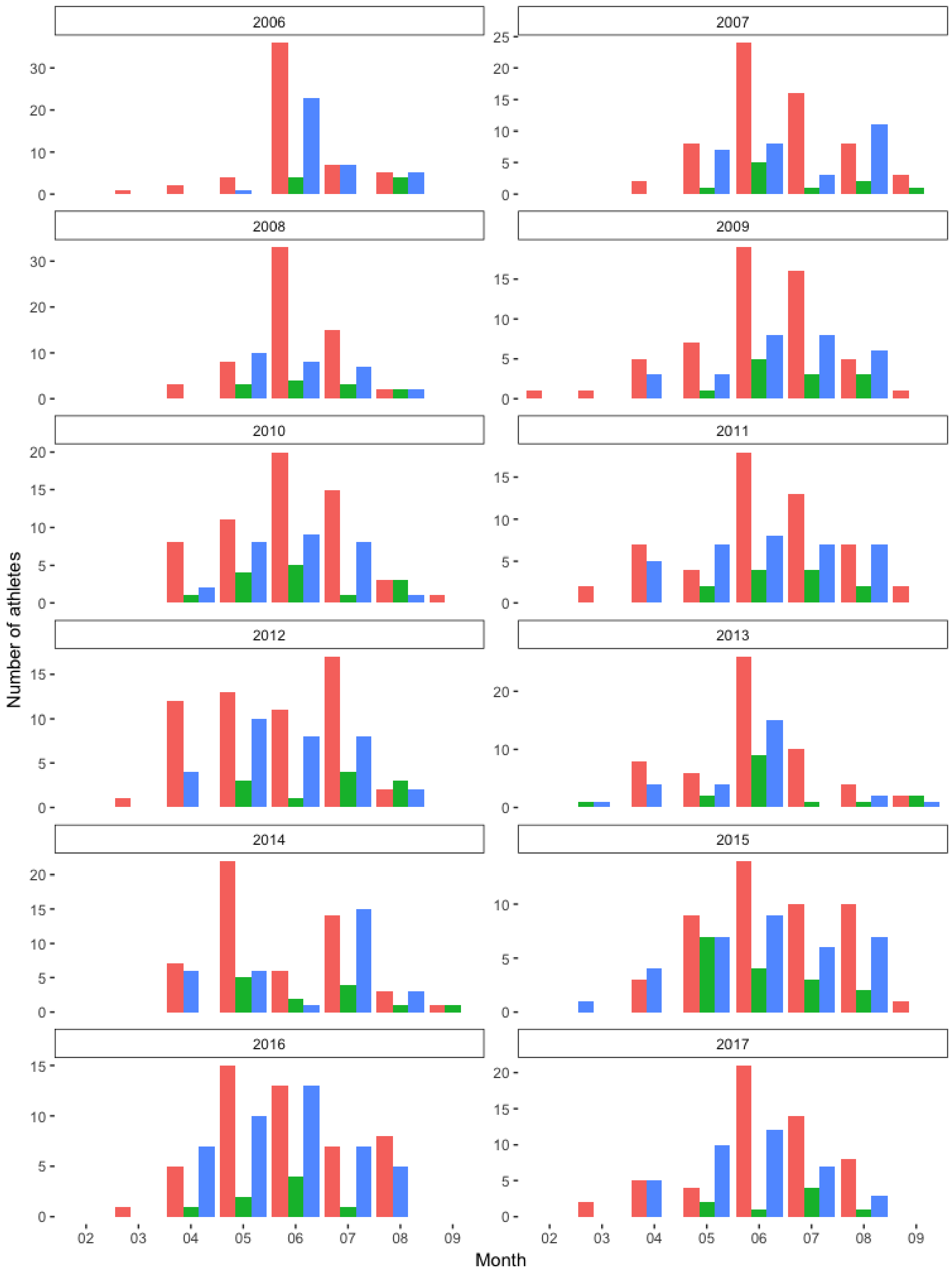
Legend Reference lines: 1 – County Championships; 2 – BUCS; 3 – AAA U20 & U23 Championships; 4 – British Athletics National Championships; 5 – ESAA Championships; 6 – AAA Senior Championships; 7 – Olympics 1500m final; 8 – Olympics 800m final

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



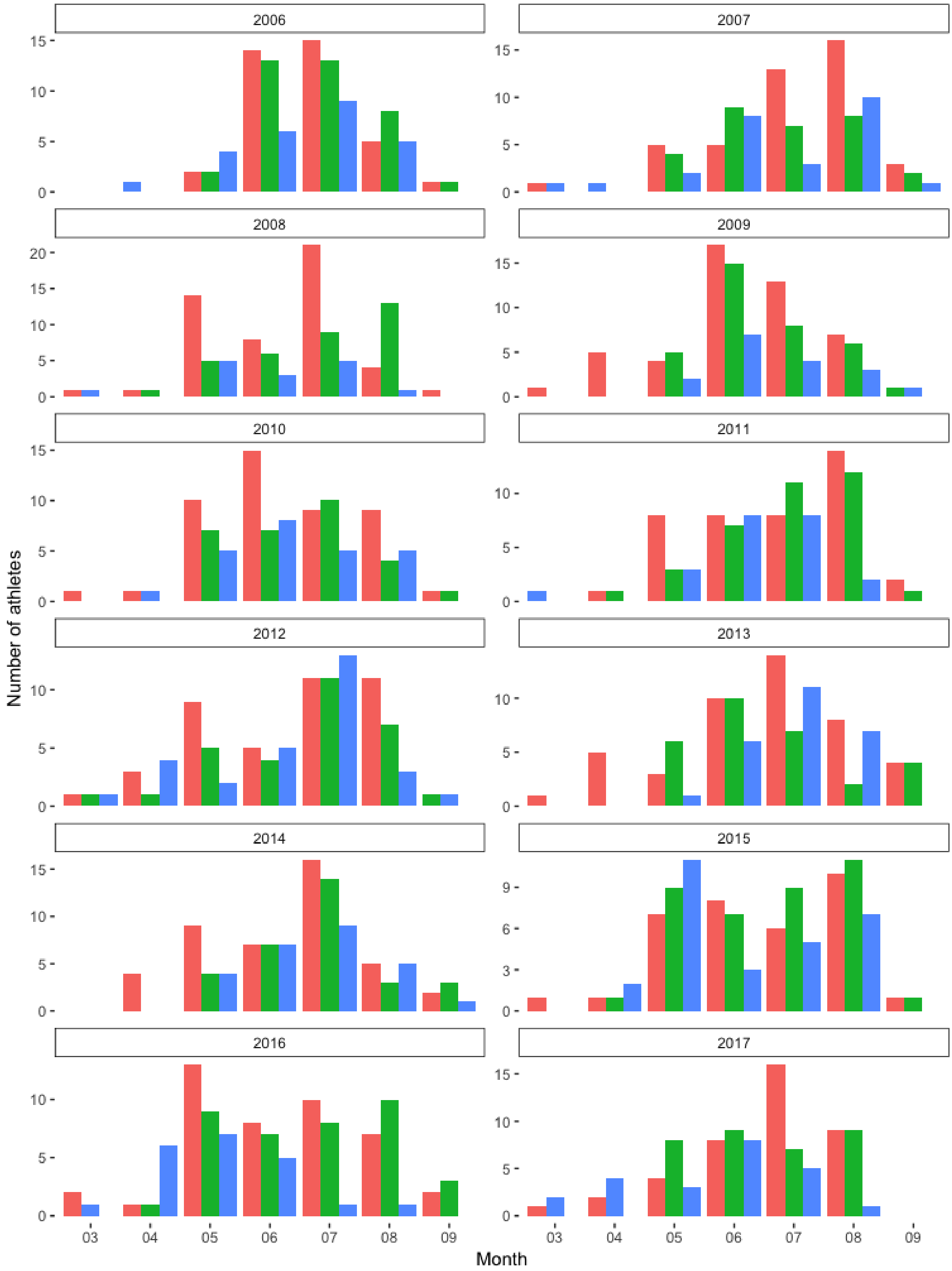
Age group legend: Red is 'Senior', 'Blue is U23', 'Green is U20'.

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



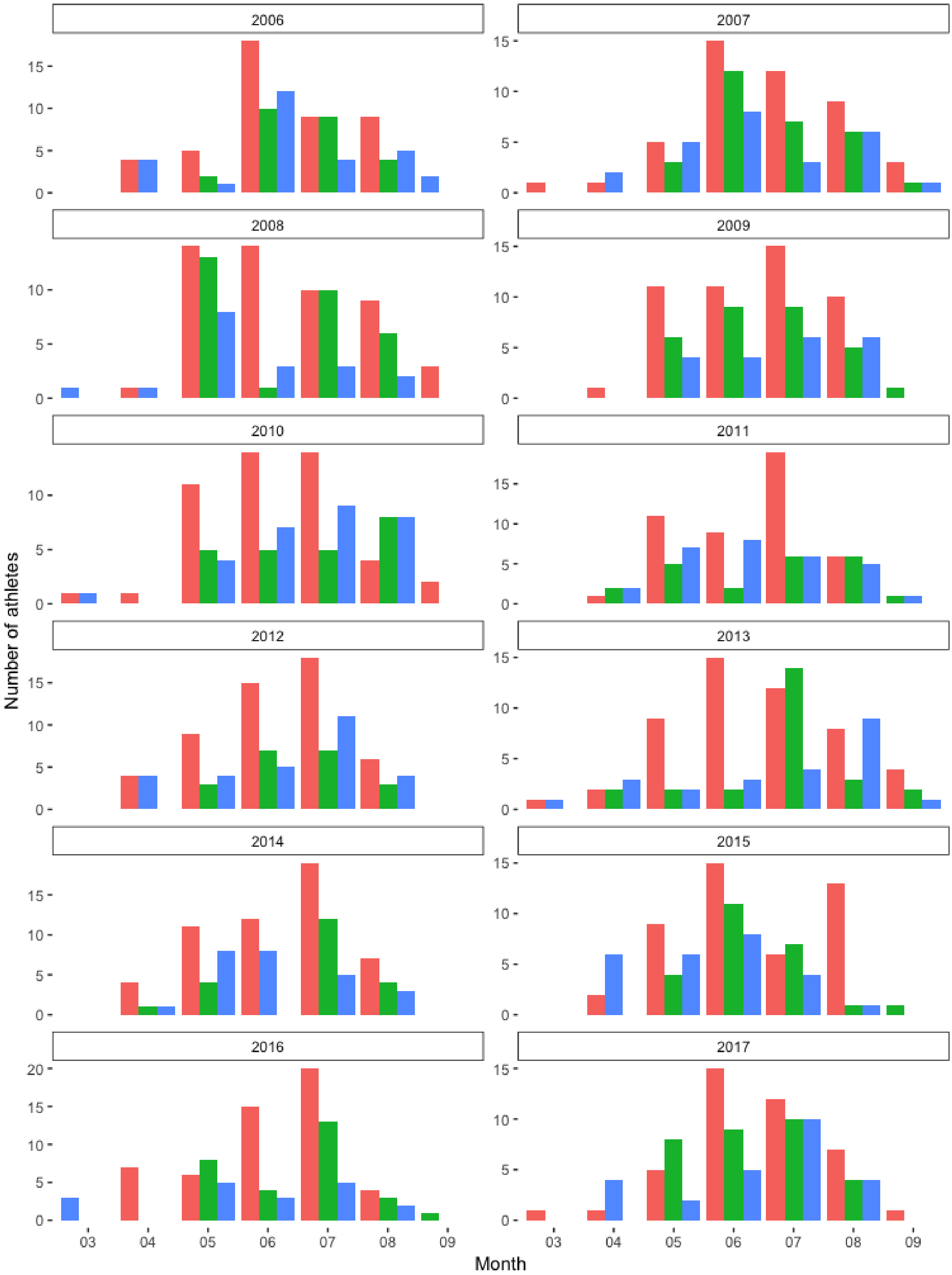
Age group legend: Red is 'Senior', 'Blue is U23', 'Green is U20'.

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'