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Research article

Tracking the performance of world-ranked swimmers

Mário J. Costa [1,3,4], Daniel A. Marinho [2,4], Victor M. Reis [3,4], António J. Silva [3,4], Mário C. Marques [2,4], José A. Bragada [1,4] and Tiago M. Barbosa [1,4] ✉

[1] Department of Sport Sciences, Polytechnic Institute of Bragança, Bragança, Portugal; [2] Department of Sport Sciences, University of Beira Interior, Covilhã, Portugal; [3] Department of Sport Sciences, Exercise and Health, University of Trás-os-Montes and Alto Douro, Vila Real, Portugal; [4] Research Centre in Sports Science, Health and Human Development, Vila Real, Portugal

Abstract

Tracking the swimming performance is important to analyze its progression and stability between competitions and help coaches to define realistic goals and to select appropriate training methods. The aim of this study was to track world-ranked male swimmer's performance during five consecutive seasons (from 2003/2004 to 2007/2008) in Olympic freestyle events. An overall of 477 swimmers and 2385 season best performances were analyzed. FINA's male top-150 rankings for long course in the 2007-2008 season were consulted in each event to identify the swimmers included. Best performances were collected from ranking tables provided by the National Swimming Federations or, when appropriate, through an internet database (www.swimranking.net). Longitudinal assessment was performed based on two approaches: (i) mean stability (descriptive statistics and ANOVA repeated measures, followed by a Bonferroni post-hoc test) and; (ii) normative stability (Pearson Correlation Coefficient and the Cohen's Kappa tracking index). Significant variations in the mean swimming performance were observed in all events between all seasons. Performance enhancement was approximately 0.6 to 1 % between seasons leading up to the Olympics and approximately 3 to 4 % for the overall time-frame analyzed. The performance stability based on overall time-frame was moderate for all freestyle events, except in the 50-m ($K = 0.39 \pm 0.05$) where it was low. Self-correlations ranged between a moderate ($0.30 \leq r < 0.60$) and a high ($r \geq 0.60$) stability. There was also a performance enhancement during all five seasons analyzed. When more strict time frames were used, the analysis of swimming performance stability revealed an increase in the third season. So, coaches should have a long term view in what concerns training design and periodization of world-ranked swimmers, setting the third season of the Olympic Cycle as a determinant time frame, due to performance stability until Olympic Games season.

Key words: Longitudinal assessment, freestyle, swimming, elite swimmers.

Introduction

The majority of the studies in swimming "science" have a cross-sectional character. Indeed, they do not consider performance stability and change as result, for example, of individual development, new training methods and/or technological sophistication. On the other hand, the longitudinal approaches regarding competitive swimming are few. Some papers aimed to obtain comprehensive knowledge about the role of bioenergetics (Pyne et al., 2001; Thompson et al., 2006) and biomechanics (Craig et al., 1985; Arellano et al., 1994; Huot-Marchand et al., 2005) issues in performance enhancement. Others tried to establish relationships between these two domains and swimming performance (Anderson et al., 2008; Latt et al., 2009a; 2009b). However, there has been little research focused on the annual performance progression (Pyne et al., 2004; Stewart and Hopkins, 2000; Trewin et al., 2004).

It was demonstrated that the longitudinal performance assessment is important to help coaches to define realistic goals and training methods (Pyne et al., 2004). Longitudinal assessment can therefore be developed by tracking the swimmers' performance for a given period of time, analyzing its progression between competitions and/or seasons. This information can be used to: (i) describe and estimate the progression and the variability of performance during and between seasons; (ii) find hypothetical chronological points determinant to predict swimmer's performance throughout his/her career or a given time frame and; (iii) determine swimmer's probability to reach finals or win medals in important competitions.

Swimming has been experiencing a very quick development in all events, since world records have been broken so often. Moreover, its maximal expression was achieved in the time frame between the Athens 2004 and Beijing 2008 Olympic Games. However, no scientific study until now has attempted to quantify and/or systematically describe these performance enhancements over the last few seasons.

A small number of attempts were made to track competitive swimmers performance. Pyne et al. (2004), in a 12 month time-frame study, made an attempt to understand the swimmers performance behaviour leading up to the 2000 Olympic Games. They reported that to stay in contention for a medal, a Sydney's 2000 Olympic swimmer should improve his/her performance by approximately 1 % within a competition and by approximately 1 % within the year leading up to the Olympics. Authors also stated that presumably an additional enhancement of approximately 0.4 % would substantially increase the swimmer's chances of winning a medal (Pyne et al., 2004). Some attempts were made to predict swimming performance as well. Trewin et al. (2004) verified that by examining the relationship between world-ranking and the 2000 Olympic performance, most of the Olympic medallists (87 %) had a top-10 world-ranking in the Olympics

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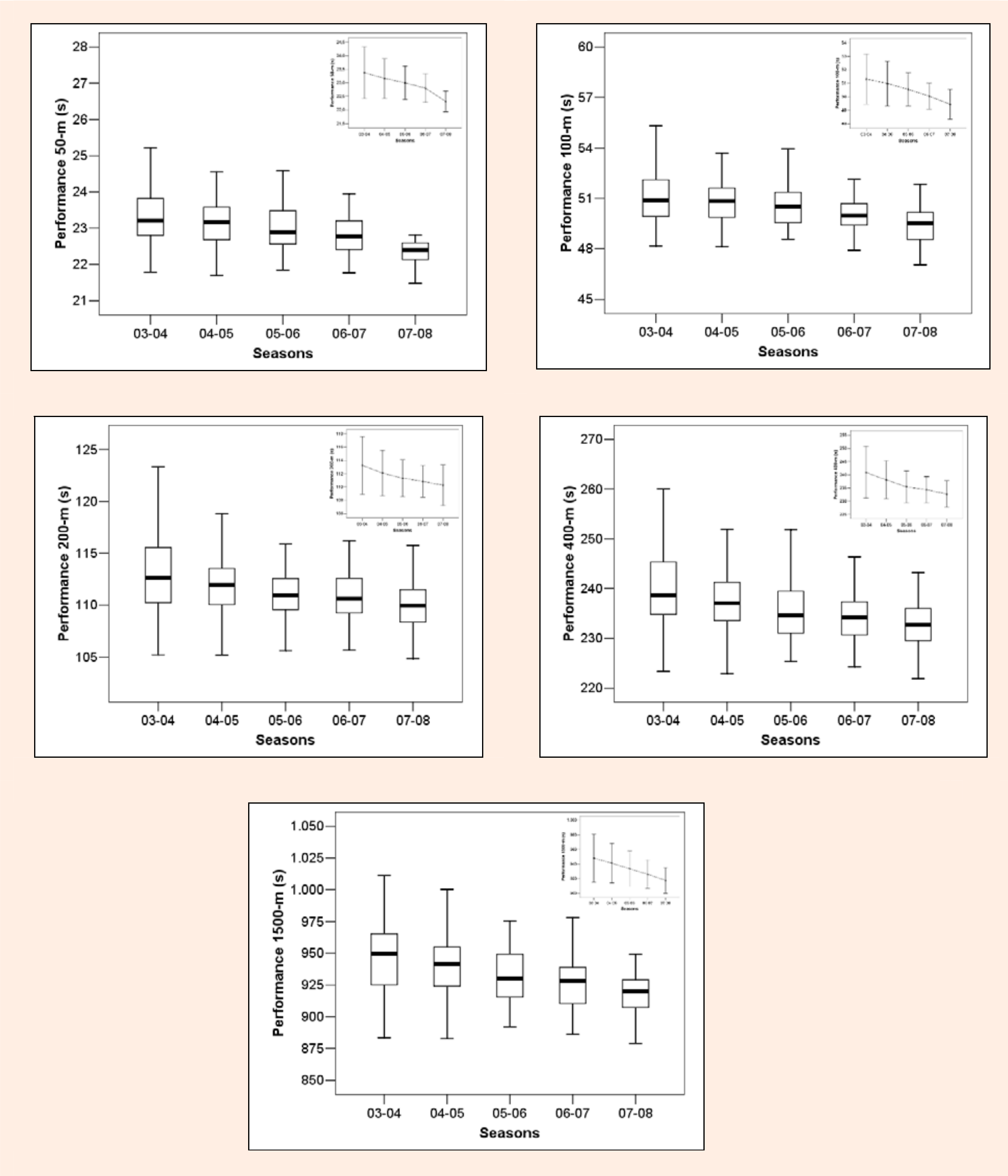

Figure 1. Variation of swimming performance during five consecutive seasons in the freestyle events.

year. Sokolovas (2006) reported that half of the American 100-top swimmers with 18 years of age have never been in that top in younger ages, such as, before 10 and 12 years. Nevertheless, appears not exist any research so far analyzing the change and stability of world-ranked swimmers' performance using the tracking approach.

The purpose of this study was to analyze the stability and change of male world-ranked swimmers' performance in freestyle Olympic events for five consecutive seasons, namely between the 2004 and the 2008 Olympic Games.

Methods

Procedures

It was considered as inclusion criteria to be a FINA's male top-150 world-ranked swimmer for long course during the 2007-2008 season, in any of the freestyle events presented in the Olympic calendar (the 50m, 100m, 200m, 400m and 1500m events). On the contrary, an exclusion criteria was considered:: (i) to be a swimmer from the FINA's top-150, but authors did not have access to season best performance in the five consecutive

Table 1. Changes (%) in mean performance time between seasons and in the overall time frame analyzed. Data are means (±SD).

	Between Seasons				Overall time frame
	03/04 04/05	04/05 05/06	05/06 06/07	06/07 07/08	03-08
50m	.84 (2.08)	.68 (1.71)	.83 (1.62)	2.13 (1.79)	4.48 (3.78)
100m	.60 (1.53)	.82 (1.67)	.96 (1.29)	1.19 (1.43)	3.58 (3.37)
200m	.94 (1.64)	.66 (1.56)	.46 (1.28)	.48 (1.65)	2.54 (3.40)
400m	1.14 (1.78)	1.08 (1.50)	.42 (1.64)	.68 (1.53)	3.33 (3.73)
1500m	.70 (1.44)	.79 (1.53)	.77 (1.80)	.89 (1.39)	3.16 (2.90)

seasons; (ii) to be a swimmer from the FINA's top-150 but not having swum the event at least one time per season from 2003-2004 to 2007-2008 for some reason. Overall of 477 swimmers and a total of 2385 season best performances were analyzed.

Ranking tables provided by the National Swimming Federation of each swimmer identified in the FINA's top-150 were also used to collect the season best performance between 2003-2004 (Athens's Olympic Games season) and 2007-2008 (Beijing's Olympic Games season). When suitable or appropriate, race times were also collected from a public swimming database (www.swimrankings.net, August 2009).

Statistical analysis

The normality of the distributions was assessed with the Shapiro-Wilk test, considering as null hypothesis that the population is normally distributed. For all events, data presented a normal distribution. Longitudinal assessment was made based on two approaches: (i) mean stability; (ii) normative stability. For mean stability, mean plus one standard deviation and quartiles were computed for each season and a given event. The relative frequency of performance variation (i.e. percentage of performance improvement) between consecutive seasons and between first and last season was also reported. Data variation was analyzed with ANOVA repeated measures followed by a post-hoc test (Bonferroni test). All assumptions to perform the ANOVA analysis were taken into account (i.e., independence, normality and homoscedasticity). Normative stability was analyzed with the Cohen's Kappa (K) plus one standard deviation, with a confidence interval of 95 %. The qualitative interpretation K value was made according to Landis and Koch (1977) suggestion, where the stability is: (i) excellent if $K \geq 0.75$; (ii) moderate if $0.40 \leq K < 0.75$ and; (iii) low if $K < 0.40$. The Pearson Correlation Coefficient between paired performances throughout the five seasons was also computed as another normative stability parameter. Qualitatively, stability was considered to be: (i) high if $r \geq 0.60$; (ii) moderate if $0.30 \leq r < 0.60$ and; (iii) low if $r < 0.30$, as suggested by Malina (2001).

All statistical procedures were computed using SPSS software (v. 13.0, Apache Software Foundation, Chicago, IL, USA). However, the K value was computed with the Longitudinal Data Analysis software (v. 3.2, Dallas, USA). The level of statistical significance was set at $P \leq 0.05$.

Results

A performance variation and improvement during the five consecutive seasons in all the freestyle events is observed in both Figure 1 and Table 1. Moreover, ANOVA repeated measures revealed significant variations in the swimming performance in the 50m event [$F_{1,93} = 57.91$; $P < 0.01$, power = 1.00], 100m event [$F_{1,97} = 105.34$; $P < 0.01$, power = 1.00], 200m event [$F_{1,98} = 55.45$; $P < 0.01$, power = 1.00], 400m event [$F_{1,91} = 67.89$; $P < 0.01$, power = 1.00] and 1500m event [$F_{1,90} = 91.81$; $P < 0.01$, power = 1.00]. In addition, Bonferroni post-hoc tests verified significant differences between all seasons in all freestyle events ($p < 0.01$). The only exception was for the pair wise comparison between the third and fourth seasons in the 400m event which was not-significant. The mean improvement between seasons ranged from 1.12 % for the 50m and 0.64 % to the 200m freestyle event. Overall mean performance improvement was between 4.48 % for the 50m and 2.54 % for the 200m.

Table 2 presents the swimming performance stability based on the K value, which expresses the stability throughout the overall seasons analyzed. And this was rather low in the 50m event (K = 0.39 ± 0.05). However, in the 100m (K = 0.46 ± 0.05), 200m (K = 0.49 ± 0.04), 400m (K = 0.43 ± 0.05) and 1500m (K = 0.44 ± 0.05) events, it was moderate. So, based on overall tracking values of the five consecutive seasons, a moderate swimming performance stability and prediction can be considered.

Table 2. Cohen's Kappa values (K) and 95 % confidence intervals (CI) in the freestyle events analyzed.

Event	K	CI 95%
50-m	.39	.34 - .43
100-m	.46	.42 - .51
200-m	.49	.45 - .54
400-m	.43	.38 - .48
1500-m	.44	.39 - .48

Table 3 presents the Pearson Correlation Coefficient values for pair wised seasons between 2003-2004 and 2007-2008. Pearson correlations were significant in all paired data ($P < 0.05$). it Can be stated that throughout the five seasons, correlations ranged from a moderate ($0.30 \leq r < 0.60$) to a high ($r \geq 0.60$) stability. Indeed, most of the pair wise correlations were $r \geq 0.60$. A high stability in what concerns swimming performance in world-ranked swimmers when more strict time frames are used seems to exist. Doing an analysis based on the peak performance season (i.e., 2007-2008 season, Beijing Olympic Games), we verify when closer the swimmers gets to the 2008 Olympics, higher is the performance stability. High stability is achieved from the second to the third season in the 100m event (r = 0.65), 200m event (r = 0.63) and 1500m event (r = 0.61); from the third to fourth season in the 50-

Table 3. Pearson Correlation Coefficients throughout all season's analyzed in the freestyle events.

50-m	03-04	04-05	05-06	06-07	07-08	100-m	03-04	04-05	05-06	06-07	07-08
03-04	1					03-04	1				
04-05	.85*	1				04-05	.90*	1			
05-06	.65*	.83*	1			05-06	.75*	.85*	1		
06-07	.49*	.65*	.79*	1		06-07	.64*	.73*	.84*	1	
07-08	.28*	.46*	.55*	.62*	1	07-08	.37*	.49*	.65*	.76*	1
200-m	**03-04**	**04-05**	**05-06**	**06-07**	**07-08**	**400-m**	**03-04**	**04-05**	**05-06**	**06-07**	**07-08**
03-04	1					03-04	1				
04-05	.90*	1				04-05	.90*	1			
05-06	.73*	.85*	1			05-06	.71*	.86*	1		
06-07	.62*	.76*	.85*	1		06-07	.49*	.68*	.76*	1	
07-08	.47*	.59*	.63*	.79*	1	07-08	.35*	.46*	.58*	.73*	1
1500-m	**03-04**	**04-05**	**05-06**	**06-07**	**07-08**						
03-04	1										
04-05	.91*	1									
05-06	.72*	.84*	1								
06-07	.44*	.61*	.69*	1							
07-08	.49*	.58*	.61*	.75*	1						

* $p < 0.05$

m event (r = 0.63) and 400m event (r = 0.73). So, during the first season of the Olympic cycle there was a lower stability of swimming performance when considering its progression until the Olympic Games season. Thus, the season previous to the Olympic Games is determinant to achieve high performances.

Discussion

The purpose of this study was to analyze the stability and change of male world-ranked swimmers' performance in freestyle Olympic events during five consecutive seasons from 2003/2004 until 2007/2008. There was a clear performance enhancement over the period of time analyzed. Based on overall tracking values of five consecutive seasons, swimming performance stability was moderate. When more strict time frames were used, swimming performance stability increased starting at the third season of the Olympic cycle.

The ANOVA repeated measures revealed significant variations in the swimming performance throughout the five seasons in all events. Bonferroni post-hoc tests confirmed significant performance enhancement over the period of time analyzed in all freestyle events, except for the pair wise comparison between the third and fourth season in the 400m event. Similar data was reported by Anderson et al. (2008) for a 3.6 ± 2.5 years. The performance enhancement over the period of time analyzed might be associated to some scientific highlights such as the kineanthropometrical characteristics (Zamparo et al., 1996), psychological factors (Robazza et al., 2008), energetic profile (Fernandes, 2006), biomechanical/technical ability (Barbosa et al., 2008), hydrodynamics (Kjendlie et al., 2008: Silva et al., 2008), genetic background (Costa et al., 2009) or nutritional issues (Zajac et al., 2009), all of which have been recently reported in the literature.

One fact consistently shown is that training and periodization procedures of swimmers are carefully designed to achieve the peak performance in the most important competitions (Aspenes et al., 2009). Swimmers preparing for the 2000 Olympics Games obtained a 2.2 % performance improvement during the final 3-weeks of their preparation (Mujika et al., 2002). Consequently, the model of training load reduction adopted has a higher effect on the swimmers performance. Yet, several researchers also pay attention to other training issues that can enhance swimming performance, such as the warm-up (Zochowski et al., 2007), the swim drills (Konstantaki et al., 2008) or the type of recovery between bouts (Toubekis et al., 2008). We can also speculate that this better coaching, together with better funding support, allows swimmers to have better training conditions, and might, in some cases, contribute to a higher professional environment to achieve better performances.

Another explanation for this performance enhancement can be the technological sophistication around the swimming suits over this specific period of time. It is known that swimsuits, covering large parts of the swimmer's body with special materials, might improve performance. The type of suit materials, such as polyurethane, the methods to sew the materials pieces, suit types and sizes, the effect of swimming suits upon wobbling body masses, and the body compression might explain the major advantages of wearing it (Marinho et al., 2009). However, there are no independent scientific reports about the effects of these swimming suits on performance.

For a 95 % interval confidence (IC), the Cohen's Kappa data, expressing the stability throughout the overall period of time analyzed, was in fact moderate. Based on the five consecutive seasons analyzed, it is clear that swimmers' performance stability is quite difficult to maintain at a high level. This moderate stability and prediction might be associated to the different periods in the swimmer's career time plan. For each event and for the period of time analyzed, some swimmers are closer to their careers' top-level, while others did not yet achieve the career top-level and the remaining ones are at the end of their careers. Moreover, there are several episodes that can also play a major role in the performance stability during a five year time frame, such as an acute or a chronic injury (Bak, 1996). Illness is experienced by almost 90 % of swimmers at some point of the career (Fricker et al., 2000) affecting somehow their performance. Most of the American elite level swimmers at the age of 18 were unknown in the 100-top at younger ages, such as 10-12 years old (Sokolovas 2006). In this sense, it is possible that with increasing time frame analysis, the stability level might decrease.

For all events, most of the pair wise correlations were r ≥ 0.60. So, when stricter time frames are used, higher performance stability can be considered. Indeed, for a two consecutive season's period, it was verified that a high performance stability and prediction can be obtained in both young female swimmers (Latt et al., 2009a) and young male swimmers (Latt et al., 2009b) at the 400m freestyle events. During the first season of the Olympic cycle there is a lower performance stability based on the Olympic Games season. This data suggests that several world-ranked swimmers take some critical decisions at the beginning of a new Olympic cycle, such as: (i) they adopt a longer resting period between the fourth season of a Olympic cycle and the first season of the new one, mainly for physical and psychological reasons, which reduces the chances of performance enhancement; (ii) they try to make deeper changes in their technique to enhance swimming efficiency or; (iii) they shift their goals to new swimming events, requiring the adaptation to new training models.

When the analysis is made based on the 2007-2008 seasons (Beijing Olympic Games), a deceleration is observed starting at the third season, as the performance stability increases. High stability is achieved from the second to third season in the 100m, 200m and 1500m events; from the third to fourth season in the 50m and 400m events. These data is somewhat in accordance to the fact that an Olympic swimmer should improve his/her performance by approximately 1 % within the year leading up to the Olympics (Pyne et al, 2004). Indeed, in this research it was found that the mean improvement between seasons ranged from 1.12 % for the 50m to 0.64 % in the 200m freestyle event. Plus, the mean improvement between seasons ranged between 1.12 % for the 50m and 0.64 %, for the 200m freestyle event. So, it seems that our data is somewhat in accordance with the Pyne's et al. (2004) results.

Examining the relationship between world-ranking swimmers in the Olympics season, with the 2000 Olympic Games performance, most Olympic medallists (87 %) had a top-10 world-ranking in that year (Trewin et al., 2004). In this sense, the season previous to the Olympic Games is determinant to achieve high performances in most events.

Conclusion

World-ranked swimmers' performance displayed great improvement between the 2003/2004 and 2007/2008 seasons in all freestyle events. World-ranked swimmers' performance increased approximately 0.6 % to 1% between seasons, and 3 % to 4% in the overall time frame. The stability and prediction of swimmers' performance based on overall Olympic cycle period was therefore moderate. When more strict time frames were used, swimming performance stability increased starting at the third season of the Olympic cycle.

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Key points

- World-ranked swimmers' performance increased each season by approximately 0.6 to 1% during the five consecutive seasons analyzed.
- The stability of swimmers' performance based on the overall Olympic cycle period was moderate.
- Coaches should set the third season of the Olympic Cycle as a determinant milestone. In that specific season, performance turns out to be high when having the Olympic Games season as a main goal.

AUTHORS BIOGRAPHY

Mário J. COSTA

Employment

Ass. Prof. at the Department of Sport Sciences of the Polytechnic Institute of Bragança, and Member of the Research Centre in Sports, Health and Human Development Portugal.

Degree

PhD student in Sport Sciences

Research interests

The biomechanical and physiological determinant factors of swimming performance.

E-mail: mario.costa@ipb.pt

Daniel A. MARINHO

Employment

Prof. at the Depart. of the Sport Sciences of the Univ. of Beira Interior and Member of the Research Centre in Sports, Health and Human Development, Portugal.

Degree

PhD

Research interests

The biomechanical and physiological determinant factors of swimming performance.

E-mail: dmarinho@ubi.pt

Victor M. REIS

Employment

Assoc. Prof. at the Department of the Sport Sciences of the Univ. of Trás-os-Montes and Alto Douro, and Member of the Research Centre in Sports, Health and Human Development, Portugal.

Degree

PhD

Research interests

The biomechanical and physiological indicators of energy cost in physical activities.

E-mail: vreis@utad.pt

António J. SILVA

Employment

Assoc. Prof. at the Department of the Sport Sciences of the Univ. of Trás-os-Montes and Alto Douro, and Member of the Research Centre in Sports, Health and Human Development, Portugal.

Degree

PhD

Research interests

The biomechanical and physiological indicators of energy cost in physical activities, namely in swimming.

E-mail: ajsilva@utad.pt

Mário C. MARQUES

Employment

Assoc. Prof. at the the Department of the Sport Sciences of the University of Beira Interior, and Member of the Research Centre in Sports, Health and Human Development, Portugal.

Degree

PhD

Research interests

Performance evaluation.

E-mail: mmarques@ubi.pt

José A. BRAGADA

Employment

Professor at the Department of the Sport Sciences of the Polytechnic Institute of Bragança, and Member of the Research Centre in Sports, Health and Human Development, Portugal.

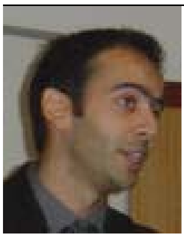
Degree

PhD

Research interests

Physiological indicators in physical activities.

E-mail: jbragada@ipb.pt



Tiago M. BARBOSA

Employment

Professor at the Department of the Sport Sciences of the Polytechnic Institute of Bragança, and Member of the Research Centre in Sports, Health and Human Development, Portugal.

Degree

PhD

Research interests

The biomechanical and physiological determinant factors of swimming performance.

E-mail: barbosa@ipb.pt

✉ **Tiago M. Barbosa**

Department of Sport Sciences, Polytechnic Institute of Bragança Campus Sta. Apolónia, Apartado 1101, 5301-856 Bragança, Portugal