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ORIGINAL ARTICLE

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Kinematics Tactics in Swimming Races on the Example of the Beijing 2008 Olympic Games and the Rome 2009 World Championships

Authors' Contribution:
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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Key words: *kinematics, distribution of speed, tactics, swimming*

Abstract

Background: *Tactics in endurance disciplines is often considered by a analysis of distribution of velocity at a distance. Long-distance swimming (800m, 1500m) is a discipline perfectly located in the above definition. Thus the purpose of the paper is to deepen knowledge on sport tactics based on the distribution of velocity by athletes training swimming at the highest level.*

Material/Methods: *The research material comprised finalists of the swimming race on the 800 meters at the Olympic Games in Beijing (2008) and the World Championships in Rome (2009). Data on the average speed for the entire distance and average speed for the 50-meter segments were analyzed. The average speed for the "halves" (350m and 400m) and "quarters" (150m, 200m, 200m, 200m) was calculated, and the specific "velocity differences index" was also identified (VDI). To illustrate the results better, a linear and non-linear regression equation was used.*

Results: *The results show that the top athletes both of the Beijing Olympics and the World Championships in Rome maintain consistency of the pace; deviations from the average velocity are low, and increasing speed happens at the finish. The analysis of non-linear regression equation confirms this observation. The second "half" of the distance is covered by the best swimmer at higher speeds compared to the first part of the distance; the analysis of "quarters" indicates that the middle one is the slowest. The values of VDI for "halves" have the lowest values in both races for the best swimmers.*

Conclusions: *The analysis of results justifies the conclusion that primarily it is the constant pace of the race that gives a chance to obtain a high result. The ultimate way in which the race is to be executed depends on athlete's individual predispositions; however, maintaining a constant high speed without speeding up at the finish proved to be an effective tactic in the case of one of the top athletes in both races.*

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Introduction

Tactics in endurance disciplines with a cycling character of movements (athletics, swimming, rowing, canoeing, skating, skiing) is considered by an analysis of distribution of velocity at a distance [1–10]. The optimal use of athletes' abilities requires a reflection on changing the pace of covering the distance. For example, already 5% pace fluctuations of a segment distance speed for long-distance running causes deterioration of the results by about 2% [3]. Therefore, it was assumed that an analysis of the distribution of velocity at a distance will be an excellent basis serving examination of tactics of covering the distance in swimming (for long distances – 800 and 1500m). Previous research on tactics in endurance disciplines with a cycling character of movements [5, 6, 9, 11 – long-distance running], [1, 8, 12, 13, 14, 15, 16, 17, 18 – speed skating, rowing, Alpine skiing, swimming] found a slight differentiation of tactics related to the distribution of velocity for successive fragments of the distance. It is assumed that a possible constant speed, with minor deviations from the average speed, is favourable due to smaller energy expenditure and results in a better outcome.

Material and Method

The purpose of this study is to deepen knowledge on sport tactics based on the distribution of velocity (kinematics of tactics) among athletes at the highest level. It deals with the following research problems:

1. Does the speed with which an athlete moves at particular fragments of the distance differ significantly?
2. Does the pace of covering segments of the distance affect the final result significantly?
3. Do the competitors taking part in the final race differ from each other in the implemented tactics of speed?
4. Is it possible to determine the most efficient tactics of speed on the basis of the analyzed races?
5. Is the best tactics of speed in swimming similar to the tactics pursued by other athletes of endurance disciplines with a cyclical character of movements?

Eight athletes (women) participating in the final swimming race on 800m at the Olympic Games in Beijing (2008) and at the World Championships in Rome (2009) were examined. Time data for the entire distance and for 50 m fragments (16 episodes) were obtained from the official website of the Beijing Olympics [19] and from the server OMEGA [20], which has been engaged in handling time measurement in swimming competitions since 1932.

Data on average speed were calculated for the entire distance and for every 50 m segment. Average speed for the "halves" (350m and 400m) and "quarters" (150m, 200m, 200m, 200m) was calculated. Data on velocity were calculated also for "halves" and "quarters" of the entire distance, but here the first 50 m of the distance were not included since a swimmer covers some of it in the air after release by jumping forward from the staring block and obtains much higher velocity than for the remaining 50 m segments.

Velocity for the entire distance without the first 50m segment, referred to as "quasi-half" (QH), is similar to the "first half" ("quasi-half" – QH) and the "first quarter" ("quasi-quarter" – QQ). To compare the velocity of "halves" and "quarters" and to estimate the tendency of velocity distribution for the entire distance, the "velocity differences index" was specified (VDI). VDI was calculated as follows [13]:

1. $((QD\text{-}QH)^2+(QD\text{-}H2)^2)*1000$
2. $((QD\text{-}QC)^2+(QD\text{-}Q2)^2+(QD\text{-}Q3)^2+(QD\text{-}Q4)^2)*1000$ [13, 14, 16]

where *H2* – velocity of the second half, *Q2, Q3, Q4* – velocity of "quarters" (second, third and fourth).

It was assumed that a lower VDI ratio is preferred (smaller differences between the segmental velocities). It can be concluded that in order to maintain a constant speed, it is preferable to swim more slowly. However, the goal of a race is to cover the distance as soon as possible, thus the main tactical task seems to be to develop the highest speed (within the limits of competitors' capabilities) with minimum fluctuations in the particular fragments of the distance [9, 13, 14, 16]. But in order to compare the "stability of speed" for competitors swimming with different average speed (athletes of the last places in the finals), the VDI index was divided by QD, defining the indicator as the "relative velocity differences' index" (RVDI).

It also specifies the line trend (linear and non-linear) for the speed at 50-meter fragments (without the first 50m) using a spreadsheet tool for Excel 2007. Additionally, for each competitor 1) the 50m speed segments in relation to the her rank in the finish in both races (Fig. 7) and 2) the developed speed in relation to the speed at a given fragment of the distance (Fig. 8) were compared using ANOVA with post hoc tests, and the test for a single attempt (Statistica 8.0).

Results

The results show that both finalists at the Beijing Olympics and the World Championships in Rome keep the consistency of pace, and deviations from the average velocity are small. The highest speed was observed for the first and the second 50m fragment and for the last and one before last 50m fragment of the race. Speeds for other segments differed depending on the place obtained at the finish. Only three of the best swimmers at the Olympics in Beijing had a ascending line of speed (a defined linear trend), while only competitors from places 1 and 3 ended the race with greatly increasing speed. There was no increasing in speed at the finish with the swimmer at the second position.

At the World Championships in Rome the first four finalists received an ascending trend line. It is worth mentioning that the competitor from position 2 (Jacson), who swam very equally in all parts of the distance, and significantly finished at the last 100m. Fluctuations of velocity in the female athletes were 1.9% (the first and last section of the distance were not included). It is the lowest noted value for both final races. Competitors from further places (with the exception of the last athlete at the finish) are characterized by a descending line of speed, which means that they swam more slowly (Fig. 1, Fig. 2).

To determine the characteristic of swimming, non-linear regression was calculated and the speed curve for the athletes of the places 1–4 in both races were plotted (Fig. 3 and 4). The most common tendency is to develop velocity with the best optimum for the athlete at the beginning of the distance, decrease the velocity slightly to the 300 m fragment, increase the speed between 300 m–500 m, allow a further fall (550 m–700 m) and finish on last two fragments. A similar trend was observed in athletes from subsequent places (5–8), the difference was only due to the velocity of fragments of the distance.

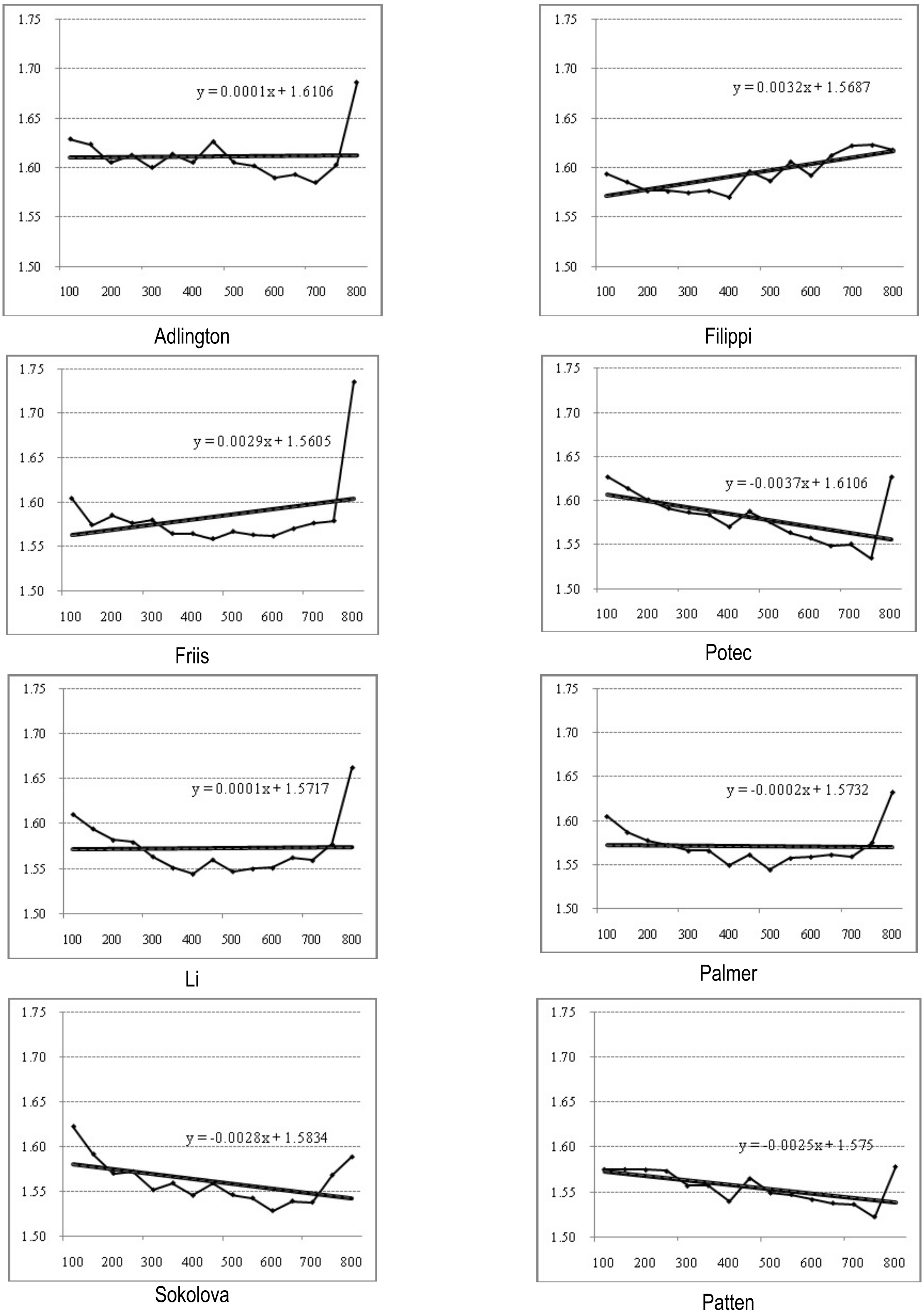


Fig. 1. Mean velocities for 50 m segments (without the first 50m) and the lines of a linear trend of the finalists of the race in Beijing. Horizontal axis – velocity [m/s], vertical axis – fragments of the distance. Numbers 1–8 are the consecutive places obtained in the competition

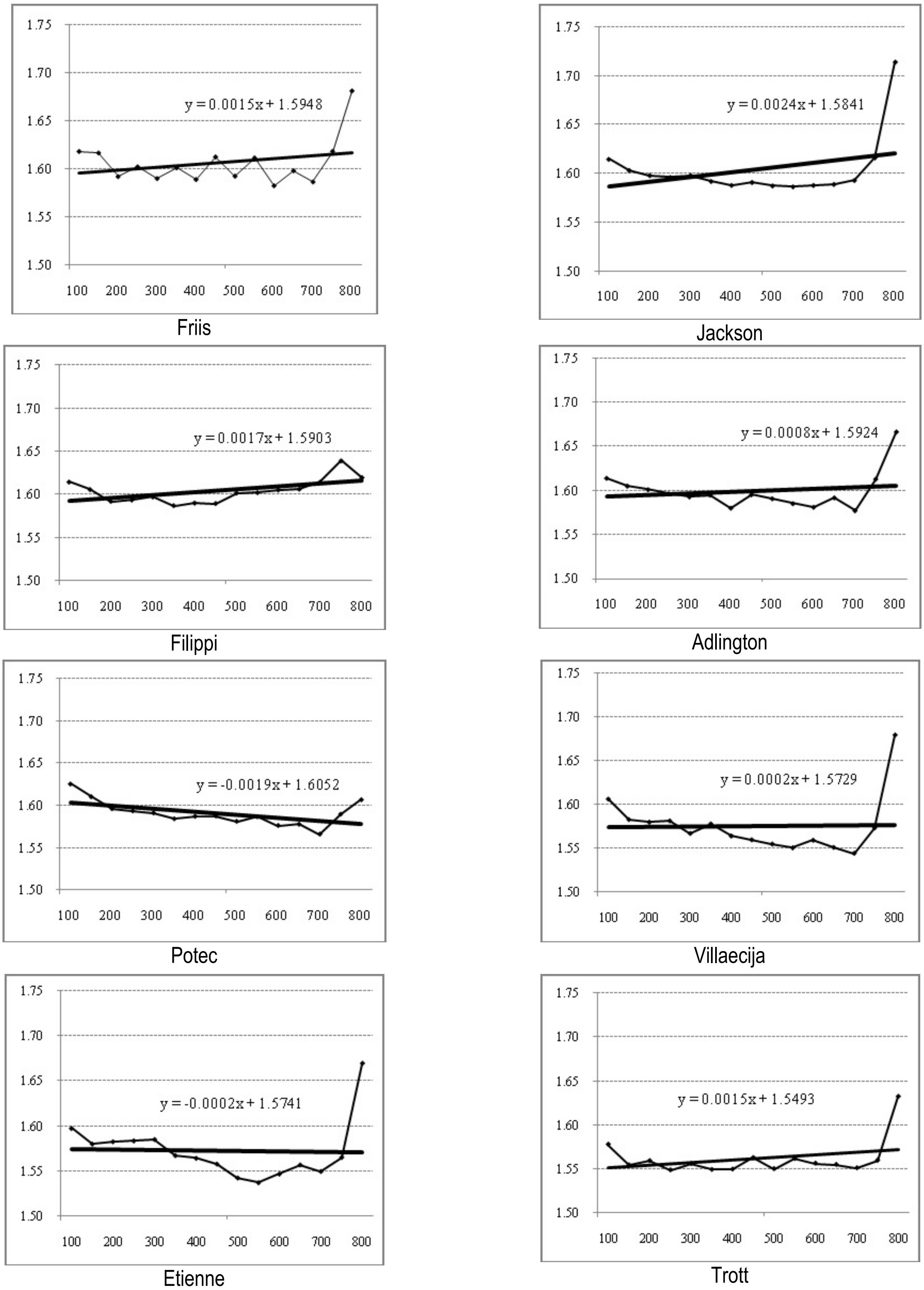


Fig. 2. Mean velocities for 50 m segments (without the first 50m) and the lines of a linear trend of the finalists of the race in Rome. Horizontal axis – velocity [m/s], vertical axis – fragments of the distance

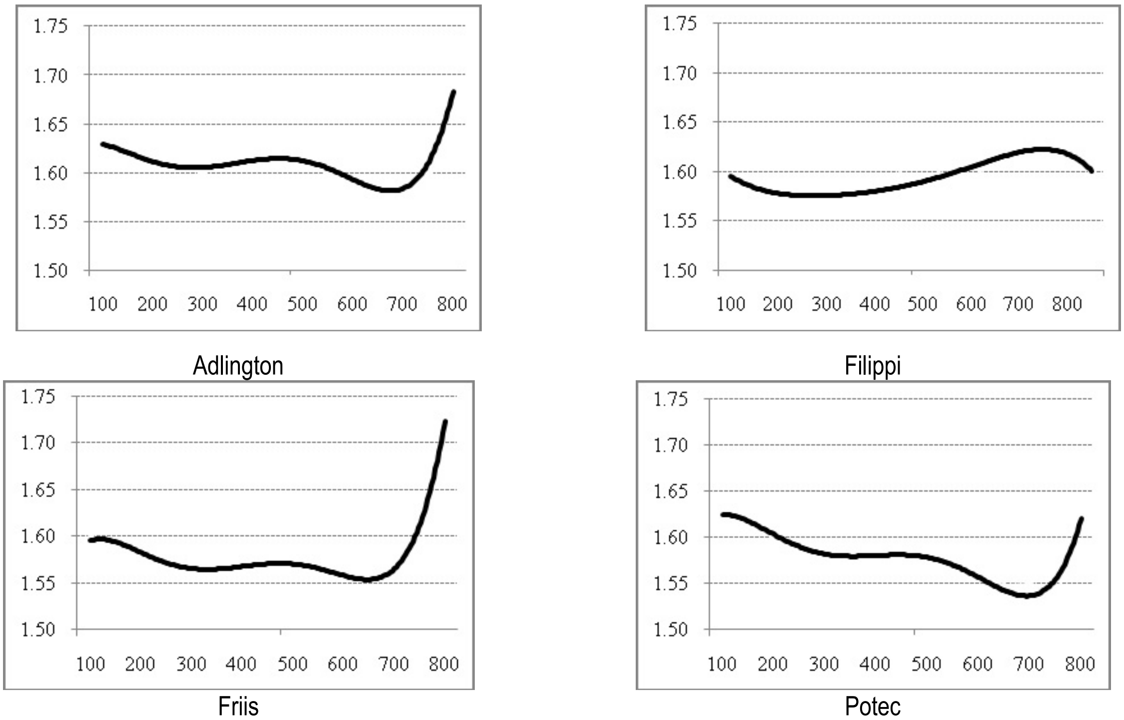


Fig. 3. Non-linear trend of velocity on 50 m fragments for the four best swimmers of the race in Beijing, horizontal axis – velocity [m/s], vertical axis – fragments of distance

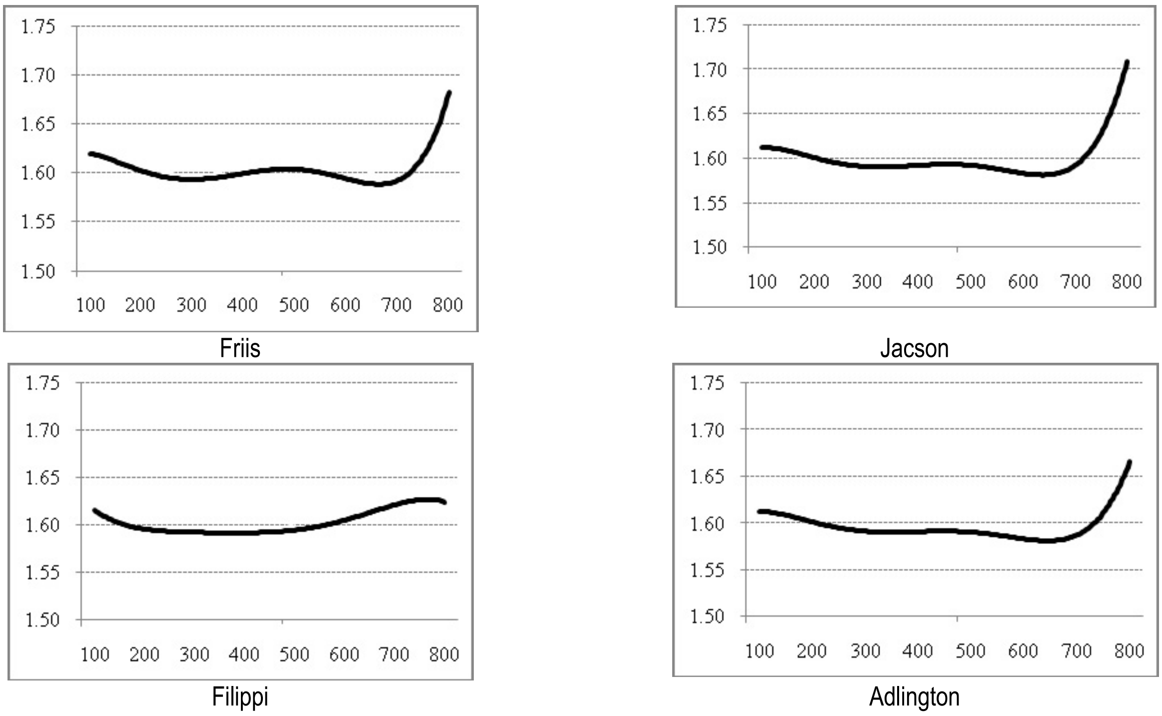
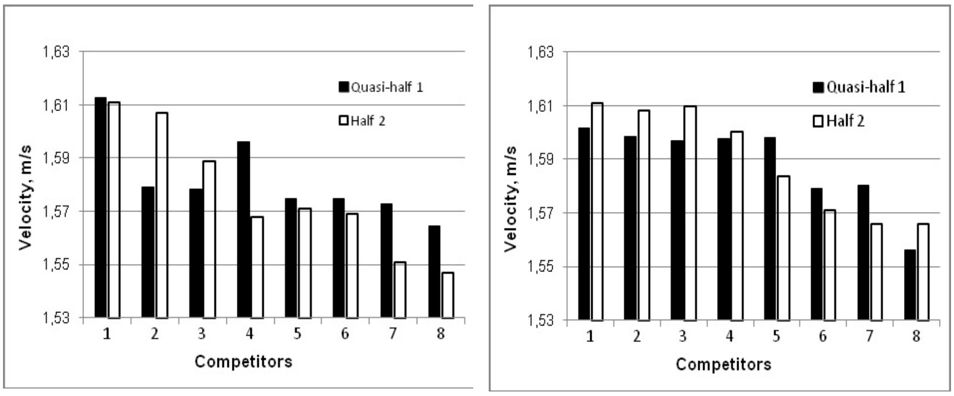


Fig. 4. Non-linear trend of velocity on 50 m fragments for the four best swimmers of the race in Rome

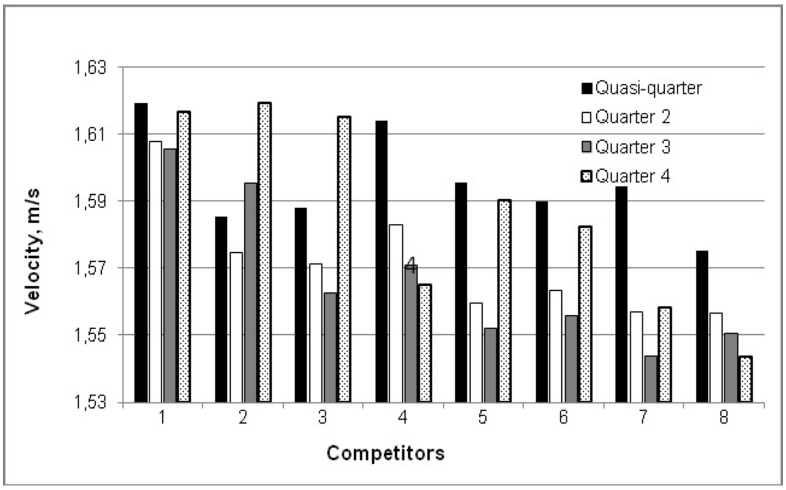
Top athletes cover the second half of the distance with a higher speed than the first one, except the swimmer from the first place in Beijing – the world record owner Adlington, in whom velocities of both "halves" were almost identical, though the second part of the distance was slightly slower (Fig. 5). It should be noted that it was a record-breaking race for Adlington, in which the oldest, twenty-year-old, world record on this distance was broken.



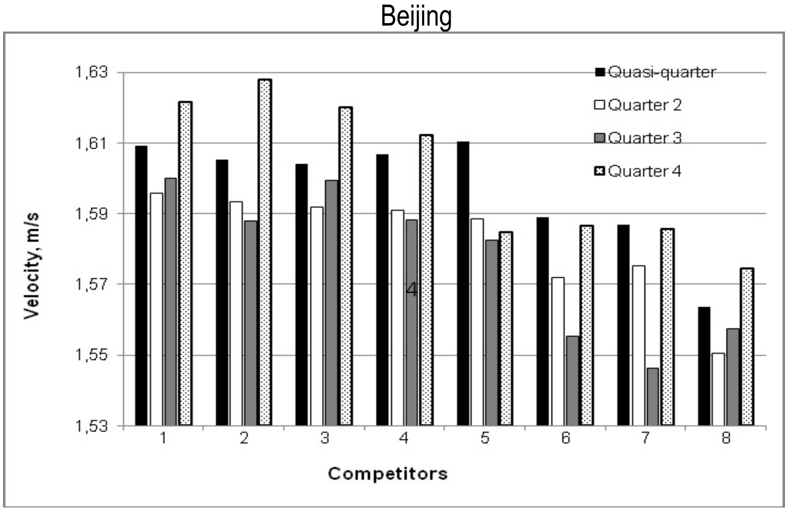
Beijing Rome

Fig. 5. Mean velocities for the QH and H in Beijing and Rome. Numbers 1–8 are the consecutive places obtained in the competition

"Quarters" of distances are covered by the athletes in a similar way: The middle "quarters" (second and third) are slower, but usually the slowest one is the "quarter" one before last; however, differences in the speed on internal fragments are minor. The development of a higher speed in the last "quarter" is typical. Only one finalist (from the last place in Beijing) covered each subsequent quarter with a decreasing speed (Fig. 6).



Beijing



Rome

Fig. 6. Mean velocities for the QQ, Q2, Q3, Q4 in Beijing and Rome. Numbers 1–8 are the consecutive places obtained in the competition

The values of VDI for "halves" take the lowest values for winners of the finish in both races, but Adlington, who beat the world record in the final of the Olympic Games, achieved the lowest possible value (0.001). The VDI for the "quarters" takes a bit higher values, which means bigger differences of the developed velocity, while VDI is also the lowest for the first swimmers at the finish. However, the indices should be studied in relation to tendencies of velocity for every "half" and "quarter" (Tab. 1, Tab. 2).

Tab. 1. Result time (min:sec) for the entire distance and mean velocity (m/s) for the entire distance, halves and quarters and their indices: VDI – velocity differences index; RVDI – relative velocity differences index for competitors in Beijing

No	Name	Result time	Entire distance	Quasi-entire distance	Quasi-half 1	Half 2	Quasi-quarter 1	Quarter 2	Quarter 3	Quarter 4
1	Adlington	08:14.1	1.62	1.61	1.61	1.61	1.62	1.61	1.61	1.62
	VDI, RVDI				***0.001****	***0.001****	***0.131****	***0.081****		
2	Filippi	08:20.2	1.60	1.59	1.58	1.61	1.59	1.58	1.60	1.62
	VDI, RVDI				*0.392*	*0.246*	*1.074*	*0.666*		
3	Friis	08:23.0	1.59	1.58	1.58	1.59	1.59	1.57	1.56	1.62
	VDI, RVDI				*0.055*	*0.034*	*1.608*	*0.998*		
4	Potec	08:23.1	1.59	1.58	1.60	1.57	1.61	1.58	1.57	1.57
	VDI, RVDI				*0.402*	*0.254*	*1.448*	*0.899*		
5	Li	08:26.3	1.58	1.57	1.58	1.57	1.60	1.56	1.55	1.59
	VDI, RVDI				***0.007****	***0.005****	*1.428*	*0.886*		
6	Palmer	08:2.4	1.58	1.57	1.58	1.57	1.59	1.56	1.56	1.58
	VDI, RVDI				***0.017****	***0.011****	***0.755****	***0.469****		
7	Sokolova	08:29.8	1.57	1.56	1.57	1.55	1.60	1.56	1.54	1.56
	VDI, RVDI				*0.242*	*0.155*	*1.436*	*0.891*		
8	Patten	08:32.4	1.56	1.56	1.57	1.55	1.58	1.56	1.55	1.54
	VDI, RVDI				*0.154*	*0.099*	***0.558****	***0.346****		

** - the lowest values of VDI and RVDI index*

Tab. 2. Result time (min:sec) for the entire distance and mean velocity (m/s) for the entire distance, halves and quarters and their indices: VDI - velocity differences index; RVDI – relative velocity differences index for competitors in Rome

No	Name	Result time	Entire distance	Quasi- entire distance	Quasi-half 1	Half 2	Quasi-quarter 1	Quarter 2	Quarter 3	Quarter 4
1	Friis	08:15.9	1.61	1.61	1.60	1.61	1.61	1.60	1.60	1.62
	VDI, RVDI				***0.043****	***0.027****	***0.383****	***0.239****		
2	Jacson	08:16.7	1.61	1.60	1.60	1.61	1.601	1.59	1.59	1.63
	VDI, RVDI				*0.046*	*0.029*	*0.941*	*0.586*		
3	Filippi	08:17.2	1.61	1.60	1.60	1.61	1.60	1.59	1.60	1.62
	VDI, RVDI				*0.081*	*0.051*	*0.424*	*0.264*		
4	Adlington	08:17.9	1.61	1.60	1.60	1.60	1.61	1.59	1.59	1.61
	VDI, RVDI				***0.003****	***0.002****	***0.408****	***0.254****		
5	Potec	08:20.4	1.60	1.59	1.60	1.58	1.61	1.59	1.58	1.59
	VDI, RVDI				*0.105*	*0.066*	*0.505*	*0.314*		
6	Villaecija	08:25.9	1.58	1.58	1.58	1.57	1.59	1.57	1.56	1.59
	VDI, RVDI				***0.035****	***0.022****	*0.721*	*0.449*		
7	Ettienne	08:26.4	1.58	1.57	1.58	1.57	1.59	1.58	1.55	1.59
	VDI, RVDI				*0.103*	*0.065*	*1.065*	*0.663*		
8	Trott	08:29.6	1.57	1.56	1.57	1.57	1.56	1.55	1.56	1.57
	VDI, RVDI				*0.047*	*0.030*	***0.305****	***0.190****		

** - the lowest values of VDI and RVDI index*

The ranges of values of velocity obtained by swimmers were defined in relation to the place to compare the level of both tested races (Fig. 7). On that basis it can be considered that a higher level was represented by competitors in the final in Rome; ranges of velocity obtained by the best swimmers are very similar. Nevertheless, it should be remembered that one of the oldest world records in swimming was beaten in Beijing (almost 20-year-old record by Janet Evans), while the other competitors swam definitely slower than the winner.

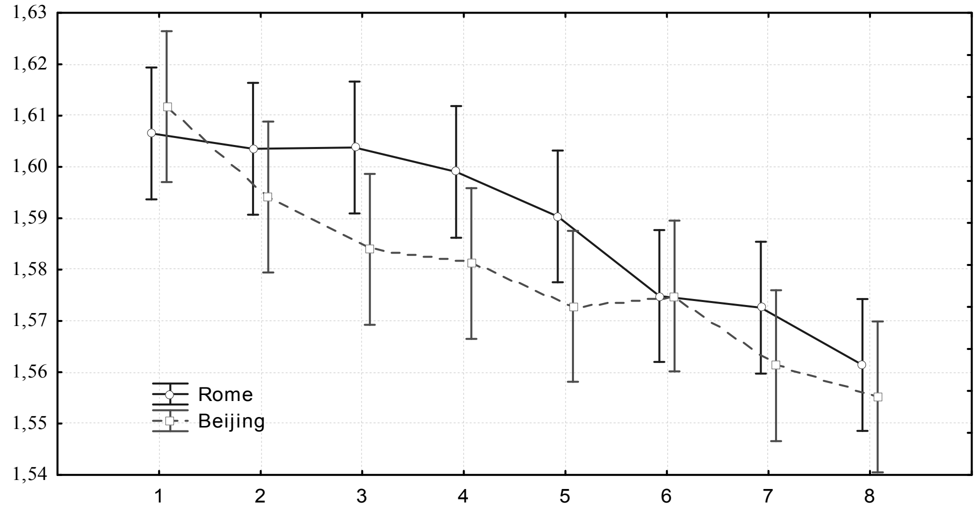


Fig. 7. The ranges of developed velocity relative to the places at the finish, horizontal axis – velocity [m/s], vertical axis – the consecutive places obtained in the competition

The structure of race in both sports events was very similar: the fastest fragments (except the first 50 m) were the second and final one, whilst the tendency of increasing velocity (finishing) was already observed in the last but one fragment.

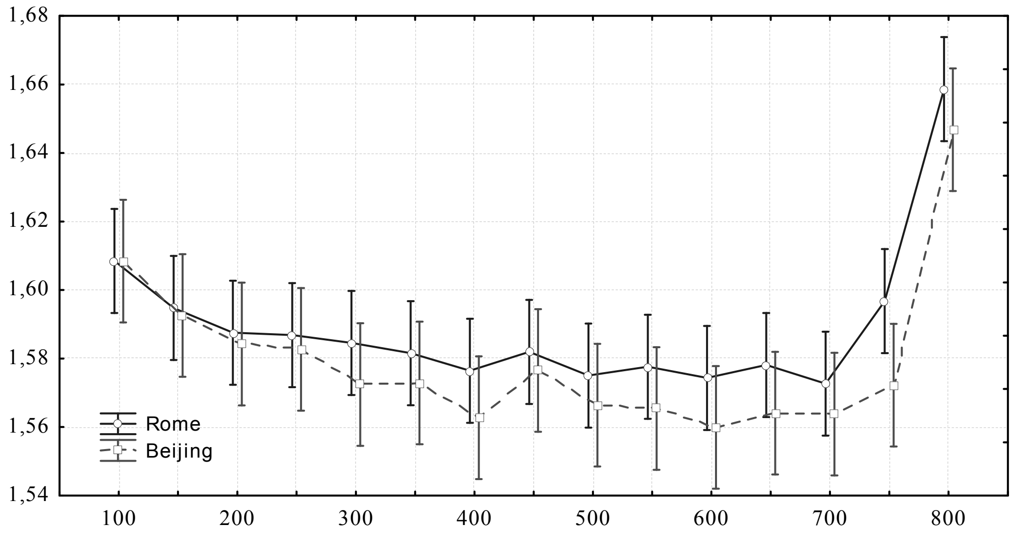


Fig. 8. The ranges of developed velocity relative to the fragment of distance, horizontal axis – velocity [m/s], the vertical axis – fragments of distance (each 50 m)

Discussion

On the basis of other authors' experimental data, Michajłow [1] wrote about the necessity of a consistent distribution of velocity in the cyclic endurance disciplines. He stated that high efficiency of consistent cyclic physical work (based on energy cost and mechanical efficiency of different systems of work) depends on the amplitude of power fluctuations from the mean value.

However, if the power fluctuations do not exceed ± 3%, these variants of distribution of forces practically correspond to consistent work. Hence, minor deviations from the average velocity (up to 3%) are the most natural and often easier than holding on strict to constant speed. It gives the possibility of elastic control of speed depending on the conditions (internal and external). Similar issues in respect to longer distances covered by swimmers were undertaken by Zhongming [7], Erdmann [13] Lipińska and Erdmann [14], Ting [15] and Lipińska [16]. It is complicated to define the optimum fluctuations of segmental velocity. It can be assumed after Michajłow [1] that the appropriate value will be the fluctuations not exceeding 3%. But because of high resistance of the water environment, primarily related to its density, maybe a different value should be adopted, which undoubtedly requires experimental studies. The carried out analyses indicate that athletes in Beijing were characterized by fluctuations of velocity from 2.7% (first at the finish) to 6% (the one before last) and respectively in Rome, from 1.9% (for swimmers from the second place) to 4% (for athletes from places 5, 6, and 7). As can be seen, the world's best swimmers do not to exceed 3% fluctuation, which can be initially taken as a the output value for possible further research in this area. The speed with which competitors covered each fragment of the distance significantly differed, which would certainly have affected the final result. Swimmers also substantially differed from each other in the values of the developed segmental velocity – this concerns athletes from the two first places at the finish in relation to athletes from the subsequent position (Beijing); competitors from the first four places in Rome significantly differed from the others. It was observed that the highest velocity is developed (with the exception of the first 50m section) in the second and final fragment. It was also confirmed at the statistical level, which may suggest that these are essential segments of the 800m distance in swimming.

In summary, achievement of the planned result is possible when the major part of the distance is maintained with relatively equal pace allowing the swimmer to rationally distribute his power to the finish. Therefore, arrangement of race tactics should predict the need to increase the pace, thus indicating the necessity of a larger loss of power at the start and at the finish.

Conclusions

Conducted analysis allow the following answers to the research questions:

1. The speeds with which the athlete moves on the consecutive fragments of distance significantly (statistically) differ; the biggest differences are observed between the second and the last segment as compared to the others.
2. Significant differences in the pace of covering fragments of the distance not always influence the final result; there were female athletes who swam unequally on subsequent segments and still achieved better results than swimmers with lesser variation of segmental velocity. The most important factor is the value of the average velocity – competitors swam faster and equally saved power for a quicker finish.
3. Athletes competing in the final differ from each other as to the realized tactics of velocity. The differences concern the velocity distribution between the first three (Beijing) and the first four athletes (Rome) and the rest of finalists. Medallists of both races apply a similar tactic of distribution of velocity both for the 50-meter fragments and for the "halves" and "quarters".
4. The most effective tactic determining a velocity of 50-meter fragments assumes a relatively consistent distribution of the pace with apparent acceleration at the finish, with a slightly rising line of speed. The tactics of the described speed of "quarters" implies that the slowest ones are the middle “quarters”, and for the "halves" the second one is faster (sometimes marginally). Leading competitors always obtain the highest speed in the last "quarter", covering the one before last “quarter” slower in order to save power for the final one. It is undoubtedly justified on physiological grounds – reducing of energy expenditure in the third "quarter" gives the possibility to uphold strength (or partially rebuild reserves of energy) for the last, decisive "quarter". Winners of both races gained the lowest values of VDI. It confirms that the key to success is a stability of the pace at a high average velocity. The abovementioned tactic relates to the best swimmers (from places 1–4).

5. Tactics of velocity observed in the studied swimmers is similar to the tactics adopted by other athletes in endurance disciplines with a cyclical characteristic of movements (long-distance running, marathon, rowing). The similarity is mainly due to the relatively consistent distribution of the pace and an increase in velocity at the finish. It seems that the prerequisite for the high-end position is to cover the second half of the distance with a velocity higher or similar to the velocity of the first one. A different tactic of velocity was observed only with one of the leading athletes - Philippi. She maintained an even and high pace but without accelerating on the last fragment, finally obtaining the second (Beijing) and third (Rome) place. It is questionable whether that lack of finish was due to a lack of power (energy exhaustion) or whether this was the athlete's personal tactic directly resulting from her physiological possibilities, consisting of a maximally high but equal pace on the entire distance leaving no reserves for acceleration at the finish.Taking into consideration the final result, it is difficult to adopt that that tactic was unfavourable. It can therefore be assumed that both a tactic of velocity with acceleration at the finish and a strategy based on a high and steady pace but without the final acceleration is optimal. The selection of tactic closely depends on the competitor's present physiological and psychological possibilities.

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