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Dynamics of variation of sports performance in light of Time Series based on Artificial Neural Networks in swimming

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A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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abstract

Background: General availability of sports results, such as current world records, world rankings, and results of the Olympic Games, offers opportunities for the analysis variation in many different competitions and sports. Current trends in the progress in sports performance have been analysed based on e.g. freestyle swimming. The focus of this study is on the analysis of variability of sports results in swimming achieved by women and men in 11 Olympic Games in 1972−2012.

Material and methods: The analysis was based on the results of top eight finalists in all four events. Four 100m sprinting events (men's and women's) included in the program of the Olympic Games (freestyle, backstroke, breaststroke and butterfly swimming) were analysed.

Results: The analyses showed that a statistically significant difference in women's real and model results was found for the most recent Olympics in Rio de Janeiro in 2016 for the 100m breaststroke swimming.

Conclusions: The predicted results suggest that during the next Olympic Games in Tokyo, dynamics of progress in women's results is likely to be faster compared to men in three discussed events: 100m breaststroke, 100m butterfly and 100m backstroke. The above trend may not be observed in these events. Therefore, future research studies should be aimed to verify this tendency and the dynamics of progress in the results in breaststroke, backstroke and butterfly stroke.

Key words: swimming, sport performance, Olympic Games, sport prediction, ANN, time series.

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INTRODUCTION

Current trends in the progress in sports performance have been analysed based on e.g. freestyle swimming [1]. The significant increase in the swimming times was observed in the 1960s and 1970s, with a noticeable stagnation observed in the 1980s and 1990s. However, world records for different swimming events have been improved many times in recent years [2]. The main driving force in this progress was regularly improved training routines, but the significant effect on the progress in the swimming performance, especially in 2008-2009, was observed following the introduction of special swimsuits that reduced body resistance in the water environment and increased swimmer body buoyancy in water. This led to 43 world records set in the 2009 World Aquatics Championships in Rome in 2009 [3, 4, 5]. FINA's ban on these swimsuits came into effect in 2010. However, the progress in swimming performance continues to be observed, whereas the analysis of world records in a long course pool reveals 5 new world records set in 20 men's events, whereas 13 records were broken in 20 women's events following 2009, i.e. after the era of polyurethane swimsuits [6].

General availability of sports results, such as current world records, world rankings, European rankings and results of the Olympic Games, offers opportunities for the analysis variation in many different competitions and sports [7, 8, 9]. Observation of the results recorded in previous years over a set period of time can be used to evaluate and forecast future results and objectives for the development in a specific sport. Furthermore, it also allows for a comparison of differences between performance in men's and women's swimming, thus revealing dimorphic differences across various events. Nevill et al. [1] found that the difference in sports results in different freestyle events between men and women has been unchanged for over 60 years (around 10%). However, analysis of the freestyle events in terms of the duration of the effort showed that the longer the distance, the smaller the differences in swimming times between women and men [10, 11].

Observation of the level of sports performance is essential from the standpoint of progression or stabilization of the results between individual sporting events. It helps set realistic training goals (achievement/meeting the minimum time standards) and choose adequate training methods [12, 13]. A long-term observation of year-by-year preparation during the season through to the Olympics Games seems to be very important, as Costa et al. [14] demonstrated in their study in 2010, which evaluated high positions in the world ranking in a year preceding the Olympic Games and stabilization of top sports performance over this season. Furthermore, around 87% of Olympic medal winners from Sydney were placed in top ten of the world ranking in his or her events [15]. A noticeable tendency for smaller differences between gold medal winners and the bottom athletes from the first eight places was observed, which substantially increases the level of difficulty in competitive swimming. Improved results are also required before the athlete is qualified for semi-finals or finals of a specific tournament, with the main objective being to achieve the best time possible during finals, where athletes compete for medals. One goal seems to be clear: consistent following of specific training plans in order to peak during the major competition, i.e. swimming during the Olympic Games [16, 17, 18].

MATERIAL AND METHODS

The focus of this study is on the analysis of variability of sports results in swimming achieved by women and men in 11 Olympic Games in 1972-2012 (and, for prediction purposes, the results from the Olympic Games in Rio in 2016). The analysis was based on the results of top eight finalists in all four events. Four 100m sprinting events (men's and women's) included in the program of the Olympic Games (freestyle, backstroke, breaststroke and butterfly swimming) were analysed. The analysis focused on a big group with top level of sports achievement in swimming. The number of study participants was 704 (768 in total with the Olympic Games in Rio) finalists of the Olympic Games, of whom 352 (384 with Rio finalists) were female swimmers and 352 (384) were male athletes. All the results were derived from the European swimming ranking [19] of the Olympic Games in 1972 (Munich), 1976 (Montreal), 1980 (Moscow), 1984 (Los Angeles), 1988 (Seoul), 1992 (Barcelona), 1996 (Atlanta), 2000 (Sydney), 2004 (Athens), 2008 (Beijing), 2012 (London) and 2016 (Rio de Janeiro). All the events were included in the program of the Olympic Games since the beginning of the analysed period. The times were recorded with the accuracy of a hundredth of a second, which was consistent with the method of recording used by the International Swimming Federation introducing electronic timing systems with swimming touchpads in 1967 [20].

STATISTICAL ANALYSIS

Examination of the results for each distance started from the index analysis and the analysis of trends concerning the variability of results in the period of 1972 to 2012. Therefore, in order to examine the dynamics of the phenomenon, the first stage of empirical examinations was based on time series (dynamic) to analyse the levels of the variable of sports result versus time [21, 22]. Analysis of variation of the dynamics of the phenomenon used indices with variable base (chain indices). The magnitude and direction of the trend were determined using moving average. Moving average values were used to determine and choose the function of the linear trend (for selected moments, in individual events). The degree of trend function fit to the empirical data was verified before preparation of the forecast for the phenomenon. For this purpose, we calculated individual coefficients of convergence, given by the following equation:

$$\varphi^2 = \frac{\sum \left[x_i - f(t)\right]^2}{\sum (x_i - \bar{x})^2}$$

The values of the coefficient of convergence are within the range of (1; 0). The value close to zero denotes good fit of the trend function to the empirical data [11, 21, 22] .

In the next step, based on the collected data, predictive test models were construed for the 2016 Olympic Games, and the forecast data were compared with the actual data in order to determine the accuracy of these models.

In another step, we presented the prediction values with prognoses for the 2020 Tokyo Olympic Games. The prognoses were prepared using the previously verifies time series. As mentioned before, the results and input data were presented in the form of mean records in the table matrix.

The second stage of the examinations focused on prediction and involved building predictive models. In the case of regression models, it is assumed that the relationship between variables is usually linear. However, since the swimming events in the analyses based on the use of correlograms pointed to non-linear relationships (parabola of results versus time), we decided to use non-linear models for the major part of the studied variables (88.23%). Consequently, this ensured that the type-II error did not occur during evaluation of the predictive values, and the non-linear estimation (where we could decide on the determination of the nature of this relationship) was obtained. For instance, it can be adopted that the resultant variable should be the logarithmic function of variables (independent variables, exponential function, function of movable averages etc.) [21, 22].

Determination and construction of models of predictive values was based on the models of time series for periods.

The model of time series we used to predict sports results was expressed by the following equation:

$$y = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \dots \beta_k x_{ki} + \varepsilon_i$$

for i =1,2,...,n

The prediction of movable average was adopted as a prognosis method. The value of the coefficient of variation was verified each time. Next, the predictive regression models (non-linear) were construed in the tabular form using the STATISTICA software. Verification of models' fit to the input data was conducted by comparison of the values predicted for the year 2016 with the actual values during the Olympic Games in Rio de Janeiro.

RESULTS

Diagrams 1 to 4 present the dynamics of variability of sports results (given in percentage terms) in individual men's and women's swimming events during the Olympic Games in 1972−2012 due to the indices with variable bases. Results of the analysis of the dynamics of variation of sports results in individual men's and women's swimming events during the Olympic Games in 1972−2012 in the system of indices with a fixed base are presented in Table 1. Table 2 presents model, real and predictive percentage values of the variation of sports results in individual men's and women's swimming events in 2016 and 2020 compared to 1972.

The results of the analysis of variance (ANOVA) revealed a statistically significant intergroup difference between men and women with respect to variation of 100m breaststroke results (both model and real) and the test values set at $p = 0.002$, $F = 12.01$ and $p = 0.003$, $F = 9.31$, respectively.

In the case of prediction for the year 2020, the result of the analysis of variance ANOVA showed a statistically significant intergroup difference between men and women for variation of 100m results for breaststroke ($p = 0.001$, $F = 14.71$), butterfly ($p = 0.003$, $F = 10.51$) and backstroke swimming ($p = 0.003$, $F = 9.32$).

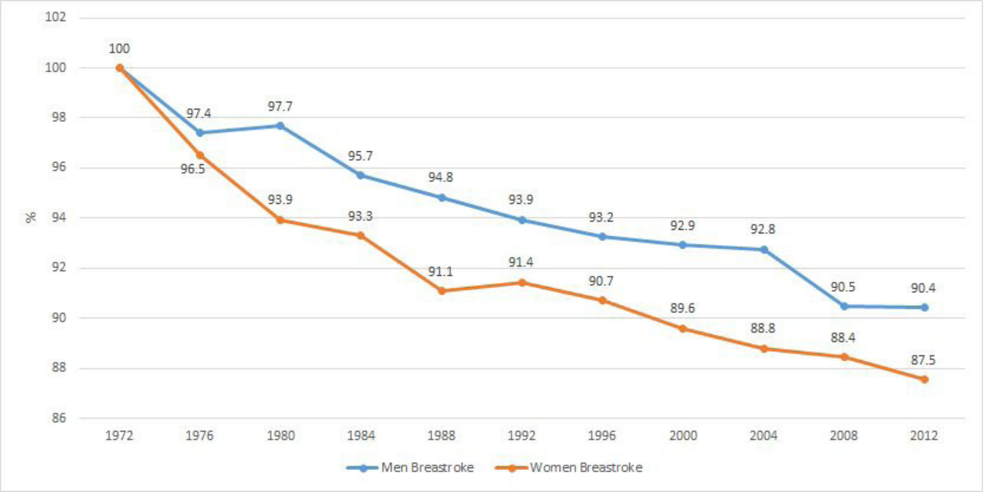

Fig. 1. Dynamics of the variability of sports results in breaststroke during the Olympic Games in 1972−2012 due to the indices with variable bases

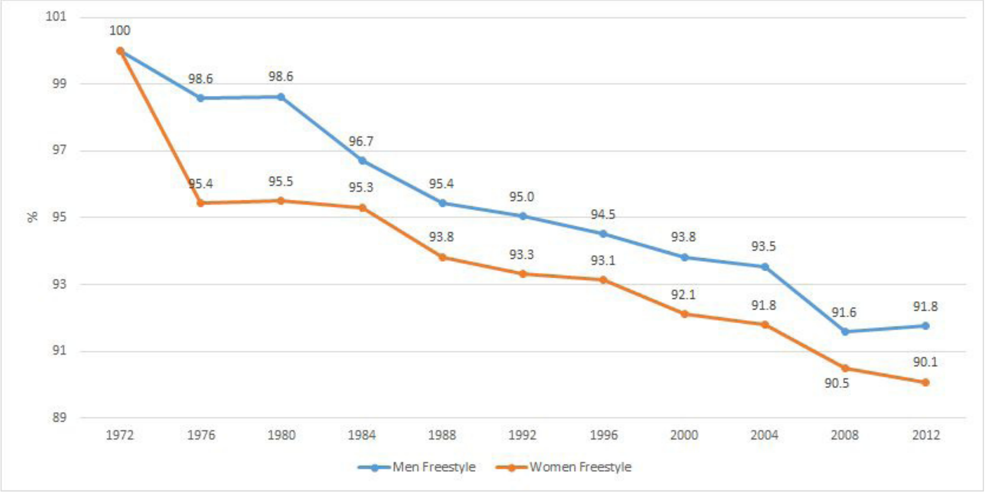

Fig. 2. Dynamics of the variability of sports results in freestyle during the Olympic Games in 1972−2012 due to the indices with variable bases

Fig. 3. Dynamics of the variability of sports results in freestyle during the Olympic Games in 1972−2012 due to the indices with variable bases

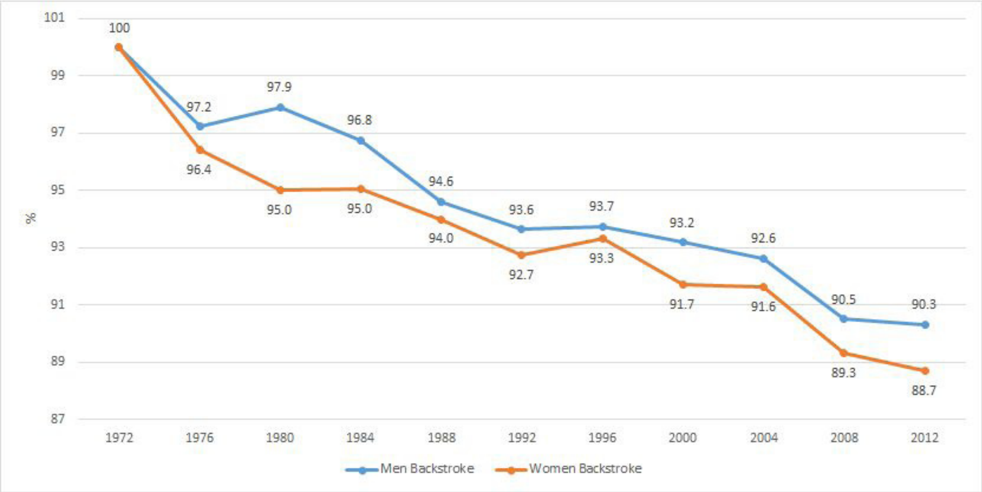

Fig. 4. Dynamics of the variability of sports results in backstroke during the Olympic Games in 1972−2012 due to the indices with variable bases

Table 1. Dynamics of the variation of sports results in individual men's and women's swimming events during the Olympic Games in 1972-2012 in the system of indices with fixed base

Year	100m Breaststroke		100m Freestyle		100m Butterfly		100m Backstroke	
	M	W	M	W	M	W	M	W
1972	-	-	-	-	-	-	-	-
1976	97.4	96.5	98.6	95.4	98.3	96.2	97.2	96.4
1980	100.3	97.3	100.0	100.1	100.0	100.8	100.7	98.6
1984	98.0	99.3	98.0	99.8	98.0	98.8	98.8	100.0
1988	99.1	97.6	98.7	98.4	98.9	98.2	97.8	98.9
1992	99.1	100.4	99.6	99.4	100.4	99.2	99.0	98.7
1996	99.3	99.2	99.4	99.8	98.6	100.5	100.1	100.6
2000	99.7	98.8	99.3	98.9	99.0	97.6	99.4	98.3
2004	99.8	99.1	99.7	99.7	99.0	100.1	99.4	99.9
2008	97.5	99.6	97.9	98.6	98.6	98.5	97.7	97.5
2012	100.0	99.0	100.2	99.5	100.9	99.0	99.8	99.3

Table 2. Model, real and predictive percentage values of the variation of sports results in individual men's and women's swimming events in 2016 and 2020 compared to 1972

	100m Breaststroke		100m Freestyle		100m Butterfly		100m Backstroke	
	M	W	M	W	M	W	M	W
Model percentage values of variation 2016	10.8	14.6*	9.5	11	9.9	11.6	9.8	12.1
Real percentage values of variation 2016	10.5	13.7*	8.1	10.8	8.9	11.3	9.5	11.7
Predictive percentage values of variation 2020	11.6	16.6*	10.3	11.8	10.8	13.6*	11.7	13.1*

** statistically significant $p < 0.05$*

DISCUSSION

In swimming, which is a sport with measurable results, the most important competition is the Olympic Games, with the most select and representative (in terms of the sports skill level) group being finalists of the Olympic Games. The analyses performed in this study assumed that the main factor to determine the level of achievement is the quality of training process and its adequate planning and programming [15, 18, 23]. An additional aspect in the level of sports performance in the period discussed in the study was the effect of non-coaching factors which can be observed in various time periods.

The changes were caused by important events in the Olympic movement over the whole period of 40 years. This was especially noticeable in the first part of this period (from 1972 to 1992), when substantial variation of the level of results was observed in both men and women. In these years, the most successful national teams were athletes from the Soviet Union, the German Democratic Republic and the USA.

Lack of progress or even a reduced level of men's results during the Olympic Games in Moscow can be found in Diagrams 1 to 4, the reason being the boycott of this sporting event by the USA and nearly 70 other countries. The reduction in the level of men's results can be mainly attributed to the absence of the US national team in Moscow, since these swimmers won 12 gold medals in 13 events in Montreal.

In women's swimming, after a dynamic increase in the level of results from the Olympic Games in Munich to the Olympic Games in Moscow from 5.0 to 6.1% in breaststroke and backstroke, a noticeable decline was observed in the Olympics held in Los Angeles, caused by another boycott, this time by the Soviet Union and the countries of the Eastern Bloc. The decline was mainly attributable to the absence of national teams from the USSR and the GDR, which, in this period, were the world swimming powers in these women's events. Slightly different results were recoded for freestyle and butterfly swimming. Although 3 athletes from the GDR participated in the 100m butterfly and freestyle finals both in 1976 and 1980, a reduction in swimming sports performance was observed in the Olympic Games in Moscow, and the trend was maintained until the Olympic Games in Los Angeles. This can be explained by equal participation of the countries in both finals, both those that boycotted the Olympic Games in 1980 in Moscow and in 1984 in Los Angeles (Diagram 2 and 3). It should be emphasized that, after a stabilization of historical situation marked by boycotts of the Olympic Games in 1980-1984, a noticeable progress was documented in the results of all analysed women's and men's events. Such substantial progress in the results in this period can be attributed to scientific and technological advances in the training process. The progress included better understanding of physiology, biomechanics of swimming motion, psychology and the theory of training [13]. However, it is worth emphasizing that the dominance of Eastern European countries was substantially due to doping, which unequivocally affected such a rapid progress in the results, especially in women's swimming [1].

In the next years (1992−2012), a substantial improvement in the results (with the exception of certain events with insignificant stagnation in women's swimming: 100m breaststroke 1992, 100m butterfly 1996, 2004, 100 m backstroke 1996 and certain men's swimming results: 100m butterfly 1992, 100m backstroke 1996) was observed. The improvement in the results in 1992-2004, not as dynamic as in previous years, can be attributed to the advances in swimming pool construction and swimming regulations (swimming pool depth, using ropes that reduce waves, angling the starting blocks towards the swimming pool, temperature, materials available for production of swimming suits) [1, 23, 24, 25]. No substantial and dynamic progress in the results in this period can be attributed to more frequent and accurate anti-doping tests.

However, a noticeable rise in the level of swimming results was observed in both men's and women's events in the second half of the first decade of the 21st century. This increase in the level of sports performance in swimming was caused by the introduction of special swimsuits that helped athletes achieve record-braking results [3, 4, 5]. This led to the noticeable improvement in the results in all the analysed events, both in men's and women's swimming during the Olympic Games in Beijing, with 25 records set in this sporting event.

A slightly different tendency for changes in the results was documented in the recent Olympics in London, where women continued to improve their results, whereas men's swimming showed stagnation. This is proved by the records set during the Olympic Games in London in 2012: women set 6 world records, whereas men succeeded in breaking only 3. The analysis of the events with short durations reveals a certain trend, especially at two last Olympic Games. The biggest progress in Beijing was found mainly for sprinting distances, mainly in men compared to women. This concerns especially 100m freestyle, backstroke and breaststroke (ca. 2%), whereas four years later, the biggest decline or stagnation was observed at the same distances, but only in men's events. Therefore, it can be concluded that the swimsuits which were allowed at these sporting events helped men achieve more record-breaking results compared to women, especially in the events with short duration of 30 to 60 seconds. The characteristic female body build improves swimming movement economics due to smaller sizes (leading to smaller resistance), lower body density and greater fat percentage (leading to better buoyancy) and shorter legs, which ensure better streamlined position [26]. This is very likely to have led to further development and improvement in the results achieved by women in swimming at the Olympic Games in London.

CONCLUSIONS

The analyses also showed that a statistically significant difference in women's real and model results was found for the most recent Olympics in Rio de Janeiro in 2016 for the 100m breaststroke swimming. Furthermore, the predicted results suggest that during the next Olympic Games in Tokyo, the dynamics of progress in women's results is likely to be faster compared to men in three discussed events: 100m breaststroke, 100m butterfly and 100m backstroke. Previous studies have documented reduced dimorphic differences in freestyle with elongation of the swimming distance. The above trend may not be observed in these events. Therefore, future research studies should be aimed to verify this tendency and the dynamics of progress in the results in breaststroke, backstroke and butterfly stroke.

REFERENCES

[1] Nevill A, Whyte G, Holder R, Peyrebrune M. Are there limits to swimming world records? International J Sport Med. 2007;28:1012-1017.

[2] Barthelot G, Len S, Hellard P, et al. Technology & swimming: 3 steps beyond physiology. Mat Today. 2010;13:46-51.

[3] Haake S. The impact of technology on sporting performance in Olympic sports. J Sport Sci. 2009;27(13):1421-1431.

[4] Neiva PH, Vilas-Boas JP, Barbosa TM, Silva AJ, Marinho DA. 13th FINA World Championships: Analysis of swimsuits used by elite male swimmers. J Hum Sport Exerc. 2011;6(1):87-93.

[5] O'Connor L, Vozenilek J. Is it athlete or equipment? An analysis of the top swim performance from 1990 to 2010. J Strength Cond Res. 2011;25(12):3239-3241.

[6] Swimming World Records. Long Course (50m) World Records. [Available at: www.fina.org/content/swimming-records, Accessed April 2018].

[7] Ostrowski A, Strzała M, Stanula A, Juszkiewicz M, Pilch W, Maszczyk A. The role of training in the development of adaptive mechanisms in freedivers. J Hum Kinetics. 2012;32:197-210.

[8] Maszczyk A, Roczniok R, Waśkiewicz Z, et al. Application of regression and neural models to predict competitive swimming performance. Percept Motor Skills. 2012;114(2):610-26.

[9] Grycmann P, Maszczyk A, Socha T, et al. Modelling analysis and prediction of women javelin throw results in the years 1946-2013. Biol Sport. 2015;32(4):345-350.

[10] Seiler S, De Koning JJ, Foster C. The fall and rise of the gender difference in elite anaerobic performance 1952-2006. Med Sci Sport Exerc. 2007;39:534-540.

[11] Stanula A, Maszczyk A, Roczniok R, et al. The Development and Prediction of Athletic Performance In Freestyle Swimming. J Hum Kinetics. 2012;2:97-107.

[12] Liu Y, Paul S, Fu HF. Accomplishments and compromises in prediction research for world records and best performances in track and field and swimming. Measur Phys Educ Exerc Sci. 2012;6:167-182.

[13] Smith DJ. A framework for understanding the training process leading to elite performance. Sport Med. 2003;33:1103-1126.

[14] Costa MJ, Marinho DA, Reis VM, et al. Tracking the performance of world-ranked swimmers. J Sport Sci Med. 2010;9:411-417.

[15] Trewin CB, Hopkins WG, Pyne DB. Relationship between world ranking and Olympic performance of swimmers. J Sport Sci. 2004;22:339-345.

[16] Balyi I, Hamilton A. Long term-planning of athlete development: the training to win phase. FHS. 1999;3:7-9.

[17] Heazlewood T. Prediction versus reality: The use of mathematical models to predict elite performance in swimming and athletics at the Olympic games. J Sport Sci Med. 2006;5:541-547.

[18] Pyne D, Mujika I, Reilly T. Peaking for optimal performance: research limitations and future directions. J Sport Sci. 2009;27:195-202.

[19] Olympic Games swimming results. Meet list by type: Long Course (50m) Olympic Games. [Available at: https://www.swimrankings.net, Accessed April 2018].

[20] Lord C. Aquatics 1908–2008 100 Years of Excellence in Sport. FINA; 2008.

[21] Sobczyk M. Statystyka [Statistics]. Warszawa: Wydawnictwo Naukowe PWN; 2002. Polish.

[22] Maszczyk A, Golas A, Pietraszewski P, Roczniok R, Zajac A, Stanula A. Application of Neural and regression models in sports results prediction. Procedia Soci Behavio Sci. 2014;117:482-487.

[23] Arellano R, Brown P, Cappaert J, Nelson R. Analysis of 50-m, 100-m, 200-m freestyle swimmers at the 1992 Olympic Games. J Appl Biomech. 1994;10:189-199.

[24] Chatterjee S, Laudato M. An analysis of world record times of men and women in running, skating and swimming. J Strength Cond Res. 1996;10(4):274-278.

[25] Wolfrum M, Rust ChA, Rosemann T, Lepers R, Knechtle B. Changes in breaststroke swimming performances in national and international athletes competing between 1994 and 2011 – A comparison with freestyle swimming performances. BMC Sport Sci Med Rehab. 2014;6:18.

[26] Tanaka H, Seals DR. Age and gender interactions in physiological functional capacity: Insight from swimming performance. J Appl Physiol. 1997;82:846-851.

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