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Longitudinal modeling in sports: Young swimmers' performance and biomechanics profile

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ABSTRACT

New theories about dynamical systems highlight the multi-factorial interplay between determinant factors to achieve higher sports performances, including in swimming. Longitudinal research does provide useful information on the sportsmen's changes and how training help him to excel. These questions may be addressed in one single procedure such as latent growth modeling. The aim of the study was to model a latent growth curve of young swimmers' performance and biomechanics over a season. Fourteen boys (12.33 ± 0.65 years-old) and 16 girls (11.15 ± 0.55 years-old) were evaluated. Performance, stroke frequency, speed fluctuation, arm's propelling efficiency, active drag, active drag coefficient and power to overcome drag were collected in four different moments of the season. Latent growth curve modeling was computed to understand the longitudinal variation of performance (endogenous variables) over the season according to the biomechanics (exogenous variables). Latent growth curve modeling showed a high inter- and intra-subject variability in the performance growth. Gender had a significant effect at the baseline and during the performance growth. In each evaluation moment, different variables had a meaningful effect on performance (M1: D_a, $\beta = -0.62$; M2: D_a, $\beta = -0.53$; M3: η_p, $\beta = 0.59$; M4: SF, $\beta = -0.57$; all $P < .001$). The models' goodness-of-fit was $1.40 \leqslant \chi^2/\text{df} \leqslant 3.74$ (good-reason-

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able). Latent modeling is a comprehensive way to gather insight about young swimmers' performance over time. Different variables were the main responsible for the performance improvement. A gender gap, intra- and inter-subject variability was verified.

1. Introduction

Talent identification, development, and follow-up are some of the major challenges that sports researchers and practitioners still face nowadays. Swimming performance is characterized by the multi-dimensional interplay of different scientific fields, where a highly complex interaction between several variables exists (Barbosa et al., 2010). Cross-sectional studies reported relationships between young swimmers' performance, Energetics (Toubekis, Vasilaki, Douda, Gourgoulis, & Tokmakidis, 2011), Biomechanics (Morais et al., 2012) and Motor Control (Silva et al., 2013). Nevertheless, from among all these scientific fields, Biomechanics plays a major role by explaining 50–60% of the performance of young swimmers (Morais et al., 2012). Probably the partial contribution of each key factor to performance may change across time, for example, over a season. However, until now no longitudinal research has been conducted about it in sports performance. Moreover, longitudinal research should help in gathering insight into: (i) how biomechanical variables interplay and affect performance; (ii) the dynamical changes that happen at these early ages; (iii) the partial contribution of each determinant factor over time.

For a long time sports research was based on the assumption that intra- and inter-subject variability should be minimized. Nowadays, dynamic systems theory and non-linear approaches suggest that variability should not be considered as a random error (Bideault, Herault, & Seifert, 2013). Evidence has been gathered lately about this topic in adult/elite swimmers (Costa et al., 2013; Komar, Sanders, Chollet, & Seifert, 2014) even though definitive answers are needed. Besides this, little or almost nothing is known about it in young swimmers. Interestingly young sportsmen, including swimmers, are supposed to be among the ones with a higher variability due to their allegedly low expertise level. It seems that athletes with lower (such as young swimmers) and very high expertise (including elite swimmers) levels are the ones with the highest variability (Seifert et al., 2011).

Until now, classical research designs and data analysis procedures (e.g., analysis of variance and regression models) selected on regular basis in sports performance were not helpful in gathering insight about such highly dynamic and complex relationships. Latent growth curve modeling is a structural equation modeling technique for longitudinal dataset. It is characterized by estimating intra- and inter-subject growth trajectories, enabling researchers to predict future development (Wu, Taylor, & West, 2009). Structural equation modeling also allows the quantification of how much an exogenous variable contributes to an endogenous variable (Morais et al., 2012). Hence, its potential to explain complex and dynamic changes as reported earlier should be explored. This longitudinal data analysis procedure is reported on regular basis in Social Sciences such as Psychology (Biesanz, West, & Kwok, 2003; Castellanos-Ryan, Parent, Vitaro, Tremblay, & Séquin, 2013). In Sport Sciences a couple of papers can be found on physical fitness and health (Maia et al., 2003; Park & Schutz, 2005) but it was never attempted in sports performance as much as we are aware of.

Therefore, the aim of this study was to model a latent growth curve of young swimmers' performance and biomechanics over a season. It was hypothesized that latent growth curve modeling would explain performance improvement. Different exogenous variables would have a higher contribution on the performance enhancement throughout the season with a significant gender effect.