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**Original Article**

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# Age of peak performance in Olympic sports: A comparative research among disciplines

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## ABSTRACT

Longo, A.F., Siffredi, C.R., Cardey, M.L., Aquilino, G.D., & Lentini, N.A. (2016). Age of peak performance in Olympic sports: A comparative research among disciplines. *J. Hum. Sport Exerc.*, 11(1), 31-41. This research aimed to study the ages of peak performance in Olympic sport disciplines, and to distinguish age groups among them. The ages (in decimal years) of athletes with the best performances at the 2012 Summer Olympics were considered (n = 3548). A total of forty sport disciplines were included; the athletics events were classified in six disciplines: Sprint, Middle-distance, Long-distance, Combined, Jumping and Throwing. A full statistical summary was produced. A regression tree was proposed for each gender to discriminate groups of sport disciplines according to age. The ages ranged from 14.0 to 52.8 years. The 72% of the athletes aged between 20 and 30 years, and the 99% aged below 40 years. The mean ages for men and women were 27.0 and 26.2 years, respectively. The regression tree analysis generated four groups of sport disciplines in men, and five in women. In men, the mean ages of the groups were: Group 1 = 24.4, Group 2 = 25.9, Group 3 = 28.0 and Group 4 = 30.8. In women, the mean ages of the groups were: Group 1 = 19.9, Group 2 = 22.7, Group 3 = 24.6, Group 4 = 26.5 and Group 5 = 28.3. The combat, gymnastics and swimming disciplines located mostly in the youngest groups in men; a similar tendency was evidenced in women, except for the combat sports. Apart from Combined, all athletics disciplines located in the groups 4 and 5 in women. On the contrary, these disciplines sited mainly in the groups 1 and 2 in men. All game and nautical sports placed in the two eldest groups in both genders, excluding women Water Polo. **Key words:** Olympic sports, peak performance, decimal age, regression trees.

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## INTRODUCTION

Sport performance is comprehended as an extent to which a motor task limited by rules of a given sport discipline is accomplished (Zahradník & Korvas, 2012). When planning an athlete's sport life, precise knowledge of the period when peak performance is more likely to occur is critical. The benefits in effectiveness and efficiency when having this information are substantial in training and competition programs. Up-to-date statistical data can provide major help to coaches and athletes at the time of designing long-term plans, bearing in mind the distinctive tendencies of the different sport disciplines.

The chronological age of highest performance differs among sports (Smith, 2003). Accurate information about the age at which peak performance is achieved for a given sport discipline at the highest levels of competition is imperative when setting realistic expectations of an athlete's future performance, as well as when implementing strategies to select and develop sport talents. More particularly, gathering data of the age of peak sport performance at the Olympic level represents valuable information for athletes and coaches involved in Olympic programs. Furthermore, identifying chronological similarities and differences in the occurrence of peak performance among the whole set of Olympic disciplines is a promising tool to enable a clearer comprehension of the link between age and type of sport in both genders.

In order to obtain accurate and current information, the research must be based on contemporary outcomes. Thus, the complete data collection of the ages of the best ranked athletes at the 2012 Summer Olympics, stratified by gender and sport discipline, is a desirable option. With the purpose of improving exactness, the computation of Age as decimal age is also an important task. Moreover, due to age variability across sports, a detailed classification of sport disciplines is crucial.

Classification and regression trees (Breiman et al., 1984) are modern statistical techniques for exploring and modeling large datasets. They are based on binary recursive partition of the predictor space into disjoint regions containing observations with similar values of the dependent variable; to make a prediction for a given observation, the mean or the mode of the observations in the region to which it belongs is typically used (James et al., 2013). These techniques are identified as "decision tree" methods, because the splitting rules used to segment the predictor space can be illustrated in a tree diagram. In classification trees the dependent variable is categorical, while in regression trees the dependent variable is continuous. In the present case, given the large number of sport disciplines involved, and the quantitative nature of the dependent variable, the regression tree is therefore a suitable method in order to discriminate groups of sport disciplines according to Age. The aim of this research was to study the ages of peak performance in the sport disciplines contested at the 2012 Summer Olympics, and to distinguish age groups among them by applying the regression tree analysis.

## METHODS

### **Subjects**

As a current indicator of age of peak performance, the ages of athletes with the best performances at the 2012 Summer Olympics held in London, United Kingdom, were considered ( $n = 3548$ ). The date of birth of the subjects was obtained from the International Olympic Committee (2015) and from Wikipedia (2015). The selection criteria for data collection in individual, double and team events are displayed in Table 1. Data of athletes that were subsequently disqualified from the competition were discarded.

Table 1. Selection criteria for data collection in individual, double and team events.

	Individual or Double	Team
Archery	Finalist	Semi-finalist
Artistic Gymnastics	Finalist	Top 4
Badminton	Quarter-finalist	
Basketball		Semi-finalist
Beach Volleyball	Quarter-finalist	
BMX Cycling	Finalist	
Boxing	Quarter-finalist	
Canoeing	Finalist	Top 4 (1)
Combined Athletics	Top 20	
Cross-country Cycling	Top 20	
Diving	Finalist	
Fencing	Quarter-finalist	Semi-finalist
Field Hockey		Semi-finalist
Football		Semi-finalist
Handball		Semi-finalist
Judo	Medal challenger	
Jumping Athletics	Finalist	
Long-distance Athletics	Finalist or Top 15	
Middle-distance Athletics	Finalist	
Modern Pentathlon	Top 20	
Open-water Swimming	Top 20	
Pool Swimming	Finalist	Top 4 (2)
Rhythmic Gymnastics	Finalist	Top 4
Road Cycling	Top 20	
Rowing	Finalist	Top 4 (3)
Sailing	Top 10 (4)	
Shooting	Finalist	
Sprint Athletics	Finalist	Top 4 (2)
Synchronized Swimming	Finalist	Top 4
Table Tennis	Quarter-finalist	Semi-finalist
Taekwondo	Medal challenger	
Tennis	Quarter-finalist	
Throwing Athletics	Finalist	
Track Cycling	Finalist or Top 8	Medal challenger (5)
Trampoline	Finalist	
Triathlon	Top 20	
Volleyball		Semi-finalist
Water Polo		Semi-finalist
Weightlifting	Top 8	
Wrestling	Medal challenger	

(1) Includes quadruple boats; (2) includes relay events; (3) includes quadruple and eight boats; (4) includes Women's Elliott 6m; (5) includes Women's Team Sprint.

### Procedures

A total of forty sport disciplines were included; the athletics events were classified in six disciplines: Sprint, Middle-distance, Long-distance, Combined, Jumping and Throwing. The classification of the athletics events is detailed in Table 2. The age in years of each athlete was calculated as decimal age, by subtracting the date of birth from the official start date of the 2012 Summer Olympics (Morgan, 2006):

$$\text{Age} = \frac{25 \text{ July } 2012 - \text{Date of birth}}{365.25} = [\text{years}].$$

Table 2. Classification of the athletics events.

Sprint	Middle distance	Long distance	Combined	Jumping	Throwing
100 m	800 m	5000 m	Heptathlon	Long Jump	Shot Put
200 m	1500 m	10000 m	Decathlon	Triple Jump	Discus Throw
400 m	3000 m stch *	Marathon		High Jump	Javelin Throw
100 m hurdles		20 km walk		Pole Vault	Hammer Throw
110 m hurdles		50 km walk			
400 m hurdles					
4 x 100 m relay					
4 x 400 m relay					

\* 3000 m steeplechase.

### Statistical Analysis

A statistical summary of Age was produced for men and women for the forty sport disciplines, including the sample size, the mean, the standard deviation and the five-number summary. A regression tree was proposed for each gender to discriminate groups of sport disciplines according to Age. The ANOVA method was selected to do the splits; the complexity parameter was fixed at 0.01. All analyses were performed using the R software environment, version 3.2.0 (R Core Team, 2015).

### RESULTS

The ages ranged from 14.0 to 52.8 years. The 72% of the athletes aged between 20 and 30 years, and the 99% aged below 40 years. The mean ages for men and women were 27.0 and 26.2 years, respectively. The regression tree analysis generated four final groups of sport disciplines in men, and five in women. In men, the mean ages of the groups were: Group 1 = 24.4 (n = 468), Group 2 = 25.9 (n = 362), Group 3 = 28.0 (n = 760) and Group 4 = 30.8 (n = 247). In women, the mean ages of the groups were: Group 1 = 19.9 (n = 88), Group 2 = 22.7 (n = 159), Group 3 = 24.6 (n = 327), Group 4 = 26.5 (n = 416) and Group 5 = 28.3 (n = 721). The sample size, the mean, the standard deviation and the five-number summary of Age for each sport discipline are presented in Table 3 for men and in Table 4 for women. The regression trees of Age for male and female athletes are depicted in Figure 1 and Figure 2, respectively. The final groups of sport disciplines generated by the tree analysis with their corresponding ranges of mean age are pointed out in Table 5 for men and in Table 6 for women.

Table 3. Men: Descriptive statistics for Age (in years) according to sport discipline.

	n	mean	sd	min	p.25	p.50	p.75	max
Archery	20	26,1	4,3	20,8	21,5	26,1	28,8	36,2
Artistic Gymnastics	72	23,7	3,5	18,3	20,9	23,5	25,2	39,4
Badminton	23	27,3	3,8	21,4	24,8	26,5	29,8	35,6
Basketball	48	27,9	4,1	18,8	24,5	27,8	31,6	35,2
Beach Volleyball	16	30,5	5,9	21,2	25,5	29,6	36,0	39,3
BMX Cycling	8	23,2	2,5	19,9	20,7	24,0	25,4	25,9
Boxing	77	24,8	3,2	17,5	22,6	24,8	26,7	32,3
Canoeing	116	27,8	4,2	19,4	24,3	27,5	30,8	39,4
Combined Athletics	20	25,5	3,0	20,5	23,5	25,2	27,5	31,0
Cross-country Cycling	15	28,2	4,7	21,6	25,5	27,5	31,3	36,6
Diving	56	23,5	4,2	17,5	20,7	22,8	26,5	33,0
Fencing	55	27,2	4,0	18,3	24,7	27,0	29,3	39,7
Field Hockey	53	27,0	3,3	19,8	24,8	27,0	29,3	36,3
Handball	60	29,8	4,2	21,9	27,0	29,8	32,8	40,9
Judo	41	26,7	3,6	20,5	23,6	25,9	28,2	34,1
Jumping Athletics	52	26,3	3,8	21,1	23,8	25,8	28,0	36,0
Long-distance Athletics	75	27,8	4,7	18,2	24,3	27,6	30,4	38,0
Middle-distance Athletics	35	25,0	3,6	17,7	23,0	23,8	27,7	31,5
Modern Pentathlon	20	26,9	3,6	19,6	24,3	26,5	29,5	33,7
Open-water Swimming	19	27,8	3,8	22,1	24,5	28,0	30,2	35,8
Pool Swimming	151	24,6	3,3	17,1	22,3	24,5	27,2	32,1
Road Cycling	40	29,5	4,3	22,1	26,5	28,8	32,3	39,0
Rowing	126	28,2	4,3	20,0	25,0	27,7	30,4	40,4
Sailing	72	31,1	5,6	21,6	26,5	31,2	35,5	44,1
Shooting	59	32,6	7,7	19,3	26,3	30,9	37,9	49,3
Sprint Athletics	71	25,3	3,8	18,7	22,6	25,3	27,8	34,9
Table Tennis	19	28,3	3,8	23,8	24,4	28,6	31,4	35,3
Taekwondo	24	25,5	3,6	18,9	23,6	25,8	28,4	32,4
Tennis	24	29,1	3,8	22,6	26,7	28,5	31,3	36,1
Throwing Athletics	48	29,2	4,4	19,3	26,8	29,5	31,1	40,5
Track Cycling	50	25,5	3,6	19,8	23,4	25,0	26,5	36,3
Trampoline	8	24,6	2,5	20,9	23,3	23,8	26,2	28,6
Triathlon	19	28,6	4,5	22,2	24,4	28,5	31,1	36,2
Volleyball	48	28,8	4,7	19,9	25,4	28,7	31,6	39,2
Water Polo	52	28,6	4,1	18,1	26,1	28,2	30,7	38,7
Weightlifting	61	24,5	3,3	18,3	21,6	23,9	27,2	31,4
Wrestling	84	26,2	2,9	19,0	24,4	26,3	27,7	33,0

n: number of observations; sd: standard deviation; min: minimum; p.25: 25<sup>th</sup> percentile; p.50: 50<sup>th</sup> percentile; p.75: 75<sup>th</sup> percentile; max: maximum.

Table 4. Women: Descriptive statistics for Age (in years) according to sport discipline.

	n	mean	sd	min	p.25	p.50	p.75	max
Archery	20	24,7	4,2	18,9	22,5	24,3	26,7	38,6
Artistic Gymnastics	60	19,4	3,4	15,8	17,0	18,2	20,6	37,1
Badminton	24	25,8	4,3	17,5	22,9	25,9	27,1	38,0
Basketball	48	28,1	3,7	20,6	25,5	27,9	31,1	37,4
Beach Volleyball	16	28,3	4,0	21,9	25,6	27,8	30,1	35,0
BMX Cycling	8	22,2	2,5	18,6	20,4	22,6	23,9	26,0
Boxing	22	26,3	4,1	17,4	23,3	26,3	29,3	33,7
Canoeing	57	27,5	5,6	18,1	23,5	26,0	29,9	47,8
Combined Athletics	19	25,3	3,8	19,5	22,9	24,6	27,6	33,0
Cross-country Cycling	18	29,4	5,8	19,7	24,8	29,2	32,8	40,6
Diving	55	23,9	4,0	15,3	20,9	24,4	26,7	33,1
Fencing	56	26,7	4,6	18,1	23,4	26,3	29,6	38,4
Field Hockey	63	26,3	3,8	18,9	23,3	26,3	28,2	35,0
Football	72	27,5	3,8	19,4	24,9	27,5	30,0	38,9
Handball	58	27,7	4,7	18,9	24,2	27,4	32,0	39,5
Judo	42	26,1	3,7	21,0	22,9	26,0	28,8	35,4
Jumping Athletics	47	28,0	4,4	20,0	25,3	27,7	30,6	40,0
Long-distance Athletics	60	28,9	4,7	18,8	26,3	28,8	30,9	39,9
Middle-distance Athletics	31	25,8	4,8	19,2	21,9	26,1	28,0	37,1
Modern Pentathlon	19	25,1	4,1	19,7	22,1	23,7	27,9	36,3
Open-water Swimming	19	25,3	4,6	19,2	21,6	24,6	27,3	37,0
Pool Swimming	151	22,7	3,4	14,0	20,9	22,6	24,7	34,9
Rhythmic Gymnastics	28	21,0	2,8	17,0	18,5	21,1	23,2	26,1
Road Cycling	39	29,3	5,7	20,5	24,2	28,8	33,3	39,8
Rowing	88	28,6	4,9	21,4	25,7	27,6	31,0	52,8
Sailing	59	28,4	4,5	20,0	25,1	27,6	31,5	42,5
Shooting	44	28,4	5,3	19,8	25,3	28,1	30,8	42,2
Sprint Athletics	71	26,8	2,8	22,0	24,9	26,4	29,4	32,7
Synchronized Swimming	60	24,3	2,8	18,0	22,4	23,8	26,0	31,3
Table Tennis	19	27,3	5,7	19,4	23,7	25,9	31,7	39,5
Taekwondo	24	23,8	3,3	18,5	21,5	24,7	25,6	31,4
Tennis	24	27,7	4,1	22,0	25,3	26,5	29,6	39,0
Throwing Athletics	46	27,1	3,6	19,1	24,2	26,9	29,4	35,2
Track Cycling	42	26,2	4,5	20,1	22,4	25,7	28,9	39,4
Trampoline	8	25,3	4,3	19,1	23,2	24,2	27,6	31,8
Triathlon	19	30,2	3,7	22,5	28,0	30,3	31,3	37,3
Volleyball	48	27,8	3,9	21,2	24,9	27,6	30,5	39,8
Water Polo	52	24,9	4,1	18,9	21,7	24,6	27,1	34,4
Weightlifting	51	25,1	4,3	17,7	22,0	25,4	27,4	36,7
Wrestling	24	28,7	4,4	19,8	24,9	29,9	31,7	35,1

n: number of observations; sd: standard deviation; min: minimum; p.25: 25<sup>th</sup> percentile; p.50: 50<sup>th</sup> percentile; p.75: 75<sup>th</sup> percentile; max: maximum.

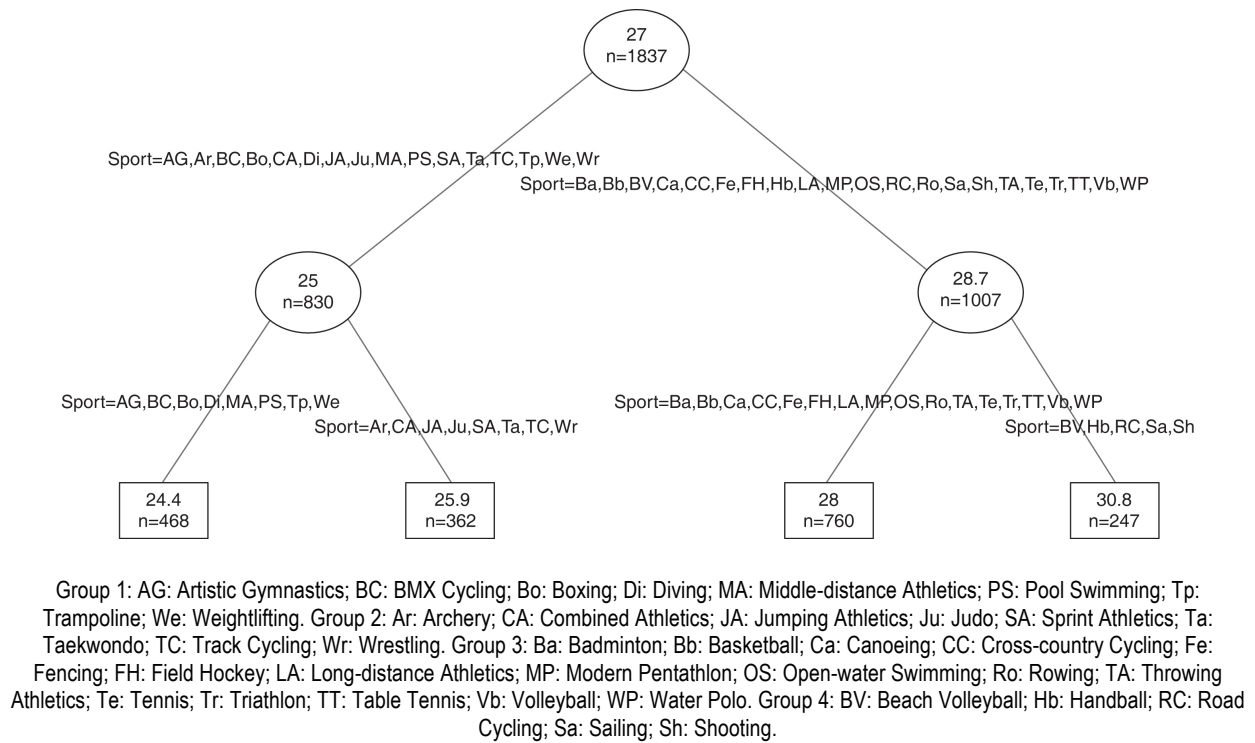


Figure 1. Regression tree of Age (in years) for male athletes.

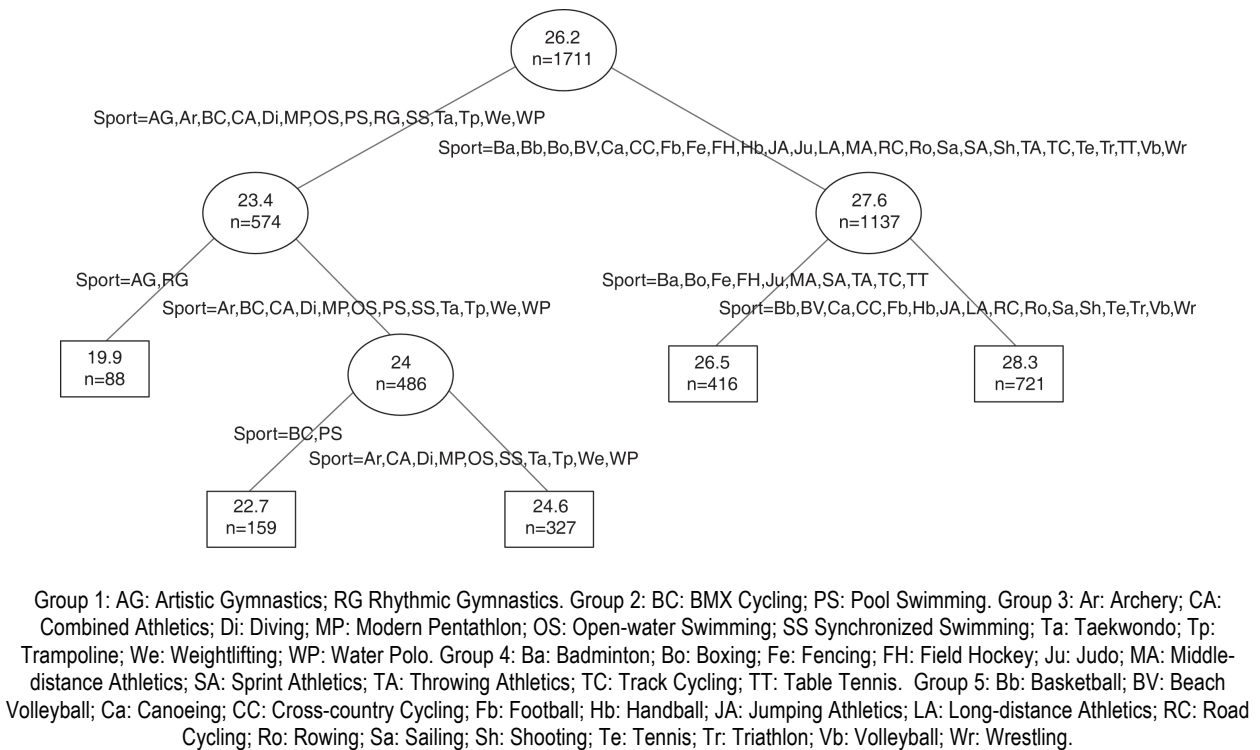


Figure 2. Regression tree of Age (in years) for female athletes.

Table 5. Men: Groups of sport disciplines generated by regression tree analysis (with ranges of mean age). The disciplines in each group are listed in increasing order of mean age.

Group 1 (23.2 - 25.0)	Group 2 (25.3 - 26.7)	Group 3 (26.9 - 29.2)	Group 4 (29.5 - 32.6)
BMX Cycling	Sprint Athletics	Mod. Pentathlon	Road Cycling
Diving	Taekwondo	Field Hockey	Handball
Art. Gymnastics	Track Cycling	Fencing	Beach Volleyball
Weightlifting	Comb. Athletics	Badminton	Sailing
Pool Swimming	Archery	L.D. Athletics	Shooting
Trampoline	Wrestling	O.W. Swimming	
Boxing	Jump. Athletics	Canoeing	
M.D. Athletics	Judo	Basketball	
		C.C. Cycling	
		Rowing	
		Table Tennis	
		Triathlon	
		Water Polo	
		Volleyball	
		Tennis	
		Throw. Athletics	

M.D. Athletics: Middle-distance Athletics; L.D. Athletics: Long-distance Athletics; O.W. Swimming: Open-water Swimming; C.C Cycling: Cross-country Cycling.

Table 6. Women: Groups of sport disciplines generated by regression tree analysis (with ranges of mean age). The disciplines in each group are listed in increasing order of mean age.

Group 1 (19.4- 21.0)	Group 2 (22.2 - 22.7)	Group 3 (23.8 - 25.3)	Group 4 (25.8 - 27.3)	Group 5 (27.5 - 30.2)
Art. Gymnastics	BMX Cycling	Taekwondo	M.D. Athletics	Football
Rhyt. Gymnastics	Pool Swimming	Diving	Badminton	Canoeing
		Sync. Swimming	Judo	Tennis
		Archery	Track Cycling	Handball
		Water Polo	Field Hockey	Volleyball
		Mod. Pentathlon	Boxing	Jump. Athletics
		Weightlifting	Fencing	Basketball
		Trampoline	Sprint Athletics	Beach Volleyball
		O.W. Swimming	Throw. Athletics	Shooting
		Comb. Athletics	Table Tennis	Sailing
				Rowing
				Wrestling
				L.D. Athletics
				Road Cycling
				C.C. Cycling
				Triathlon

M.D. Athletics: Middle-distance Athletics; L.D. Athletics: Long-distance Athletics; O.W. Swimming: Open-water Swimming; C.C Cycling: Cross-country Cycling.



## DISCUSSION

A long-term training plan covers a period of 10-15 years of an athlete's competitive life (Smith, 2003). There are multiple factors that have influence on the athletic performance. The physical, technical, tactical and psychological factors are conventionally recognized as core components of sport training (e.g., Matveyev, 1981; Harre, 1982; Bompa, 1999; Platonov, 1997; Verkhoshansky, 2002; Smith, 2003). The conditional and coordinative abilities, the level of tactical knowledge and the psychological skills are essential aspects that greatly define the chances of success in competition. Optimal performance involves and integration of each of these components (Smith, 2003).

The required levels of the physical, technical, tactical and psychological capacities vary among sports. The relevance of each of these factors depends on a specific sport discipline. For instance, the relative importance of the physical, technical, tactical and psychological components is not the same for a marathon runner as for a gymnast or a basketball player (Zahradnik & Korvas, 2012). These differences likely contribute substantially to the broad range of ages of peak performance of the top Olympic athletes.

Valuable information can be achieved from the results of the data analysis on the ages of the best ranked athletes at the 2012 Summer Olympics. The overall statistical description exposed the main features of the data distribution. The age range was about 39 years. More than two third of the athletes aged between 20 and 30 years, and nearly all of them aged below 40 years. On a general average, male athletes reached the age of peak performance approximately one year later than female athletes. The stratified results by gender and sport discipline exhibited in Table 3 and Table 4 are generally consistent with recent studies related to specific sport disciplines at high levels of competition (e.g., Elmenshawy et al., 2015; Hollings et al., 2014; Hunter et al., 2011; Kovalchik, 2014; Malcata et al., 2014; Wolfrum, et al., 2013).

On the other hand, the regression tree analysis on Age identified a matching pattern among the disciplines, defining 4 groups in the end nodes in men, and 5 in women. The combat, gymnastics and swimming disciplines located mostly in the youngest groups in men; a similar tendency was evidenced in women, except for the combat sports. Apart from Combined, the athletics disciplines sited in the two groups with the highest mean age in women. On the contrary, these disciplines placed mainly in the two groups with the lowest mean age in men. All game and nautical sports located in the two eldest groups in both genders, excluding women Water Polo. Among the cycling disciplines, BMX showed the lowest mean age in both male and female athletes, and set in the youngest group of the regression tree for men and in the second youngest group of the regression tree for women.

This study provides a rigorous statistical analysis by gender of the ages of peak performance for the whole set of sport disciplines included at the 2012 Summer Olympics, with the exceptions of Equestrian, where men and women competed equally against each other (Wood, 2015), and Men's Football, where there was an age restriction (Valcke, 2010); the Tennis' mixed doubles event was also excluded. Measures of central tendency, spread and position are presented, stratified by gender and sport discipline. Furthermore, the use of a modern statistical approach allowed to identify similarities and discrepancies among the full spectrum of disciplines.

This research was intended as a contribution for a better understanding of the relationships between age, gender and type of sport, and, consequently, for the enhancement of the coaching and talent identification strategies. Moreover, an accurate description of the distribution of the ages of peak performance for men and women at the different Olympic disciplines is profitable information at the time of planning long-term

training programs for events at the highest levels. Besides, the results of this study may be used in combination with information about the time required to reach the highest levels of competition in the different sport disciplines, in order to estimate the chronological setting of the phase for in-depth specialization towards maximum performance.

### **Limitations**

Although the results obtained in these study are in general consistent with others reported in recent literature, the conclusions emerged from them should be updated on the basis of future data. In addition, a more detailed classification of sport disciplines may be an improved alternative for sports with a large number of events.

### **CONCLUSIONS**

The ages of peak performance cover a wide range at the Olympic level. On average, male athletes reach the highest levels of performance at a more advanced age than female athletes. As a general trend for both genders, the disciplines involving very specific technical skills include the youngest athletes, such as the gymnastics and swimming disciplines. On the other hand, the eldest athletes are mostly found in sports requiring higher levels of tactical skills, such as game sports, and also in nautical sports. It would be advisable to collect subsequent data to confirm these tendencies.

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