CHAPTER 20

Learning From Racing

Valery Kleshnev and Volker Nolte

For an athlete to reach a top level, such as setting a new world record, many factors have to come together: extensive training for many years, excellent coaching, best equipment, prior experiences in high-profile competitions, choice of the best tactics to cover the race distance in shortest time, favorable weather conditions, and so on. It is then a philosophical question as to whether the athlete could have done even better. Would it have been possible to start the final sprint 10 strokes earlier or to try a little harder? Would a change in the rigging have made another small difference? Could the peaking before the race have been better? Would the athlete have been even more motivated to pull more if he had known that the world record could be achieved?

Whenever athletes arrive at a certain level, theoretically they can do better the next time. They only need to train a little harder, a little smarter, and a little more motivated with a little better equipment. One needs to accomplish a particular performance and to train on a certain level to be able to get to the next level. An athlete needs to experience the feeling of a specific rig, stroke rate, stroke length, and boat speed to be able to confidently use it in the important competition. Rowers have to train their muscles to be able to reach and maintain a certain power. If they trained at a maximum of 20 spm with a maximum power output of 200 W, they would never be able to row a world-best time.

All these are the reasons why world-best times are usually set only by world-class crews and improvements happen by small margins. Striving to improve performance is integral to high-performance sport, and all people involved in it put forth their best effort to be successful. Athletes dedicate a lot of time and effort to perfect their abilities. Coaches put training programs together that are better than the ones before and work hard to teach their athletes better technique with better methods. Support staff and researchers try to find ways to get the most out of the power that each athlete produces.

In the best-case scenario, everyone works well together as a team and improvements are accomplished. Many rowing associations have organizations in place with the goal to work together, improving the sport outcome. The necessary qualifications of athletes, coaches, and support staff are recognized, and therefore national team programs are not run out of clubs but out of national training centers.

The same thoughts apply to any level of sport performance. The long-term preparation of athletes, the qualification of coaches, and the knowledge of experts are recognized in learn-to-row, high school, club, university, and regional programs. We are educated to understand that we cannot start over from scratch when we want to be successful.

It is therefore critical that we look back and see what has been done by successful programs. We need to identify the parameters of the highest performing programs, learn from their successes, and understand the mistakes that they made so that we will not repeat them. Also, the historical perspective provides the benchmarks that need to be met. Of course, we can learn the most from the top performers in rowing. Since they have already reached the highest levels, we can make use of their extensive experience. Thus, the study of races at the highest level will bear the most insight.

LONG-TERM TRENDS IN BOAT SPEED

Long-term performance in rowing is difficult to analyze because it is significantly affected by weather conditions. Therefore, we analyzed long-term (1900-2005) trends of world records in similar endurance events, including 1,500 m running (figure 20.1*a*) and 400 m freestyle swimming (figure 20.1*b*), and compared them with rowing (figure 20.1*c*).

It is obvious that the trend lines in all of the analyzed sports have similar patterns. We can define five common periods.

1. T1 (Before 1920) *Fast growth* of performance (1% to 1.5% per year) occurred in this period, which can be explained by the initial development of technique and training methods. Note that the trend in M8+ is already quite flat during this time because initial development occurred before 1900.

2. T2 (1920 to 1950) *Slow growth* of performance (0.5% per year) was caused by two World Wars, the amateur status of the athletes, and lower competition due to separation of the communist East and capitalist West sport systems.

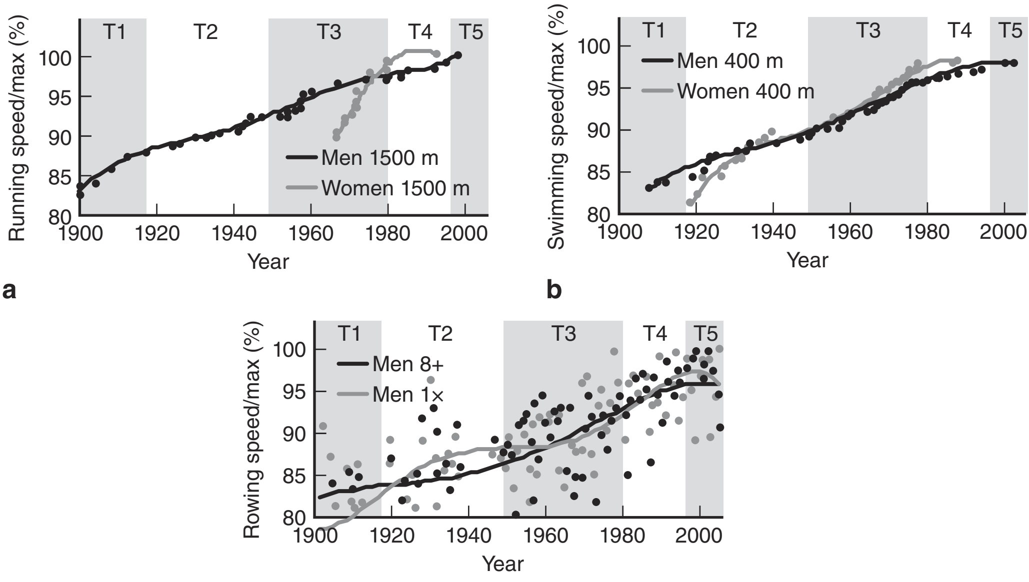

FIGURE 20.1 **Long-term trends of performance in *(a)* running, *(b)* swimming, and *(c)* rowing.**

3. T3 (1950 to 1980) *Very fast increase* of performance (1%-2% per year) occurred when Eastern Bloc countries joined Olympic sport in 1952. Sport became a political factor and a professional activity, which led to a boom in the development of training volume, methods, and doping. This performance growth was even faster among women because it coincided with initial development in some women's events.

4. T4 (1980 to 1996) *Slower performance growth* (0.5%-0.8% per year) occurred because training volume approached its biological limit, effective training methods became widely known, and improvements were made in doping control. Rowing performance continued to grow relatively faster (1.5% per year) than in athletics and swimming. We can speculate that the reasons for this include equipment development (e.g., plastic boats and oars replaced wooden ones, inventions of new blades) and FISA actively promoting rowing and popularization of modern training technologies.

5. T5 (1996 to Present Day) *Stability* of and even decreases in performance have occurred in this period, which can be seen in the latest trends of the yearly world-best times in athletics (www.gbrathletics.com). We can speculate that the reasons for this could be further development of doping control (such as blood doping tests) and sociological factors. Nevill and Whyte (2005) note that "many of the established . . . endurance running world records are nearing their limits . . . the athletic and scientific community may continue to explore greater performance gains through use of pharmacology and the evolving science of gene doping." The authors state that in a sport like running, where technique and training seem to be developed to their maximum, further improvements of world-best times is limited to currently prohibited methods. On the contrary, in a highly technical sport like rowing there are still considerable advancements to make, most significantly in the area of biomechanics.

SHORT-TERM PERFORMANCE TRENDS

Which nations have been the most successful in rowing over the last two decades? How have the performances of countries varied over the years? To answer these questions, we analyzed the number of points acquired by each country at world championships and Olympic Games using a standard system and assigning the following points: 8, 6, 5, 4, 3, 2, and 1 for the places from first to seventh (i.e., 8 points for first place). Presumably, the main goal for all countries is medal performances, not points. One gold medal is much more significant than two fourth places, although they both give the same 8 points. However, the points system reflects the overall performance of a country, allowing comparison between countries with different levels of results (with and without medals), and can give smoother trend lines. Figure 20.2, *a* through *f*, shows the distribution of points for the dominant rowing associations in the 14 Olympic boat classes over the last 17 years. It also shows the linear trend, which reflects variation in performance over the years.

In total, Germany scored about 40% more points than each of its nearest rivals, Australia and Great Britain. However, the trends are quite different: Great Britain exhibited continuous growth of performance (+5.6% per year). Australia maintained a constant level (0.2%), but Germany's performance decreased slightly (−2.5%), related mainly to the unsuccessful years of 2007 and 2008.

Statistics reveal a slight decrease in the number of points for the next five successful countries: United States, Italy, Canada, France, and Romania. However, in most cases, the decrease does not reflect a weakening in performance but rather increasingly close

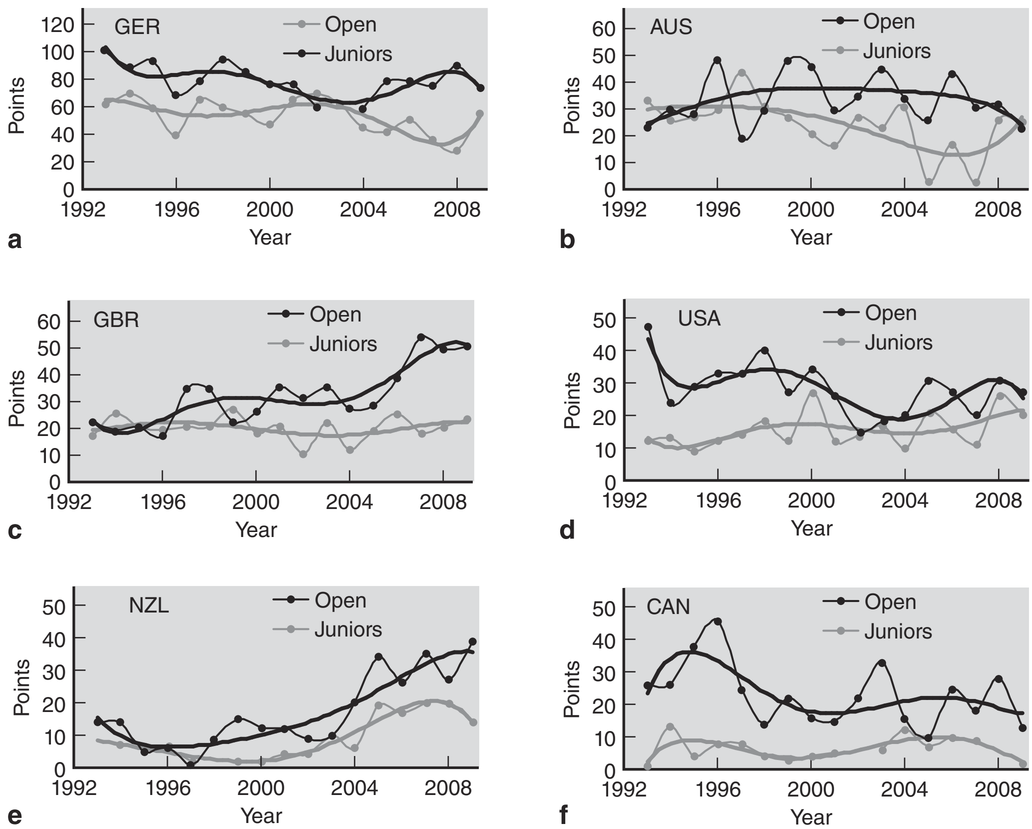

FIGURE 20.2 Development of the points reached by 6 of the top 10 rowing nations at world regattas in the open (adult) and junior categories.

competition in which points are shared between more competitors. New Zealand is in ninth place but has displayed a real improvement in performance since 2003, reflected by a 10% growth in the trend. The next two countries (Denmark and Netherlands) have displayed negative trends.

Behind these traditional rowing nations, there are four rising powers that all displayed positive trends (place according to points at world regattas and change in points over the 17-year period): Poland (12th place, 6%), Belarus (13th place, 4.2%), China (14th place, 5.5%) and Czech Republic (15th place, 10%). However, the highest growth (24% per year) was by Greece (27th place), with a rapidly improved performance since the Athens Olympics. Quite positive trends were displayed by Estonia (26th place, 12.7%), Finland (34th place, 18.5%) and Cuba (36th place, 10.4%).

It is hypothesized that the continuation of a country's success lies in its development system, so it is interesting to see which country has the most successful junior program. Figure 20.2, *a* through *f*, also displays the points reached by the top six rowing nations at the junior world championships over the last 17 years, calculated using the same method as before. The superpower here is the same: Germany, which gained nearly 2.5 times as many points as the second (Italy) and third (Romania) countries. The changes in performance are small, which is evidence for a stable junior rowing system in these three countries. The next country in the ranking (Australia) displayed a moderate negative trend (–4.5%), followed by Great Britain, which displaced a constant trend (–0.2%), and France (6th place,

−3.3%). Russia is still in seventh place, but it has displayed a strong negative trend (−7.4%) caused by a sharp fall in performance over the last 5 years. Russia could be overtaken soon by the United States (8th place, +3%), Poland (9th place, −0.2%), Belarus (10th place, 1.1%), and Czech Republic (11th place, 1.1%). The highest growth in the performance of juniors can be found in China (14th place, +14%), New Zealand (15th place, 11.4%), Greece (21st place, 9%), Bulgaria (22nd place, 12%), and Lithuania (27th place, 13.2%).

How do performances by juniors and adults correlate with each other? We found a high positive correlation (0.85) between points scored in the open and junior categories in the 36 best countries. This is a trivial observation, because the countries with better development of rowing would probably perform better in both categories. The correlation between percentages of growth was smaller (.36) but also positive and statistically significant ($p < .05$). This means that the changes in performance in junior and adult categories are related. We have not analyzed the U23 category here because its world championship was established only in 2001, so a statistical analysis would be limited.

What factors affect performance in the open and junior categories? Can we see an influence of one on the other? It is difficult to answer these questions statistically. Figure 20.2 shows comparisons of performance in both categories by various countries. In some countries (e.g., Germany), we can see that changes in the performance of juniors happened 3 to 4 years before they occurred in the open category, which could be related to the progression of a generation of athletes from juniors to adults. For other countries (e.g., New Zealand), peaks and troughs in performance occurred simultaneously in both categories. This could be explained by overall trends in rowing development in those countries, such as funding level, leadership system, training methodology, and coach education. A third group of countries (Great Britain, United States, and Canada) displayed independent trends of performance by juniors and adults. This probably reflects the separation in organizational structure for junior and elite rowing. Their elite rowing has been organized mainly on a professional basis, whereas the junior structure is based on clubs and school rowing.

In conclusion, there is a relationship between performances in the junior and adult categories, but its nature varies significantly from country to country. The information provided here could be useful for further studies of organizational and sociological factors in rowing development.

PROGNOSTIC OR GOLD-STANDARD TIMES

Analysis of the world-best times in the open, U23, and junior categories has shown that on average, U23 crews are 3.5% slower and juniors are 5.1% slower than their adult colleagues. Small boats and female crews display greater differences from the corresponding open categories than do large boats and male crews.

The world-best times do not show how performance changes over the years; therefore, we analyzed trends in the boat speeds of world championship winners. We found that in juniors, the speed grew by 0.203% every year from 1993 to 2008 (figure 20.3). In U23, performance grew much faster; from 2001 (when the first U23 world championships took place) to 2008, the average annual improvement was 1.09%. The reasons for this huge improvement could be statistical (small sample and high variation of boat

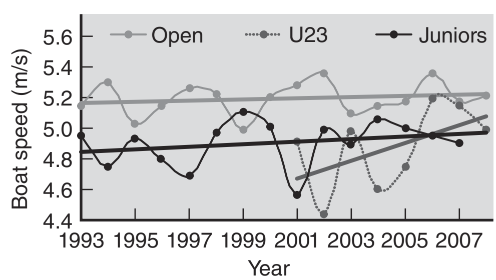

FIGURE 20.3 Average boat speed and its trends in 11 comparable boat categories.

speed owing to weather conditions), but it also could be a real increase in performance related to tougher competition in this relatively new event. If we relate the data to the 0.082% yearly improvement by the winners in the open category (Kleshnev, 2003), we can conclude that in juniors, the performance improved more than twice as fast as in adults. The speed of silver and bronze medalists also grew faster than that of winners (by 1.11% and 1.15% in U23 and by 0.205% and 0.207% in juniors), which means the competition became tougher everywhere.

How can we derive prognostic times? This question is not simple to answer. There are a number of possible approaches:

- Use world-best times. However, in this case the standards can be affected by some exceptional speeds depending on both performance and weather.
- Use the average speed of winners at world regattas (world championships and Olympic Games) over the years and its trends (Kleshnev 2005). However, in this case the prognostic speed will not be high because it will be related to average weather conditions. Various methods of filtering are ambiguous and not statistically significant.
- We can try to solve the problem by using a combination of both methods. The average boat speed for all boat types was taken from the world-best times. Then, it was multiplied by the ratio of speeds in various boat types taken from the average of the winners at world regattas from 1993 to 2008 (see figure 20.4). Finally, trends were applied to the average of each category. However, the U23 trend was taken as an average of the trend of the open and junior categories, because the lack of data points in the U23 category would have made it an unreliable value that would have produced a high prognostic standard.

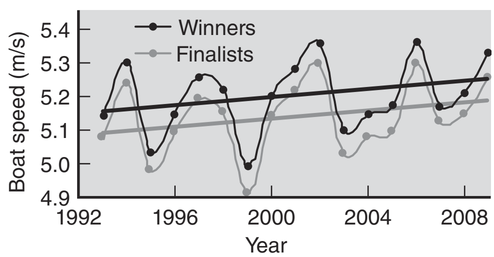

FIGURE 20.4 Average boat speed for all 14 Olympic boat classes and its trends over the last 17 years.

TABLE 20.1

Prognostic Times for Winners at World Regattas in 2012

Boat type	Open	U23	Juniors
W1x	7:11.5	7:25.7	7:32.0
M1x	6:32.5	6:45.5	6:51.4
W2−	6:52.9	7:06.7	7:12.6
M2−	6:16.5	6:29.0	6:34.6
W2x	6:39.5	6:52.7	6:58.7
M2x	6:02.1	6:14.1	6:19.6
M4−	5:41.0	5:52.4	5:57.6
LW2x	6:47.0	7:00.4	—
LM2x	6:07.2	6:19.4	—
LM4−	5:46.2	5:57.7	—
W4x	6:08.5	6:20.7	6:26.3
M4x	5:33.2	5:44.3	5:49.4
W8+	5:53.1	6:04.9	6:10.2
M8+	5:18.6	5:29.2	5:34.1

With this method, we obtained the following prognostic times in table 20.1 for the winners in 2012.

At the 2009 world championships, the average speed of the winners was 5.33 m/s (see figure 20.4), which is the third-fastest average after the 2002 world championships in Seville and 2006 championships in Eton (both 5.36 m/s). The trend in speed has grown by 0.12% per year. However, human factors cause only 8.5% of variation in boat speed; the remaining 91.5% is caused by the weather.

It is interesting to compare the results of the winners of the 2009 world championships in Poznan with our prognostic times (see table 20.2; Kleshnev, 2009).

Small boats were the fastest according to the percentage values, which were affected by the weather conditions. The boats racing on the second day of finals showed similar speeds at the 2008 Olympic Games in Beijing; curiously, the U.S. crew (winners in W8+ at both world regattas) clocked the exact same time—6:05.34!

The winner's speed shows a growth of 0.121% per year, but for silver and bronze medalists, the slope of the speed trend line was even higher: 0.127% for both. This means the margins between the medalists are getting closer from year to year. In RBN from 2005 to 2008, we found that margins didn't change much over the years, but now a trend toward smaller margins has appeared. Table 20.3 shows the average margins (in seconds) from the winners in the 14 Olympic events and slopes of the trends.

The negative slope of the margins presented in table 20.3 tells us that the silver medalists reduced their margin to the winner by 0.03 second every year, so they would catch up within 40 years, and bronze would do the same by 2062. Obviously, this won't happen, and the current tendency should change in magnitude and possibly direction. However, these facts confirm that the competition is getting tougher and tougher. Recently, we saw the Olympic final in the W2x, where only 0.01 second separated gold from silver and 0.23 second separated silver from bronze. In contrast, sixth place in the finals has been falling away from the winners over the last years.

TABLE 20.2

Comparison of 2009 World Championship Results With Prognostic Times for 2012*

Boat	2012 Prognostic time	Time winner at worlds 2009	% of prognostic speed	Growth % per year
M2−	6:16.5	6:15.93	100.15%	−0.02%
W1x	7:11.5	7:11.78	99.94%	0.10%
M1x	6:32.5	6:33.35	99.78%	0.03%
LM2x	6:07.2	6:10.62	99.08%	0.28%
LW2x	6:47.0	6:51.46	98.92%	0.26%
LM4−	5:46.2	5:50.77	98.70%	0.24%
M2x	6:02.1	6:07.02	98.66%	−0.06%
M4x	5:33.2	5:38.33	98.48%	0.19%
M8+	5:18.6	5:24.13	98.29%	0.25%
M4−	5:41.0	5:47.28	98.19%	0.02%
W2x	6:39.5	6:47.18	98.11%	−0.04%
W4x	6:08.5	6:18.41	97.38%	0.11%
W2−	6:52.9	7:06.28	96.86%	−0.02%
W8+	5:53.1	6:05.34	96.65%	0.30%
Average			98.51%	0.12%

The growth of the boat speed is based on data for 17 years compared with the results at the 2009 world championships.

TABLE 20.3

Time Difference Between Crews Placing in the Finals of the International Championship Racesand the Winner of these Races – Average of the 14 Olympic Boat Classes.

Place	2nd	3rd	4th	5th	6th
MARGIN					
Margin (s) at the 2008 Olympics	1.34	2.34	4.58	7.84	12.17
Margin (s) Average 1993-2008	1.78	3.24	5.40	8.26	11.62
Slope (s/yr)	−0.03	−0.04	−0.05	−0.01	0.02

RACE STRATEGY AND TACTICS

Race strategy and tactics have an influence on the results and the times rowed. There is considerable discussion about which strategy or tactic offers the best opportunity to succeed, and although there will always be crews racing their individual way, they are of course influenced by the tactics of their competitors and have to react to them. For example, a crew who leads can observe their competition and even influence trailing crews with their wake. Therefore, it is important to see which demand is set on crews by the competition.

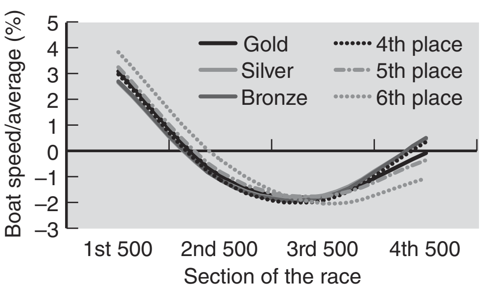

FIGURE 20.5 Average race strategy in the finals of world championships and Olympic Games from 1993 to 2009.

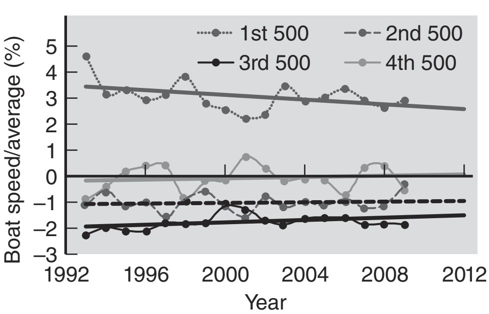

FIGURE 20.6 Trends in the strategy of the winners of world championship and Olympic Games finals over the last 17 years.

Race Strategy

Race strategy is the total distribution of crew effort during a race. It can be expressed as a sequence of four numbers representing the ratio (%) of the crew's boat speed during each 500 m section to the crew's average boat speed over 2,000 m.

The most typical race strategy of the winners in world regattas regarding their speed during the four 500 m sections of the race measured relative to the average speed of their whole race is as follows: The first 500 m are rowed about 3.1% faster, the second and third 500 m are rowed −1.0% and −1.8% slower, and the last 500 m are rowed nearly at the level of the average speed over the race (figure 20.5). The last 17 years have seen little change in this strategy; however, with the increasing overall speed, the velocities for the various parts of the races tend to move slightly toward the average speed (figure 20.6).

Using the current trends, we can deduce the following typical strategy of the winners for the year 2012: 2.56%, −0.95%, −1.53%, 0.05%. This strategy does not differ much from the previous average numbeAs always, silver and bronze medalists were relatively faster over the last 500 m, but they lost to the winners mainly during the second 500 m, which was an unusual feature of the Beijing Olympics. National federations showed distinctive race strategies in the finals of the Beijing Olympic Games (table 20.4).

The Czechs and Germans were fastest at the start and therefore had the highest variation of boat speed over their races. Dutch and French rowers had the fastest finish, and New Zealand and Poland had the most even distribution of boat speed. British rowers had the most balanced race strategy, which reflected their leading performance in Beijing.

TABLE 20.4

Race Strategies of National Federations at the 2008 Beijing Olympic Games

Country	>*n**	0-500m	500-1000m	1000-1500m	1500-2000m	Variance
AUSTRALIA	7	3.5%	–1.3%	–1.8%	–0.2%	2.5%
CANANDA	5	3.4%	–1.4%	–2.1%	0.3%	2.8%
CHINA	6	2.5%	–1.6%	–2.0%	1.3%	2.7%
CZECH REPUBLIC	4	5.3%	–1.1%	–1.5%	–2.2%	4.1%
FRANCE	4	3.2%	–2.1%	–2.6%	1.7%	2.9%
GREAT BRITAIN	10	3.1%	–1.7%	–1.8%	0.6%	2.5%
GERMANY	7	4.0%	–1.8%	–2.4%	0.4%	3.1%
NETHERLANDS	4	1.8%	–1.5%	–2.0%	1.9%	2.2%
NEW ZEALAND	5	2.0%	–1.7%	–0.9%	0.8%	2.1%
POLAND	4	2.1%	–0.5%	–1.5%	0.0%	2.1%
USA	7	2.6%	–1.4%	–1.0%	0.0%	2.2%

n = number of crews in the finals.

Race Tactics

Race tactics are the distribution of crew efforts relative to other competitors in the race. They can be determined

1. relative to the average speed of all competitors in the race, where ratios of individual boat speed to the average of the race are produced for each section, or
2. relative to the closest competitor. Five pairs of place-takers were defined (1st–2nd, 2nd–3rd, 3rd–4th, 4th–5th, 5th–6th) and ratios of their boat speed were produced for each section of the race.

In both methods, sequential numbers of the fastest and slowest sections relative to other competitors were defined. Twelve possible combinations were composed in a matrix of race tactics (see table 20.5). For example, tactic 1-4 means the first 500 m section of the race was the fastest and the last section was the slowest relative to other competitors.

TABLE 20.5

Number Of Crews Using Specific Race Tactics in Finals of the World Regattas Based on Their Placing

Tactics	PLACE						Total Number of crews
	1st	2nd	3rd	4th	5th	6th	
1-2	4	6	10	17	8	4	49
1-3	8	9	12	12	14	7	62
1-4	24	8	7	9	27	47	122
2-1	4	9	14	5	11	9	52
2-3	4	6	4	4	3	9	30
2-4	14	8	6	10	20	28	86
3-1	11	16	10	13	12	7	69
3-2	11	3	5	4	8	2	33
3-4	19	9	6	7	9	3	53
4-1	20	38	33	26	13	5	135
4-2	15	21	17	20	8	10	91
4-3	6	7	16	13	7	6	55

We analyzed race tactics of 14 Olympic boat types during the last 10 years. Some results are shown in table 20.5.

- The most popular race tactics were the 4-1 (135 of 837 cases, or 16.1%) and 1-4 (14.6%) patterns.
- Tactic 1-4 was the most popular for the later winner (24 of 140 cases, or 17.1%) as well as for the fifth-place (19.3%) and sixth-place (34.3%) crews. In contrast, the 4-1 tactic was the most popular among the silver-medal (27.1%) and bronze-medal (23.6%) crews. In other words, if a crew put all efforts in the first 500 m of the race, then the tactic would be one of winning at all costs. If a crew saved energy for the last 500 m, then it had more chances to win a medal but fewer chances to win a gold medal.

This finding was confirmed by analysis of the pairs of competitors. In 61 cases (43.6%), the winners took the maximal advantage over the silver medalists during the first 500 m section of the race (see figure 20.7, *a-c*).

In contrast, nearly one-third of silver and bronze medalists had beaten their competitors in the final 500 m of the race.

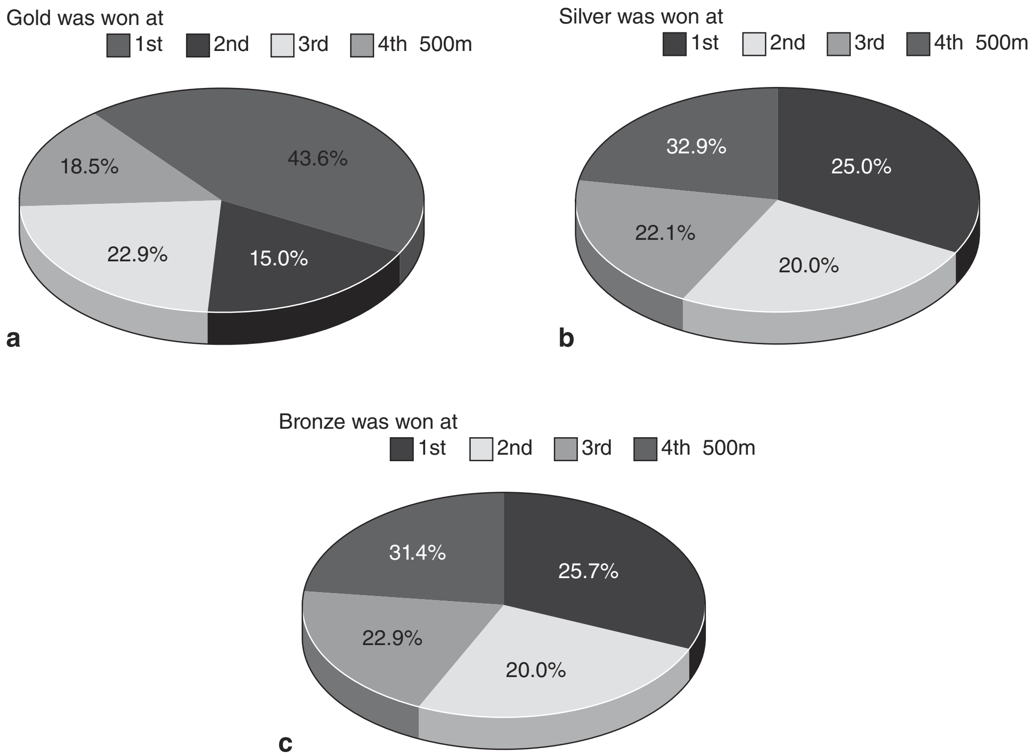

FIGURE 20.7 **Medalist placing at the first 500 m of all races of the 14 Olympic boat classes in the finals of the world races over the last 10 years.**

STROKE RATE: DISTANCE PER STROKE

The product of distance per stroke and stroke rate equals race pace. Therefore, it is easy to understand that the distance per stroke and stroke rate directly influence race speed. Of course, both factors also influence each other, and one cannot easily be increased without influencing the other.

Stroke Rate

Analysis of stroke rate during the 2004 Olympic Games in Athens was conducted similarly to the analysis of stroke rate for the 2000 Olympic Games and the 2002 world championships (Kleshnev, 2001). The measurements were done for medal winners using official video footage and measured around 70% of the total number of strokes. The data were filtered and compared with official split and final times.

The average stroke rate of the medal winners in the 2004 Olympic Games was 37.86 spm. The same parameter in the 2000 Olympics was 38.07 spm, and in the 2002 world championships it was 38.19 spm. Thus, we can see a small decrease in the average stroke rate. From 2000 to 2002, the average stroke rate increased in small boats (singles, doubles, and pairs, except in the LW2x). Medal winners in big boats (quads, fours, and eights) lowered their stroke rates in the last years (table 20.6).

TABLE 20.6

Average Stroke Rate (spm) Over 2,000 m by Medalists of 2000 Olympic Games, 2002 World Championships, and 2004 Olympic Games

	STROKE RATE (SPM)						
Year	**W1x**	**M1x**	**W2–**	**M2–**	**W2x**	**M2x**	**M4–**
2000	33.5	35.9	38.4	38.8	35.8	38.0	40.1
2002	33.9	36.4	36.2	38.6	35.7	38.3	41.7
2004	35.0	36.7	37.6	39.1	36.3	38.3	39.8
Year	**LW2x**	**LM2x**	**LM4–**	**W4x**	**M4x**	**W8+**	**M8+**
2000	36.8	38.9	40.5	36.2	40.2	39.3	40.7
2002	35.7	38.6	40.8	38.4	40.3	39.7	40.4
2004	35.9	38.9	40.4	37.5	37.4	38.2	38.8

The winners had a higher variation (ratio of the standard deviation to the average over four sections of the race) of the stroke rate (5.1%) compared with silver (4.7%) and bronze medalists (4.0%). This tells us that the winners are capable of sprinting at a higher rate at the start and finish of the race but they use lower rates at cruising speed.

On average, the winners had about 1 spm lower stroke rate (37.3 spm) than silver (38.3 spm) and bronze medalists (38.2 spm). This difference was the most significant in winners in LM2x (3.8 spm lower than second place and 2.6 spm lower than third place), W2– (2.5 and 1.4), and W2x (1.7 and 4.4).

Modeling of Effective Work Per Stroke

It is obvious that the distance per stroke (*DPS*) decreases as the stroke rate (*R*) increases at constant speed (*V*), because the duration of the stroke cycle (*T*) becomes shorter:

$$DPS = V \times T = 60\ V\ /\ R.$$

To maintain *DPS* at a higher stroke rate, we need to increase speed proportionally, which never happens in practice. So, let us ask: What do we need to preserve DPS as the stroke rate increases?

From pure common sense, the main objective is to sustain the application of force (*F*), stroke length (*L*), and mechanical efficiency (*E*). The effective work per stroke (*WPSe*) integrates all these parameters and is used as the key variable of the method:

$$WPSe \sim F \times L \times E.$$

The hydrodynamic drag resistance force (*F*), speed (*V*), and power (*P*) generated by the athlete are related as follows:

$$F_d = k \times V^2,$$

$$P = V \times F_d = k \times V^3,$$

where *k* is some nondimensionless drag factor depending on the boat type and weather conditions.

WPSe can be expressed in terms of power (P), stroke cycle time (T), speed (V), and stroke rate (R):

$WPSe = P \times T = P \times (60 / R) = 60 \times k \times (V^3 / R)$.

If the values of *WPSe* and k are equal for the two sections of the race with different stroke rates (R_0 and R_1), then using the previous equation we can derive the ratio of the boat speeds (V_0 and V_1) for these sections as follows:

$V_1 / V_0 = (R_1 / R_0)^{1/3}$.

Correspondingly, the ratio of *DPS* values is

$DPS_1 / DPS_0 = (R_0 / R_1)^{2/3}$.

This means that with increase of the stroke rate, the boat speed increases as the cube root of the rate and *DPS* decreases as cube root of the square of the rate.

To use these last two equations, we don't need to know factor k, because we assume that it is the same for the two sections. However, this is applicable only for the same boat, rowers, and weather conditions, which is a limitation of the method. On ergometers, k is constant and the method can be used without limitations.

Figure 20.8 illustrates these two equations and represents dependencies of the boat speed and *DPS* on the stroke rate at constant effective work per stroke.

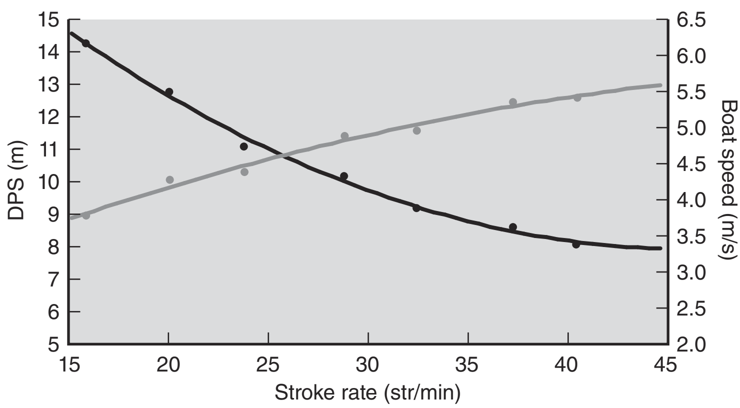

FIGURE 20.8 Dependence of boat speed and *DPS* on the stroke rate. Solid lines = model values at the constant *WPSe* for all stroke rates. Points = measured values. Position of a point below the model line = lower *WPSe* above the model line = higher *WPSe*.

The most practical implication of the method is the definition of prognostic or model values of speed V_m and distance per stroke DPS_m at a given stroke rate R_1 , which can be achieved at the constant effective work per stroke *WPSe*:

$V_m = V_0 \, (R_1 / R_0)^{1/3}$,

$DPS_m = DPS_0 \, (R_0 / R_1)^{2/3}$.

An important question is what values we use for the base values of V_0 and DPS_0. The possible solutions are

1. the average of all samples taken for the analysis at various stroke rates,
2. minimal or maximal values of the stroke rate, and
3. target racing speed and stroke rate.

The first option should be used for race analysis, because it represents the average speed and rate over the whole race. We can use option 1 in a step test as well, but option 3 also makes sense.

Finally, ratios of the real values V_i and DPS_i, for each race section to the model values were used to evaluate the effective work per stroke at each of the sections. This allows a comparison of how technique efficiency changed for each race section:

$eV_i\ (\%) = V_i / V_m$,

$eDPS_i\ (\%) = DPS_i / DPS_m$.

Tables of normative splits at various training rates can be derived using spreadsheet software. They can be used to target specific boat or ergometer speeds at various racing rates (table 20.7).

TABLE 20.7

Sample Table of Normative Values

Stroke rate (1/spm)	Split time (min) for 500 m	Speed (m/s)	% to target race speed	*DPS* (m)	Strokes per 500 m
16	2:11.04	3.82	76.3%	14.31	35
20	2:01.64	4.11	82.2%	12.33	41
24	1:54.47	4.37	87.4%	10.92	46
28	1:48.74	4.60	92.0%	9.85	51
32	1:44.00	4.81	96.1%	9.01	55
36	1:40.00	5.00	100.0%	8.33	60
40	1:36.55	5.18	103.6%	7.77	64
44	1:33.53	5.35	106.9%	7.29	69

These sorts of tables can be used in a number of ways; following are two examples.

1. Your target for a 2 km ergo race is 6:00 minutes or an average of 1:30 minutes for 500 m at stroke rate 36 spm. If you can train at the rate of 18 spm at a split of 1:53 minutes per 500 m, your muscles are ready to produce the same amount of work per stroke as required for your target result and rate.
2. You can train at a split of 1:48 minutes per 500 m at stroke rate of 20 spm. This means your muscles are ready to produce a 2 km race time of 5:44 minutes at the rate of 40 spm. If you can't produce this result, you lack endurance.

This method

- can be used for race analysis in cyclic water sports, such as rowing (Kleshnev, 2006), swimming (Garland, Hibbs, & Kleshnev, 2009), and canoeing;
- can be employed to evaluate strength and speed endurance using a step test in cyclic water sports; and
- does not require sophisticated equipment (only a stopwatch or stroke-rate meter) and can be used in everyday training.

CONCLUSION

Race experiences are powerful. Real-world performances tell us that what can be done and how it has been done. We know which equipment was used and which rig was chosen. We can measure the stroke rates and chart the strategy. We also can study the crew's preparation and the training methods that were employed. We can examine how the crew was selected and the path that the rowers took to reach the point where they were selected.

We can compare all of this information with our own program and identify differences. Though human performance is more complex than looking at a linear series of actions that could be repeated, we will be able to identify areas that are vital for a certain performance. For example, training five times the week for half a year will not make you competitive on the world level, and rowing at stroke rate of 30 spm will not win international races.

The more we analyze the performance of crews, the more information is collected that could potentially lead to confusion. Therefore, coaches must bring all the aspects together and translate them into a language that their athletes understand, get excited about, and use for their benefit. A simple copy of a successful program is seldom victorious. Finding the right pieces in all the information that races present us with and integrating them in a smart way into one's own program is what takes performance to new heights.

With the data presented, we can identify which parameters have to be met in order to produce a certain performance. Training performances are a clear indicator of race performances!

To beat a certain opponent, a crew has to do a little more, a little better, a little bit smarter. This does not seem to be impossible, and thus we will continue to see performances improve. It is not hard to see why we have this excitement of continuous improvements and top class racing in our sport.

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