

STROKEARCS

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BIOMECHANICS

APPLYING BIOMECHANICS TO IMPROVE ROWING PERFORMANCE

Editors Note: The following is an abbreviated version of the original presentation by Dr. Peter Schwanitz at the 1990 FISA Coaches Conference in Athens. Dr Schwanitz presents recommendations for improving rowing performance based on research conducted at the former East German Sports Science Centre (FES) in Berlin. His analysis is based in part on parameters obtained from boats equipped with biomechanical measuring devices. His primary measurements are the velocity of the inboard of the oar and the force applied to the inboard of the oar. These are simply means to objectively measure characteristics which are usually subjectively determined by the coach. Dr Schwanitz shares the thought provoking findings of his many tests from the 1980's in the GDR.

1. Improvement of Rowing Performance

Every rowing race has a winner. The winner the individual or the crew – has rowed the racing distance in the fastest time with the highest average boat speed. The final performances by rowers in the finals of the top international competitions (World Championships and Olympic Games) are the result of important and complex efforts by the rowers and the coaches.

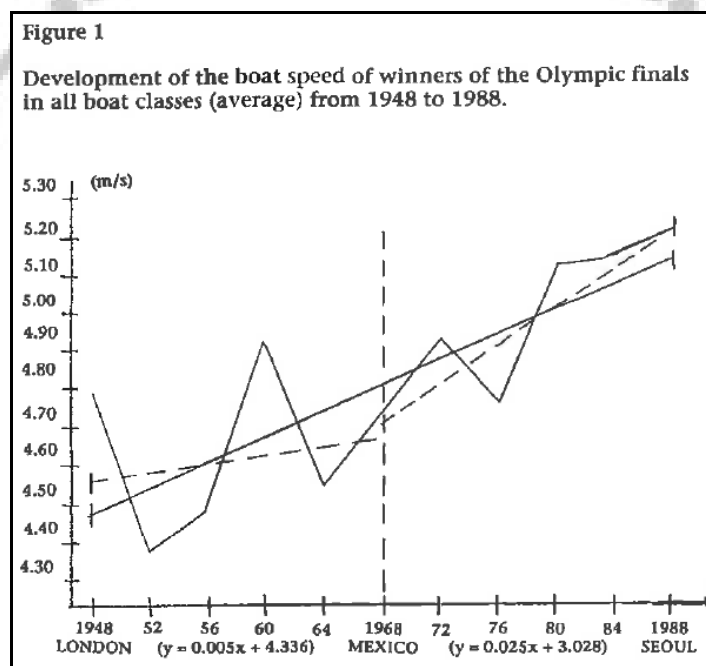
The results make it possible to evaluate, among other things, the effectiveness of the training, the creatively efficient effort of the athlete during training and competition, and the development of modern materials for the production of boats, oars, and other equipment. In order to draw conclusions about future success in competitive rowing it is important to have a general idea of the trends in racing times in the finals of previous top international competitions. If this is regarded as a benchmark for the development of performance requirements in rowing, it is important to emphasize that the performance is influenced by two factors: The human factors (personal abilities, fitness, rowing technique, etc.) and the non-human factors (boat, equipment, weather, regatta course, etc).

Three questions about development of performance will be addressed in this section. The answers to these questions are based on the following:

- the winning times of all boat classes for men in the World Championships and the Olympic Games; and
- The results of test races performed in measuring boats by FES – Berlin in cooperation with Humbolt University in Berlin.

Question 1: How has the race performance (boat speed, racing times) developed?

Figure 1 shows the development of the boats speed of winners of the Olympic finals in all men's boat classes from 1948 to 1988.



If you analyze the average boat speed of all winners of the men's Olympic Finals (except the 4x) from 1948 (London) to 1988 (Seoul), it is clear that from one Olympic Games to the next, the average boat speed over the racing distance has increased by 1.3 percent.

It is interesting that the development in the average 1st place time corresponds to the relative development in the single sculls. From this one may cautiously draw conclusions about the development of the individual performance.

If this period of time is divided then (see dotted lines in Fig 1) from 1948 (London) to 1968 (Mexico) the first place times in an Olympic cycle improved on average 1.9 percent. Winning times in the period since 1968 have improved at a rate greater than the previous period.

The result is that boat velocity, as a mean value for the Olympic winners of all boat classes has increased on average by 1.9 percent in an Olympic cycle. The relationships in velocity between boat classes (mean values) of the winners have stabilized (see Table 1).

Table 1

Speed relationships for men (winners in all World Championship and Olympic Games 1958 - 1989) as a percentage of the men's eight.

Boat Class	Scheyer 1958	Herberger 1970	Schwanitz 1985	Schwanitz 1989
2+	80	79	79	79.4
1x	82	83	80	80.3
2-	84	85	83	83.2
2x	89	89	87	87.1
4+	90	90	89	89.8
4-	92	93	92	92.3
4x	-	-	96	96.2
8+	100	100	100	100.0

Question 2: How are the racing performances in the Olympic cycles of the 1992 and 1996 likely to develop?

Future increases in speed over 2000m have been calculated based on improvements in performances. It should be noted that weather is included as an "average condition". Therefore the expected improvement implies "average" weather conditions (i.e. calm, small waves etc). For example, for the three boat classes 1x, 2-, and 8+, the improvement in the racing time and the boat speed in the cycles of 1992 and 1996 are clear in Table 2.

Table 2

Mathematical adjustment of the improvement in boat speed from the World Championships and Olympic Games, 1974 to 1988, (winning performance) and concluding in 1992 and 1996.

		1x	2-	8+
Velocity (m/s)	1988	4.81	5.04	5.98
	1992	4.88 (+1.5%)	5.14 (+2.0%)	6.06 (+1.4%)
	1996	4.96 (+1.6%)	5.26 (+2.3%)	6.16 (+1.7%)
Winning time (min)	1988	6:56	6:37	5:35
	1992	6:50	6:29	5:30
	1996	6:43	6:21	5:25

Question 3: How are the key technical parameters likely to change in the cycles 1992 and 1996?

Assuming constant stroke rate in the three selected boat classes, the Olympic winner in 1992 and 1996 will have to:

- reduce the total number of strokes in the race
- increase the propulsion per stroke in comparison to the winner of 1988 and 1992 (see Table 3a and 3b)

Table 3a

Increase in propulsion (cm) per stroke and reduction in the number of strokes (SZ) as a function of reduced racing times and constant stroke rate (1988; 1992; 1996)

Stroke Rate in 1988		32 (1x)	34 (2-)	38 (8+)
Reduced number of strokes necessary at given stroke rate	1992	-3	-5	-3
	1996	-4	-4	-3
Extra distance needed per stroke (cm)	1992	12	18	15
	1996	18	19	15

Table 3b

Increase in the stroke rate as a function of reduced racing times and constant propulsion per stroke.

Year	Stroke Rate (strokes per minute)		
	1x	2-	8+
1988	32.0	34.0	38.0
1992	32.5	34.7	38.6
1996	33.0	35.4	39.2

Assuming constant propulsion in the three boat classes, stroke rates must increase.

Now it is interesting to see the consequences of the probable quantitative improvement of important rowing technique parameters and their relative percentage changes (see Table 4). These data were obtained from measurements of the former East German National Team.

Table 4

Empirical, mathematically based consequences of the improvement in boat speeds from 1974 to 1988 for the quantitative shaping of biomechanical parameters in a representative rowing cycle (X), (parameter as [power-] function of the boat speed).

		1x	2-	8+
Stroke power	1988	576	559	591
	1992	602 (+ 4.5%)	597 (+ 6.8%)	619 (+ 4.7%)
	1996	632 (+ 5.0%)	646 (+ 8.2%)	656 (+ 6.0%)
Drive power	1988	1017	931	1186
	1992	1041 (+ 2.4%)	962 (+ 3.3%)	1221 (+ 3.0%)
	1996	1068 (+ 2.6%)	997 (+ 3.7%)	1267 (+ 3.7%)
Drive force	1988	535	471	484
	1992	542 (+ 1.3%)	484 (+ 2.7%)	493 (+ 1.9%)
	1996	550 (+ 1.5%)	499 (+ 3.6%)	504 (+ 2.2%)
Drive speed (m/s)	1988	1.95	2.21	2.46
	1992	1.97 (+ 1.0%)	2.24 (+ 1.5%)	2.49 (+ 1.2%)
	1996	2.00 (+ 1.5%)	2.29 (+ 2.2%)	2.53 (+ 1.6%)

PIHZ = power in the full rowing stroke, PIHEF = power in the effective drive portion, FIHEF = force on the inboard or inside lever, and VIHEF = velocity of the inboard or inside lever. P = mechanical performance; F = force; V = velocity; IH = inboard; EF = effective drive ("work in the water").

Editor's note: the reader should note the percentage increases in power necessary for the additional boat speed to be required as measured on the inboard part of the oar.

In the three boat classes the highest percentage rates of increase in the realized average performance (P) on the inboard (PIH) are shown for:

- a rowing cycle (PIHZ)
- The effective drive (PIHEF) in the rowing cycle.

The product of the factors “force on the inboard or inside lever” (FIHEF) and the “velocity of the inboard or inside lever” (VIHEF) with the mechanical performance of the inboard show a minor rate of increase within an Olympic cycle.

In general it should be noted that the increase in boat speed puts demand on the athlete to exert more power on the inboard and to attain a higher velocity on the inboard.

2. Applying Interdisciplinary Contributions to Improve Performance

The definition of biomechanics can be described as the effects of mechanical laws on and in the living organism and their mechanically measurable reactions of the organism to these effects.

Thus biomechanics has its basis in both the physical and biological sciences. Therefore, one should not depend solely on mechanical findings to determine how to achieve competitive goals, (victory, best possible result, faster, etc)

This knowledge must be translated for use in interdisciplinary synthesis and an application oriented training plan. The following four questions and their answers attempt to substantiate this claim.

Question 1: What are the possibilities and limitations of the contributions of biomechanics to the sport of rowing?

The essential focus of biomechanics in rowing has and always will be rowing technique

Most objectives of biomechanical research are to explain the propulsion-causing powers and accelerations of the rowing stroke during competitions, both in theory and in practice. This research also tries to explain the effects of the development of equipment.

Theoretically explained biomechanical knowledge and the empirical findings that create successful rowers are the bases for forming a technical concept. The application of the concept has contributed to the improvement of rowing performance.

The biomechanics of athletic movements in the endurance sport of rowing can improve performance, especially if it considers biomechanical/energetic and biological/energetic interactions. The task in this connection is:

- to investigate the movement sequences during competition and training in order to explain those mechanical causes that influence the biological/conditional effects;
- To develop rowing technique as a biomechanical solution process that can be applied to the effective biological/energetic development in training as well as result in higher speed during races.

It is important to develop and identify rowing technique from a biomechanical perspective, which makes it possible for the athlete:

- to achieve the fastest racing times and the highest average boat speed over the rowing distance on the basis of his or her individually available energy potentials at the lowest possible external resistance;
- to achieve the fastest time over a given distance on the basis of his or her individually available biological energy potential and taking into account the biological-conditional objectives for the particular training area at given resistance conditions (boat type, gearing, area of blade, etc.).

Question 2: What research could form the basis for the establishment of a rowing technique for training and competition?

In practice you can find different force-time curves on the oarlock [$F=f(t)$] with an approximately equal impulse area. These can be classified as shown in Figure 2.

Figure 2
Schematic representation of different force - time curves in rowing.

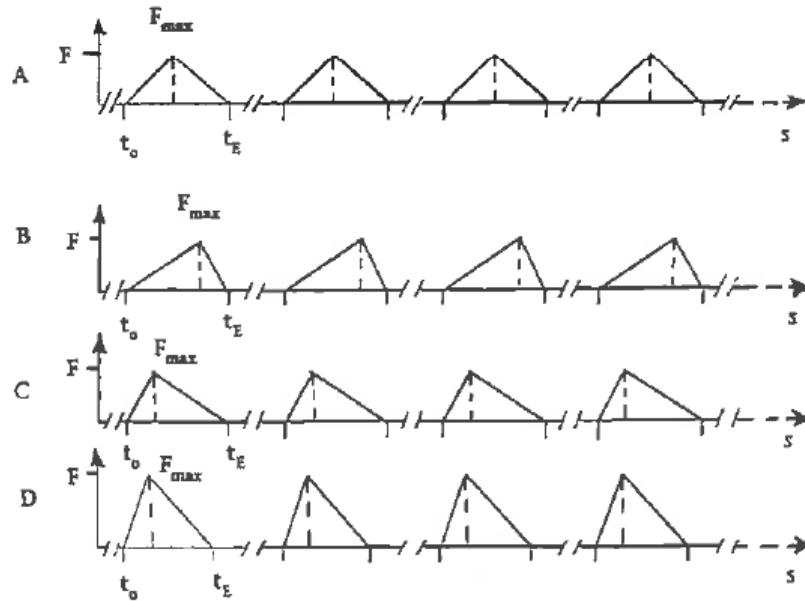
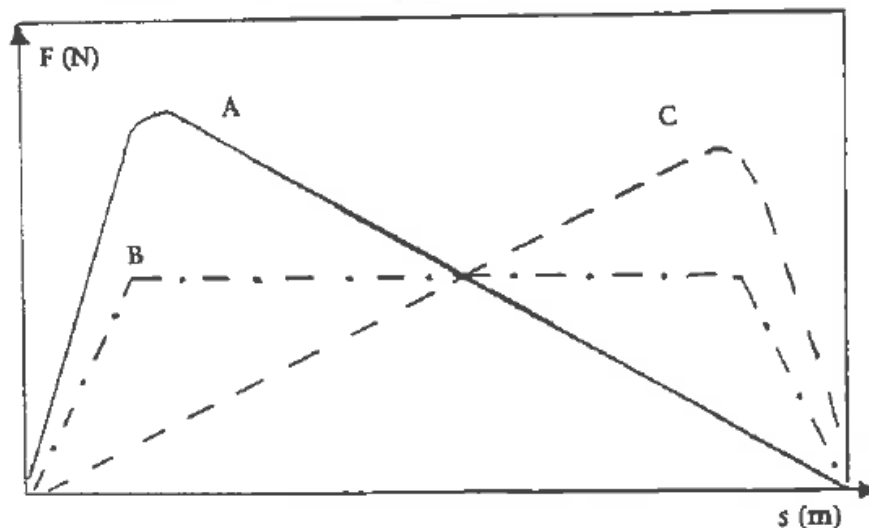


Figure 3
Schematic representation of typical curves of force as a function of distance with constant work (acc. Müller, 1962)



“A” emphasizes the middle of the drive – synchronous force of leg, upper body and arm musculature is dominant. “B” emphasizes the end of the drive – synchronous forces of the upper body and arm musculature is dominant. “C” emphasizes the beginning of the drive – synchronous forces of the leg and upper body musculature is dominant. “D” strongly emphasizes the beginning of the drive with no emphasis on the remainder of the drive.

The strongly schematized force/time curves appear in rowing of all classes, including World and Olympic Champions!

But which of these curves will now be useful? Trying to get the answers from the science of biomechanics alone won't be enough. The following accounts should give some help in making decisions.

“The work is all the more inefficient the more tension there is in the muscle at the end of the effort, because the work is wasted isometrically, without producing any performance.” (Landois-Rosemann, 1962, p. 504)

“The force/distance curves with a short steep rise to the peak of maximum force and a subsequent flatter fall off the end of the work distance appears to be the most favorable. The effectiveness of the energy turnover for equal work is, in comparison to other curves, the highest, since the necessary energy turnover is the lowest.” (Landois-Rosemann, 1962)

This information disqualifies an orientation towards hard pressure at the finish of the rowing stroke, and it highlights an emphasis on the beginning of the stroke.

“Equal work, realized through extreme tension of the different muscle groups, results in various local loads. The higher loads manifest themselves in the smaller muscle groups (i.e. the legs) and the lower loads in the larger muscle groups (i.e. the arms) (Hollmann/Hettinger, 1976)

From this statement it makes sense to employ a synchronous whole body effort of muscle potentials, taking into account the different force potentials of the leg-, back- and arm muscles. Emphasis on the finish of the stroke should be deemphasized because of the high local load on the arm muscles.

“There are two alternate ways to increase performance (in the mechanical sense, as a product of force and movement velocity): you can increase either the force or the movement velocity. The physiological processes react more strongly to changes in movement velocity than to changes in force.” (Landois-Rosemann, 1962; Roth/Schwanitz/Korner, 1989)

Thus, it makes more sense to improve the time of the movements during the whole drive where the body parts work synchronously. The necessary high velocity on the inboard can be carried out throughout the slower movements of the legs, upper body and arms while they work individually.

“A high force development in the beginning of the rowing stroke seems to be the most effective with regard to the most favorable body position for a proportional development of the force potentials. The position of the body in the beginning of the drive can be compared to the position of a weightlifter at the beginning of the weightlifting process” (Gjessing, 1979)

In light of the previous statement, one should emphasize the beginning of the drive portion of the stroke. Empirical research carried out by this author has produced the following results:

- The average boat speed per stroke rose with the rowers increased force exertion on the inboard at the beginning of the drive;
- The increase in boat speed did not parallel the increase of average force past the 90 degree position of the oar relative to the splashboard;
- The recorded increase of inboard velocity in the area of the drive is therefore mostly a function of higher boat speed initiated by the higher inboard force at the beginning of the drive (Schwanitz, 1975)

Therefore, one can justify an emphasis on the beginning of the drive as well as an orientation towards increasing the force in the middle of the drive and in the finish in order to make use of reserves (Schwanitz, 1976). In the discussion about the effectiveness of the rowing stroke, Nolte (1985) raised the aspect of the hydrodynamic lift, which supports the orientation towards the beginning of the drive.

Summary

From a biomechanical, biological and training-method point of view, there are reasons for an efficient rowing technique that takes into account the aspect of load as well as the propulsive effect during training and competition. The emphasis of the force on the inboard, in order to produce a powerful first part of the drive, characterizes this rowing technique and should be encouraged.

In addition to the emphasis on the first part of the drive, the force on the inboard should be produced in the tangential direction to the inboard, especially before the 90 degree position. A common expression for this force expression should be “row around the oarlock”.

The intention of all training methods is to increase the individual performances in the drive phase. This also covers the common forms of diagnosis used in biomechanics, rowing technique and sports medicine. These usually show the effects of training under defined test conditions.

The increased force exertion and movement velocity as components of the mechanical performance are the correlated partners of the biological and mechanical criteria, with the drive given first priority. Here one should pay attention to the fact that the coordination requirements of the recovery phase are particularly high. In training it is important to carry out a conscious conditioning of the muscles used during the recovery at race intensity to counter conditionally caused coordination problems and to ensure the propulsive effect in the drive by paying special attention to the reversal movement into the entry.

Question 3: What should the coach and athlete know about rowing in different boat classes?

An analysis of training methods with boat measurement technology of FES Berlin in 1978 gave results which later, strengthened the considerations of the rowing federations of the former GDR with regards to decisions about loads. Rowing in different boat types will, under the same training conditions (distance, stroke rate), put different demands on

the athlete and result in different loads. A comparative examination of inboard velocities in similar tainting ranges gives the following results:

- Recovery: The profile of the inboard velocity and the time bases approximately match in the various boat classes;
- Drive: As the boat classes get bigger the acceleration on the inboard in the beginning of the stroke increases, and the drive time decreases considerably. (Refer to Table 5.)

Table 5
Load relevant aspects of changes in the mechanical work in rowing

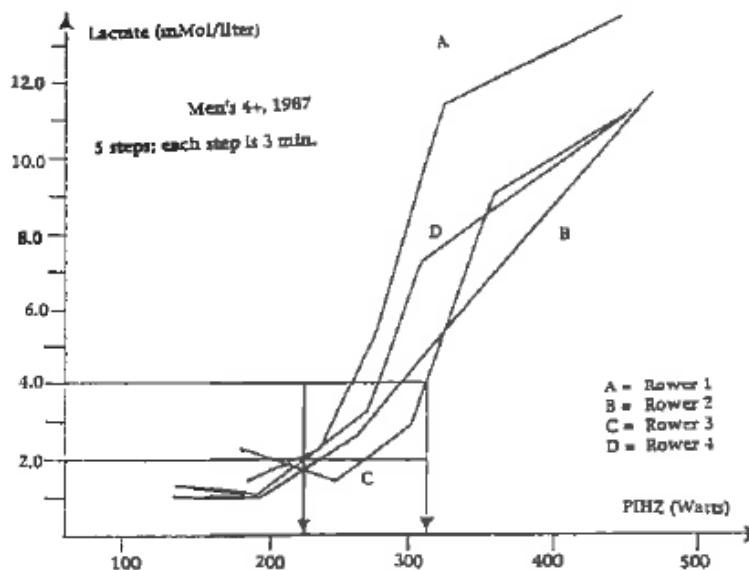
If rowing with the same load demands (Watts) and the same stroke rate

in small boats	→	in big boats
with high load	→	with easier load
with big blades	→	with small blades
with heavy resistance (ergometer)	→	with light resistance (ergometer)

then, in the direction of the ARROW:

- the amount of inboard power during the drive-phase decreases
- the inboard velocity during the drive-phase increases
- the drive-phase time decreases
- the time of the recovery increases

Figure 4
Lactate as a function of the power of rowers of a 4+ in a measuring boat



Question 4: How does the individual rower deal with the requirements of the specific boat classes?

The research in the biomechanically explained movements of the different boat classes made it possible to qualify the diagnostics of the measurement boats in such a way that that the individual load requirements and effects during training could be clarified, along with the development of rowing technique. This led to an experiment in 1987 carried out by Korner (training methodology), Roth (performance physiology) and Schwanitz (biomechanics).

The object of the experiment was the rower's mastery of the boat type specific requirements. Four athletes each carried out the following tests in 1x, 2+ and 4+ measuring boats:

- A five step test (one step: three min.);
- one unit of basic endurance training (90min.; stroke rate =20-22)

Inevitably there were the same general requirements (stroke rate, boat velocity) for every step for the four rowers in 4+. However, every rower showed very different realizations of the demands of every load level from the biomechanical point of view. The analysis of the biomechanical parameters shows great dispersion among the rowers at the same load input (between 4 and 25 percent). It was striking that:

- the highest individual deviation in the load steps appeared at lower velocity

- at all load levels the inboard velocity showed the smallest individual deviation, which is mechanically explainable

The overall impression of a team is often formed by that which one can see, such as movements of the body parts relative to each other and to the boat as well as movements of the oars and the boat. In general, one can conclude that:

- The different load demands of each boat class and of each step in the test show very individual results in rowing technique and physiological load.
- In every load of the step test the performance on the inboard as the product of the inboard force and the velocity shows particularly large differences for every rower in all boat classes.
- Performance, force, velocity, lactate and other biological parameters determined as functions of the load in the different boat classes by the same rowers confirm the necessity and the possibility of emphasizing the individual control of performance development by means of biomechanical/rowing technique parameters and characteristics. (See example of this analysis in Fig 4.)

The results of this experiment were used to prepare the athletes of the rowing federation of the former GDR for the 1988 Olympic Games in Seoul. Early in 1988 the women's sweep rowing team was diagnosed according to this method and given training recommendations, later in June selection tests were carried out to form crews in different boat types.

A basic endurance load test of more than 90minutes at the stroke rate 20-22 showed:

- large differences among rowers in performance, force and velocity on the inboard
- Different amounts of force and velocity among the rowers
- Different lactate concentrations that prevented at least one rower from reaching the biological training goal

As the training progressed all four athletes tended to:

- decrease the inboard velocity during the drive
- increase the inboard velocity during the recovery
- reduce the force on the inboard
- reduce the performance on the inboard during the drive

The following facts can be applied to the examined boat classes:

- depending on the length of time and intensity of the training session on the water, a relatively early tendency of decreased rowing technique was observed;
- The biggest deviations in the technical parameters from rower to rower happened under low intensity training.

These facts strongly support Roth's demands in 1987 for a transition from methodology/biological training concept to a methodology/biomechanical training concept to improve the performance of the active rowers.

Conclusion

The previous improvements in times and the average boat speed in the finals of top international competition are milestones in the development of rowing performances. They are the result of human factors, developed by training and experience and influenced by non human factors. In terms of Olympic cycles, the relative increases in the average boat speed of 1.5 percent to 2.0 percent are also likely in the future.

The biomechanics of athletic movement based on physical and biological sciences can improve rowing performance, especially in biomechanical/energetic and biological/energetic contexts.

The following two essential tasks should be emphasized:

- the improvement of rowing technique to help the biological/energetic development during training, which leads to a higher boat speed and faster times in competition;
- The examination of movement patterns during competition and training to explain the mechanical causes in biological-conditional effects.

From a biomechanical and biological point, there are reasons for adopting an efficient rowing technique, the most important characteristics of which is the emphasis on the first part of the drive.

In order to perfect the technique and fitness as a synthesis for further improvement in rowing performance, one should find and pay special attention to the specific aspects of each boat class and the individual use of these characteristics.

The conscious use of boat characteristics depends on ones knowledge of rowing in big boats versus small boats. For example, when going from a small boat to a big boat, one experiences:

- reduced drive times;

- increased inboard velocity;
- increased emphasis on the first part of the drive;
- reduced drive-phase proportion in comparison to the whole stroke cycle (changed rhythm relations);
- increased inboard velocity on the performance of the drive

Knowing about the individual characteristics of a certain boat class, one will be able to prescribe the correct work load and gear the athlete in training towards a successful performance.

Diagnostic methods to check certain abilities specific to rowing should allow a variation of the loads that will enable the athlete to reach the limits of his or her current individual ability. It is therefore possible to make low risk assessments of the training effectiveness, and to give recommendations more likely to succeed in the further development of performance.

A diagnosis of the rowing technique should be done along with keeping track of the rowing performance. For this reason it is recommended that you make a system of diagnoses (video analysis, dynamic-graphical measurements, individually or together):

- full stroke cycle and drive portion evaluations;
- competitive evaluations in test and regatta environments;
- Work load evaluations.

Abbreviations

Variables:

P = Performance

F = Force

V = Velocity

T = Time

S = Distance

Indices:

B = Boat

EF = Effective Drive

IH = Inboard part of the oar

FL = Recovery

Z = Rowing Cycle

Example:

PIHZ = average performance (P) on the inboard (IH) of one rowing cycle (Z) in the rowing stroke.

Reference Parameters:

SF = Stroke Rate

GA = Basic Endurance

WSA = Specific Endurance necessary for competition

S = Sprint

WK = Competition

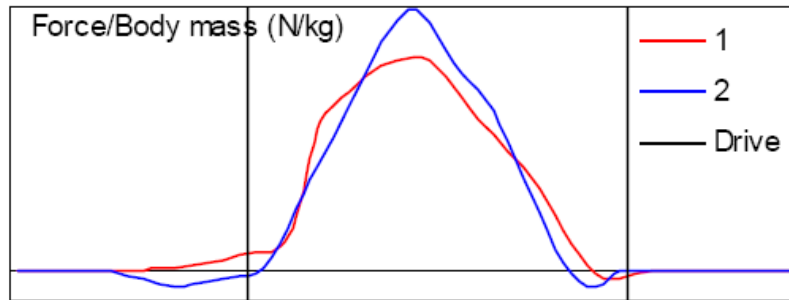
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BIOMECHANICS

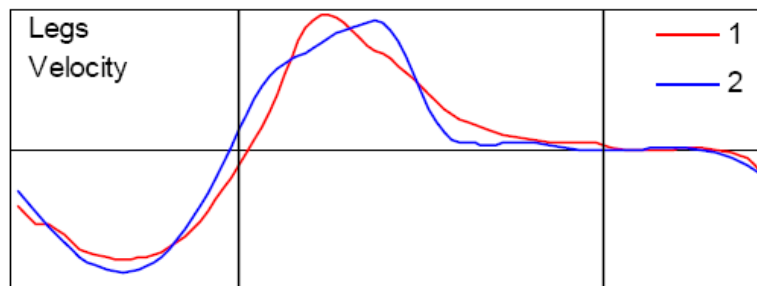
FORCE APPLICATION DURING THE DRIVE PHASE

... increasing the force faster at catch is very important for achieving efficient rowing technique? Below are force curves (as a ratio to body mass) of two crews, where the **crew 1** increases the force much quicker than the **crew 2**, but crew 1 has relatively lower maximal (7.27 and 8.84 N/kg, correspondingly) and average (3.84 and 4.09 N/kg) force application:

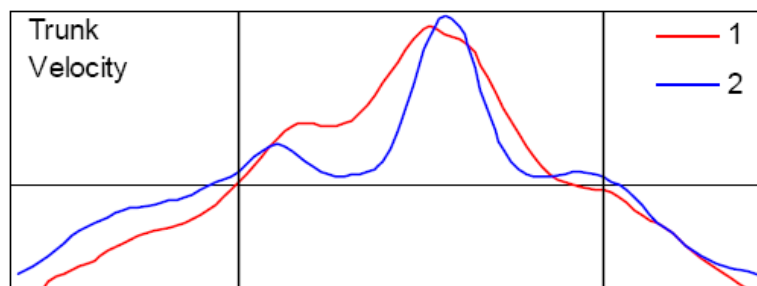


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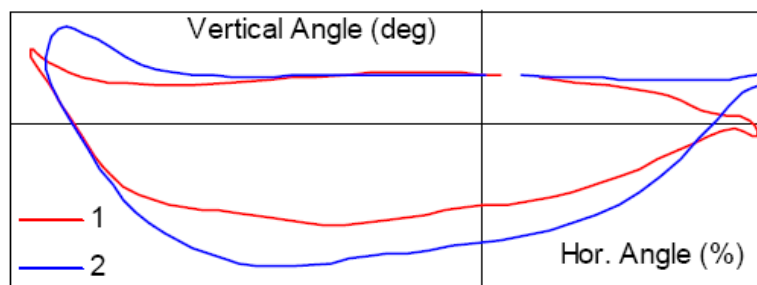
It is also important, that the first crew increases the force by means of faster leg drive, good connection with the trunk work and more horizontal and shallower blade path:



2

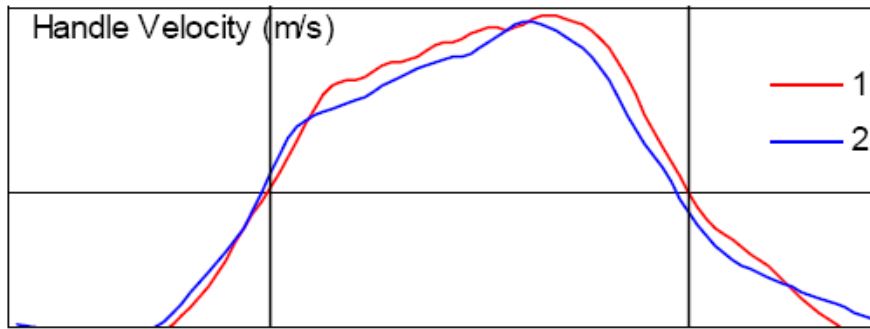


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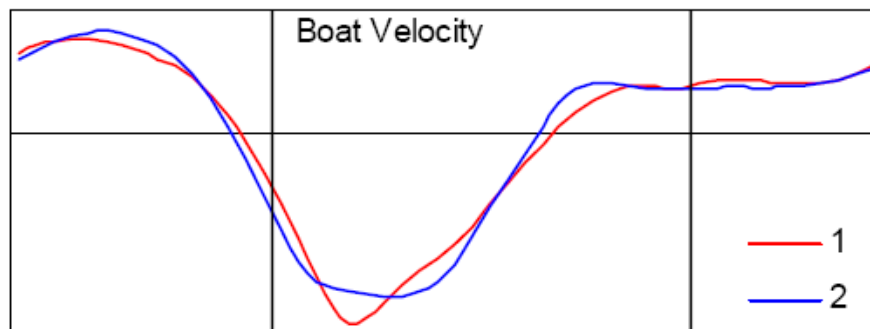
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As the consequence, the handle velocity of the first crew increases at catch up to higher value and maintain it longer during the drive:

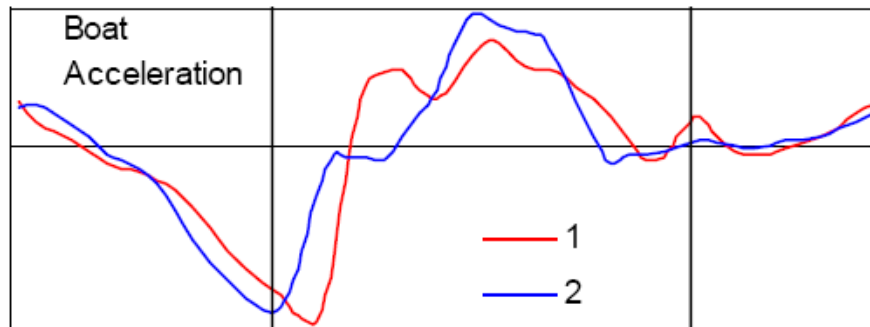


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The boat speed and acceleration curves of the first crew have deeper negative peak at catch (7.6 and 7.1 m/s²), but much quicker increase afterwards.

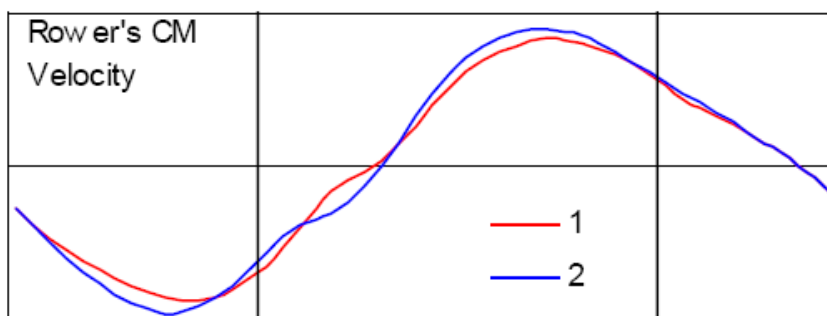


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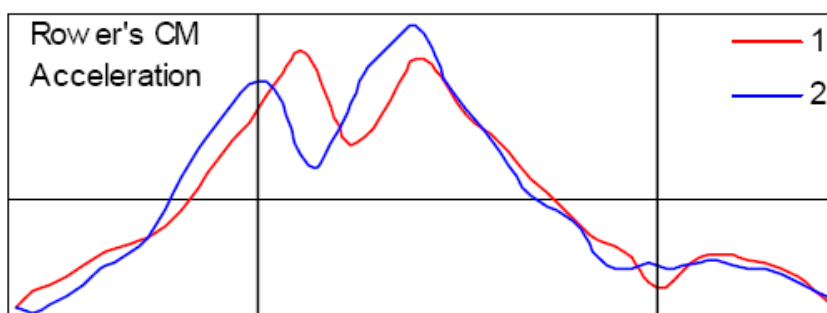


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This creates faster moving support on the stretcher and helps to accelerate rower's centre of mass (RBN 1/2004):



8



9

We can figure out three main reasons of higher efficiency and better performance of the first crew:

- Higher power production due to higher handle speed and in spite of lower force application (4.06 and 3.83 W/kg, 5.6% difference equal to 6s gain over 2000m);
- Lower fluctuations of the boat speed (deviations were 0.70 and 0.72 m/s), which cause higher boat velocity efficiency (98.17% and 97.64%, 2s faster over 2000m);
- Lower inertial losses caused by lower fluctuations of the rower's CM speed (9.4% and 11.4%, 2s faster over 2000m).

Finally, the overall gain due to better technique of the first crew was approximately 10s over 2000, which was nearly equal to the margin between two crews in the race.



SELECTION

UNDERSTANDING GOLD MEDAL STANDARDS

What is a Gold Medal Standard?

A Gold Medal Standard (GMS) is the theoretically predicted fastest possible time that a crew of a particular class can race the Olympic distance of 2000 m.

In Canada, The GMS times are developed by Rowing Canada Aviron (RCA) (often the Director of High Performance) based on gold medaling international performances. The GMS times are reflective of what RCA deems a necessary time for a crew to win a gold medal internationally (World Championships and Olympic Games). As international race times improve, GMS times change to reflect advances in training, equipment, and competitiveness. Therefore, the GMS times published by RCA are adjusted often on a four year basis to coincide with the Olympic quadrennial.

Understanding Gold Medal Standards

Currently (2008), The GMS time for a Heavyweight Men's 8+ is 5:19. That means that if a men's 8+ can race 2000 m in a time of 5 minutes 19 seconds they should be able to achieve a gold medal performance at the either the World Championships or the Olympic Games.

Similarly, the GMS time for a Lightweight Women's 2X is 6:45. A lightweight women's 2X should be able to achieve a gold medal performance internationally if they can race 2000 m in a time of 6 minutes 45 seconds. There are GMS times for every boat class that is raced in international competition. GMS times are often inferred for crews for which there is no international event (e.g. Heavyweight Women's 4+). Junior GMS times are typically used for Masters.

Gold Medal Standard Percentages

What is most useful in the analysis of performance is not the *time* a crew rows the 2000 m distance but rather the *percentage of Gold Medal Standard time* (GMS%) achieved. For example, if a men's 8+ rows 2000 m in 5:53 we want to know what percentage this time represents of the fastest possible GMS time of 5:19.

A time of 5:53 represents a boat velocity of 5.666 m/s as calculated by:

$$\text{velocity} = \text{distance} / \text{time} = 2000 \text{ m} / 353 \text{ s} = 5.666 \text{ m/s}$$

Similarly, the GMS time of 5:19 represents a velocity of 6.296 m/s (the velocity associated with the GMS time is called the *prognostic speed*). So the GMS% achieved by the crew that rowed 2000 m in 5:53 is given by:

$$5.666\text{m/s} / 6.296\text{m/s} = 0.9037 = \mathbf{90.37\%}$$

Why are Gold Medal Standard Percentages Useful?

Class Comparison

In the previous example a men's 8+ rowed a 2000 distance in 5:53. Imagine now that a lightweight women's 2X covers the same distance in a time of 6:53. Which is the higher quality crew?

The GMS% achieved by the men's 8+ is 90.37% (as shown in the example above). The GMS time for the lightweight women's 2X is 6:45. Following the same calculation above the lightweight women's 2X GMS% is 98.07%. Despite the fact that the men's 8+ was a full minute faster, the lightweight women's 2X is the superior crew. While these crews will never race in competition the lightweight women's 2X will compete in their event at a much higher level. Class comparison is also useful on an ongoing basis. In a weekly time trial crews can measure how they are performing on a

regular basis relative to other crews regardless of class. This can be particularly encouraging for developing crews who improve their GMS% each week compared to experienced crews.

Team Selection

Every regatta represents a slightly different level of competition. Achieving a gold medal performance at World Championships is definitely more difficult than winning a gold medal at a local club regatta. GMS can be used to assess the competitiveness of a crew at any competitive stage of rowing.

Example #1: Cut Off Lines

There are 6 crews of both junior men and women that are interested competing at the Eastern Interprovincial Rowing Championships. The coach selects a distance that is reflective of the race distance at that regatta and evaluates the crews in a time trial format.

The results look like:

Crew 1 88.1%
Crew 3 87.9%
Crew 5 87.8%
Crew 2 86.9%
Crew 4 82.1%
Crew 6 79.9%

Which crews should qualify to go to the regatta? This is not an easy question to answer. First and foremost, the selection committee (or coach) must be aware of the *philosophy* of the team under selection.

Inclusive Philosophy: The inclusive team philosophy is one in which the selection committee (or coach) intends to send a full team to the regatta regardless of the level of competitiveness of each crew. This can be achieved by starting with Crew 1 and working down the ranking until a full team is achieved. This ensures the best and largest possible team but does not consider the team's competitiveness.

Competitive Philosophy: If the philosophy of the team is to send only those crews that will be competitive it must first be established what GMS% is reflective of a gold medal performance at that specific regatta. Crews that are then close to this level of performance in the time trial should be considered and those that are not should be cut.

To determine the GMS% that is reflective of a gold medal performance for varying regattas coaches and selection committee members must use their expertise and discretion. Often coaches and the selection committee will base the interpretation of the results on one or two crews that are in the time trial that have previously achieved a high level of success at the regatta. For example, if Crew 3 above were a lightweight men's 2X that were gold medalist at the same regatta a year ago, it can be inferred that a GMS% of ~88% is reflective of a gold medal performance at that level of competition. If Crew 3 cannot be used as relative performance indicator (perhaps Crew 3 has significantly improved or detrained over the year) coaches and selections committees must use subjective experience to establish what % is reflective if a gold medal performance.

Let's continue to assume that 88% is reflective of a gold medal performance. If the philosophy of the team is to send only gold medal hopeful crews, Crews 1, 3, and 5 should strongly be considered. If the philosophy of the team is to send crews that will simply be competitive, perhaps top qualifying top 3 or making a final of 6 boats, Crews 1, 3, 5, and 2 should be considered.

You will never remove all subjectivity from team selection procedures. GMS are an excellent way to promote fairness, transparency, and to minimize subjectivity.

Example #2 Improving Your Chances

Often at regattas coaches are faced with the dilemma of two events being very close together and having the same athlete(s) in both races. At some regattas "hot seating" is possible but at higher levels of competition you must choose to focus on only one event. GMS% can be used to determine in which event you are most likely to achieve a higher level of performance.

As an example, a coach has to decide whether to race two masters women in a 2X or to include them in a masters women's 4X. The scheduling of events at a regatta prevents them from racing both events. If the goal is to achieve the highest level of performance the coach could organize a time trial in practice and obtain a GMS% for both combinations of crews over the race distance to determine which crew is performing at the higher level of competition. If the 2X achieves a GMS% of 83.12% and the 4X achieves a GMS% of 84.91%, the coach should race the 4X at the regatta. Interestingly the coach could also use GMS% to make the exact opposite decision. How? GMS% can be used to assess the competitiveness of a particular event at the regatta. If for example the masters women's 4X event that the women are going to enter is extremely competitive with the top six boats finishing within 0.5% of each other year after

year the coach might opt instead to enter the masters women's 2X event for which the crew is, according to GMS%, less competitive. If the master's women's 2X event normally only has 3 entries with poor GMS% achieved historically, this might be a great shot at a medal.

Common Pitfalls of Using GMS

GMS% Dependence on Conditions

Gathering on water performance data, such as hosting a weekly time trial or timed pieces in practice, allows you to monitor your progress. However, unlike many sports where performance times are highly reproducible, rowing times are not. Times in rowing are significantly influenced by many factors such as wind, current, water temperature, water depth, and water composition. These factors change from course to course, day to day, and minute to minute. Since times are highly variable so too are GMS%.

As an example, I have personally measured a change in 500 m splits on Lake Banook of 3-5 seconds from April to November as the water temperature increases. You may improve your 1000 m time by as much as 10 seconds over the season and not really be any faster. The improvements are a result of warmer water and less resistance on your hull.

As another example, coaches cannot compare crews GMS% outside of about a 3-4 minute window. If a crew races a 1000 m time trial and another crew follows immediately afterwards GMS% are comparable. However, if both crews are separated by a substantial amount of time wind conditions can significantly change making a relative comparison useless. You can certainly not compare results from crews given time data collected on different days. Unfortunately, coaches do this all the time.

Misinterpreting the Meaning Behind 1%

It is easy to confuse the significance behind the on water time differential between crews when you consider only the GMS%.

If a heavyweight men's 1X achieves a GMS% of 94.10% and another heavyweight men's 1X achieves a GMS% of 91.10% it might be tempting to conclude that they are relatively the same speed. After all, there is only a 3% difference in speed between scullers. But what time differential does that 3% represent. In this case, for a GMS of 6:33 for the men's 1X, a difference of 3% is equal to a 10 second lead! That is approximately 50 m or 6 boat lengths of open water! 1% GMS is a significant amount of time.

How are Gold Medal Standards used in Nova Scotia?

GMS are used in Nova Scotia by the Nova Scotia Rowing Association (NSRA) as part of the provincial team selection document. Crews that aim to compete for the Nova Scotia Provincial Team at the Canada Summer Games, Eastern Interprovincial Rowing Championships, or the National Rowing Championships will be subject to a time trial and assessed using GMS%. As described above, a selection committee (consisting of a mediator and a representative of each club) will draw a cut off line from GMS% results that result from a time trial conducted by the Provincial Team Coach. The Provincial Team coach is normally responsible to select and nominate crews to the time trial stage but is omitted from the final selection process to promote accountability and to remove coach subjectivity. Athletes are made aware of results in a timely manner and a formal appeals procedure is in place.