New on the Scene - The Big Blades

Author: Klaus Filter (GER)

A new design of oar blades has been seen around the world this spring. They are called the "big blades" and were introduced by Concept II of the United States (table 1). The idea for these blades has been around for a long time but no one has been able to perfect the design and necessary adjustments. The following text is a summary of investigations done by the Dreissigacker brothers in the fall of 1991.

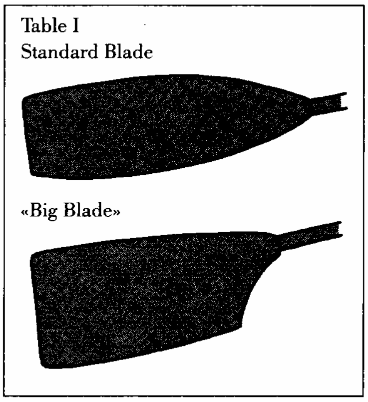


Table I

Theory

A. Suppose the outboard lever of an oar or scull is shortened and the spread stays the same. We all know from experience that this will result in a lighter load at the handle (table 2). Now, suppose the blade size is increased until the original load is again felt at the handle. Because of the shorter lever arm, the same force and velocity at the handle will now generate a greater force and slower velocity at the blade. This greater force at the blade will propel the boat faster. The slower velocity means that the blade slips less through the water. In other words, more work is done on the boat and less work is done on the water - therefore, in theory, a more efficient oar.

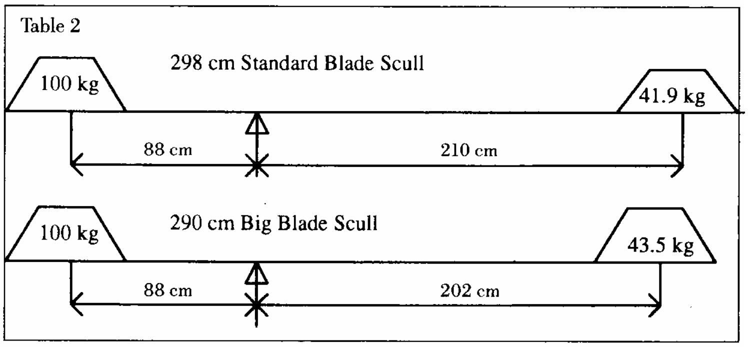


Table 2

B. There are limits, however, to how far this approach can be taken before negative factors will outweigh the positive. Some of these negative or limiting factors might be:

1. Blade width will become too much to handle. The blade must be designed to minimise handling problems.
2. The blade might backwater at the inboard edge. This can be reduced by shortening blade length.
3. There might be wind resistance when the blade is squared on the recovery. This is partially compensated for by a reduced outboard length.
4. There might be extra weight with a larger blade. This is partially compensated for by a reduced outboard length.

C. There are other oar variables that were specifically not changed so that there would not be too many things changed at once. The following areas are definitely worthy of study but are not addressed here:

1. *Overall load* - Only oars of equal perceived load were compared in all tests.
2. *Spread and angles at the catch and release* - Spread and inboard were the same in all tests.
3. *Blade curvatures and angle of attack* - There is a lot that can be done here. However, our initial tests did not show any improvement.

Implementation

A. After some initial trials with quickly constructed prototypes, we settled on a general blade shape that would hopefully:

1. Maximise width without impairing handling.
2. Shorten the blade somewhat without losing too much blade area.
3. Maximise blade area within the length and width constraints.

B. Then we followed this pattern of experimentation:

1. Guess at a larger blade size and shorter outboard.
2. Test row and change either blade size or outboard until load feels the same as with standard oar (without changing spread or inboard).
3. Do timed pieces alternating between new prototypes and standard oars.
4. If prototype does not show significant increase in speed, go back to step 1 and try a slightly smaller blade and slightly longer outboard.
5. If prototype shows significant increase in speed (approximately equal to predicted speed increase), then make more prototypes and send oars around for further testing.

C. This process produced the following sizes for sweeps and sculls:

1.	*Width:*	*Big Blade*	*Standard Blade*
	sculls:	21.5cm	17cm
	sweeps:	25.5cm	20cm

2. *Overall Length:*

Overall Length:	*Big Blade*	*Standard Blade*
sculls:	290-292 cm	298cm
sweeps:	376cm	383.5cm

Sweeps: approx. 20% bigger
Sculls: approx. 15% bigger

Field Testing

A. The inherent problem in field testing is the difficulty of isolating the variable being tested. The following are six factors that can affect test results, along with some proposed procedural remedies:

1. *Competition* - a) only do timed pieces with one boat at a time; or b) do pieces with a number of boats but have one boat not change oars at all. Compare all times to the unchanged boat as well as comparing the same boat piece to piece.
2. *Weather and Water Conditions* - test on a calm day in still water.
3. *Fatigue* - at least four pieces should be done at an outing, switching oars at each piece.
4. *Control of power due to submaximal effort* - make sure pieces are short enough to allow 100% effort.
5. *Familiarity with equipment* - a) avoid racing starts; b) alternate the oar used on the first test piece each day; c) repeat test after two weeks of using only new oars in practice.
6. *Other rigging factors* (including load, pitch, oar weight, etc.) - make sure all rigging factors are equal.

Examples of early results of testing the big blade

A. Concept II results: CII testing in pair without coxswain. Big Blade tested with 12'7", 12'6". A total of twelve 500 meter pieces at 32 strokes per minute were done over three days. Results: Big Blade was an average of 2.4% faster (measured with a speed meter).

B. Best results: Lightweight sculler Peter Haining (GB) tested Big Blades with 298 cm sculls 12 x 250 m at 32 strokes per minute switching oars every three pieces, running starts. Results: Average time per 250 meters with Big Blades - 52 seconds. Average time per 250 meters with 298 cm standard - 56 seconds. Big Blade was 7% faster.

C. Worst results: Sculler Brian Sweenor rowed 2 x 1000m with Big Blades followed by 2 x 1000m with standard blades against 4+ at 32-33 strokes per minute. By time, the Big Blade was 3% slower; by margin, the Big Blade was 1.25% slower.

D. The only comparative non-CII sweep results: Dartmouth College (USA) did 4 x 5 minute pieces with two fours switching oars every piece. Big Blades always won. Princeton did 2 x (long steady-state pieces, 700m, 500m) with two fours switching between sets. Big Blade always won.

Do You Need Hatchets to Chop Your Water?

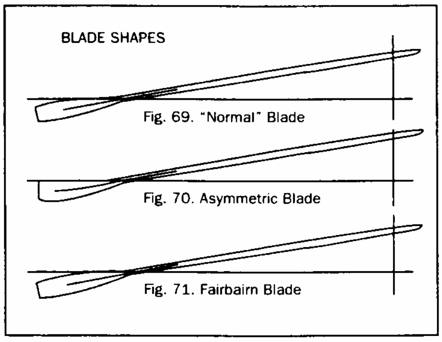
An Analysis of Big Blades and How They Work

Author: Volker Nolte

Big blades came onto the American rowing scene in the fall of 1991 and were greeted with much interest and speculation. The new blades are shorter than "traditional" blades have a larger spoon area and an asymmetric shape. The reaction of rowers and coaches was "Do we really need the new blades? Are they faster? Do they require a new rowing technique?"

People have been experimenting with the blade shape for years. When oars were made of wood, almost every coach had his preferred shape, and you could find many different templates in boat-building shops. Even asymmetric blades were available back then (see figure 1).

Figure 1: Different blade shapes in a German rowing textbook (Ruder, Boot und Bootshaus) from over 50 years ago.



Theoretical research indicates very clearly that there is a lot of room to improve on the efficiency of the "normal" symmetric blade. For instance, figure 2, from research in Germany, illustrates that the "normal" blade is far from being optimal.

Most of the boat builders currently offer asymmetric oars. The British company, Hi Lock, claims to have started the new development and points out that a British double scull used Hi Lock Power Blade sculls at the 1991 World Championships.

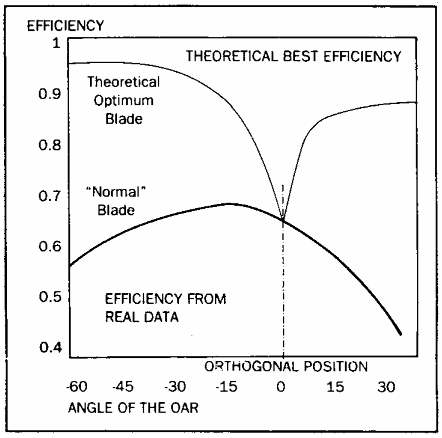
How Does the Big Blade Work?

Any new blade design would let you row faster if it were hydrodynamically more efficient, which means the power you apply on the oar handle results in a greater power output on the blade, resulting in acceleration of the whole mechanical system of rower/boat/oar. The definition of efficiency (E) namely is:

$$E = (\text{Output}/\text{input})$$

Output = propulsion *in the rowing direction*, and input = power applied on the oar handle.

Figure 2: Hydrodynamic efficiency of a "normal" sweep blade as it compares to the theoretical best efficiency of a blade as a function of the oar angle. Note that the figure indicates the efficiency of the blade can be improved about 15% overall (from Affeld/ Schichl).



Therefore, the first explanation for the higher efficiency of the big blade was that because of its shorter outboard lever, applying the same force and velocity at the handle would generate a greater force and slower velocity at the blade, and that the greater force would propel the boat faster.

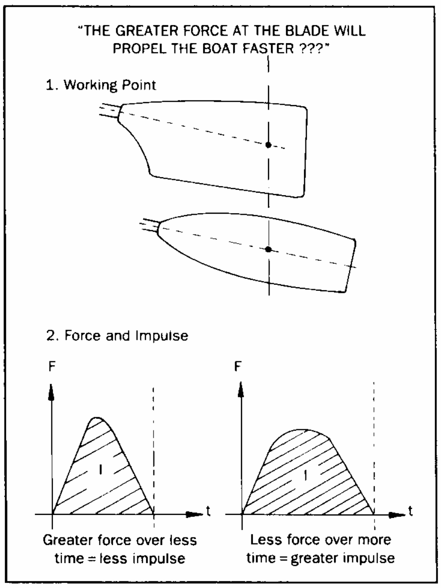
Although this explanation sounds logical, there are some doubts. First, this argument applies only for the larger spoon area. The asymmetrical shape would not have any effect. Furthermore, based on this theory, it would be logical to extend the area even more; however, the modified version of Concept II's big blade (introduced to make retrofitting easier) has a smaller area rather than a larger one (3 cm shorter) and has performed comparably to the original.

Secondly, only further research could verify whether the working points (the centre of the pressure) on the "normal" and big blade are a different distance from the oarlock. If the working points for both oars were the same distance from the oarlock, both blades would effectively have the same outboard length and therefore produce the same amount of force on the blade.

Thirdly, further research is also necessary to determine whether the impulse (the amount of force applied over the duration of the drive) is affected by the different blades. For instance, a higher peak force doesn't automatically ensure greater propulsion. If the force is greater, but it is applied over a shorter period of time, the impulse could be less than if you applied less force over a longer period of time (see figure 3). The impulse is the real measure of the amount of propulsion produced by a blade, and the big blade's effect on it is not yet known.

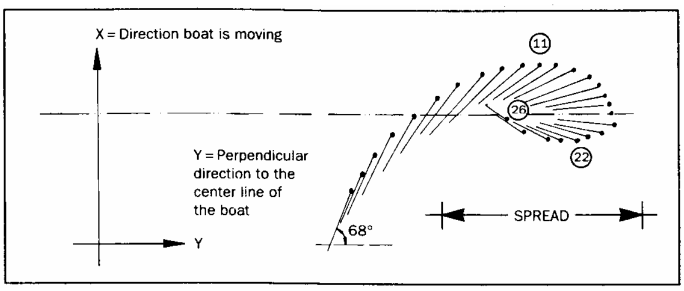
Another theory to explain the effect of the new blade is that the assumed slower velocity of the blade through the water means the blade slips less through the water as Concept II states in their advertisements. Stämpfli goes on to say their blades can eliminate all the slip. However, the propulsion force on the blade is directly proportional to the square velocity. Therefore, as indicated by proven physical laws, we must have movement of the blade relative to the water because without movement, no force can be put on the blade. And there is only one way to get more force on a given blade: the blade must move faster through the water.

Figure 3: A larger spoon area does not automatically mean that the propulsion would be higher because it is not known how the working point and the impulse are affected by the new blade design.



Some video footage borrowed from Dick Dreissigacker helps provide a clearer understanding of how a blade works in the water. The video was shot from a bridge down to the water. The camera was fixed, and some scullers rowed through the picture. A video camera shoots 30 pictures per second, and in figure 4, the position of the blade is shown for every picture in which the blade was in the water. The boat is moving in x-direction, and since you can take the spread as a reference distance, the displacement and consequently the velocity of the blade, as well as the angle of the oar can be measured.

Figure 4: The movement of the starboard blade of a single during the drive. Data from a video film, made with a stationary camera vertically down from a bridge (x = rowing direction, y = perpendicular direction to the centreline of the boat).



The bigger points indicate the end of the blade, and the connected lines show the angle of the oar for every picture. The oarsman who rows close to race speed catches 68 degrees from the orthogonal line (the point at which the oar is perpendicular to the centreline of the boat). The blade moves for 11 pictures (= 0.37 seconds) *in* rowing direction, then another 11 pictures *against* the rowing direction, and in the finish, four pictures again *in* rowing direction (= 0.13 seconds). The drive lasts 26 pictures (= 0.87 seconds). The blade travels 57% of the time in rowing direction, which corresponds with data found in literature (Nolte, Affeld/Schichl). This finding may be surprising in the first place, but there is evidence that the rowing blade acts like an aeroplane wing, when it travels in the rowing direction. Lower pressure occurs on the back side of the blade, which therefore gets sucked in the rowing direction. This phenomenon is called *hydrodynamic lift* (Counsilman, Nolte), comparable with the aerodynamic lift of the aeroplane wing. It is important to understand that *lift* indicates a force pulling on the back of the blade.

The velocity of the blade in x- and y- direction is shown in figure 5. At the catch, the blade travels more than 2 m/sec in the rowing direction. A few pictures later, the velocity in y-direction is maximal. This means the blade has a huge velocity relative to the water in the beginning of the drive. Therefore, the forces on the blade are maximal at this moment, and the blade has a *positive slip*, which is movement of the blade relative to the water, in the rowing direction. Only when the blade moves with a negative x-velocity (this means the blade moves against the water and produces drag), can you find a *negative slip*.

Figure 5: The velocity (v) of the blade in the water during the drive (x = rowing direction; y = perpendicular direction to the centre line of the boat; p = number of picture; t = time in seconds.)

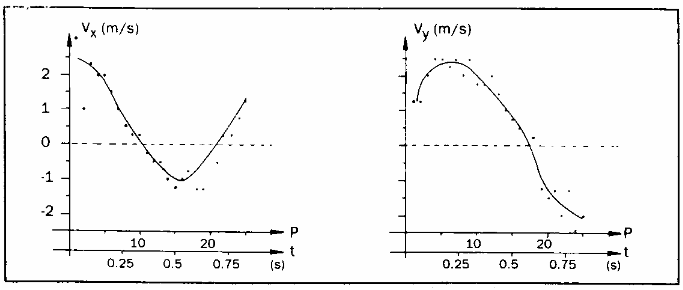
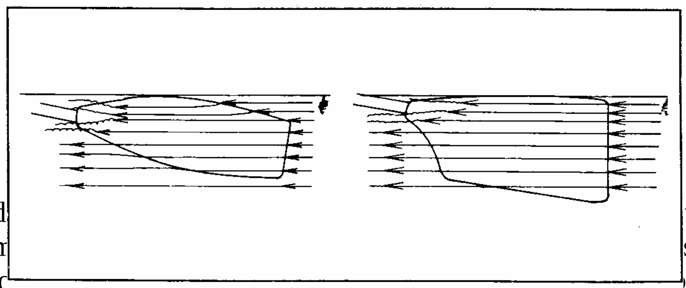


Figure 6: The flow of the water around the big blade is hydrodynamically better because the blade allows the streamlines to pass more undisturbed.



With the und … why the big blade presum … s the water streamlines tc … rtex that are hydrodynamically less effective. Figure 6 illustrates this idea.

These thoughts indicate the big blade could work more efficiently than the symmetric blade. This means it seems possible to produce more positive slip with the asymmetric blade which would give the boat a longer travel distance during the drive, which implicates a higher velocity of the boat. It's now up to scientific tests to prove this theory.

Some Experience with Hatchet Blades

Some research has already been done with the new blades. Concept II has reported on a large number of test races and announced the new blade seemed "a few percent faster." Anyone who has ever tried to validate a technical change in rowing by comparing times of test races knows how difficult it is. Not only weather conditions but also the psychological and physical condition of the rowers (can they work on the same performance level for different races?), and the technical requirements (can they row with each piece of equipment in the same way?) change from test to test, which makes comparisons and conclusions difficult. The following analysis tries to overcome these problems by using results from official races, assuming that the world's top national team eights perform their best at major regattas, and that they are able to repeat their performance consistently. Last year's major regattas were chosen for this comparison. The final times were almost the same, which means that the conditions were very similar.

Table 1: Comparison of resulting times in international races in 1992 of the top men's eights. Direct comparisons are only done if both boats were in the same race.

Part I

Nation	Heat - Olympic Games			Final - Olympic Games		
	Blade	Time	Difference	Blade	Time	Difference
ROU	Big	5:30.21	2.77 sec	Big	5:29.67	1.33 sec
GER	Macon	5:32.98		Big	5:31.00	
2.77 sec - 1.33 sec = 0.44 sec ≈ 0.4%						

Part II

Nation	Final - Luzern			Semi-Final - Olympics			Final - Olympic Games		
	Blade	Time	Diff.	Blade	Time	Diff.	Blade	Time	Diff.
USA	Big	5:30.35	1.64 sec	Big	5:37.11	1.51 sec	Big	5:33.18	2.18 sec
GER	Big	5:28.71		Big	5:35.60		Big	5:31.00	
2.18 sec - 1.51 sec = 0.67 sec ≈ 0.2%									

In the first part of table 1, the eights from Germany and Romania are compared. The Germans rowed in their heat at the Olympic Games with the Macon ("normal") blades, and in the final with the new hatchet blades. The Romanians won the heat by 2.77 seconds, and beat Germany in the final by 1.33 seconds. The Germans rowed 1.44 seconds or 0.4% faster in the final, relative to the Romanians. From the comparison with the U.S. eight we know that the Germans rowed a good race in the final, which indicates that the change of the blades resulted in a maximum increase of 0.4% of the speed.

Obviously, the comparison only includes one example. Therefore, the results of the analysis do not constitute a final conclusion, but they do support some theories:

- A boat gains a little advantage by using the big blades.
- The increase in speed is less than 1%.

Further Considerations

Some coaches may have observed greater improvements in the speed of their crews after switching to the big blades, and some results may even prove it. In particular limited technical abilities seem to have a greater advantage, but it's worthwhile to study this phenomenon more closely. There are reasons other than physical or biomechanical for a change in speed after switching to big blades:

- ***Psychological:*** Especially inexperienced rowers may be very excited to get the new oars they've heard so many magical things about.

- ***Rigging:*** The big blades react less sensitively to the pitch of the boat. One degree more or less pitch can be absorbed, which means that a poorly rigged/pitched boat has less influence on the rowing. Assuming that less experienced teams normally also have less experienced coaches, and lesser quality equipment, the new blades may help adjust these disadvantages.

- ***Technique:*** Inexperienced rowers with less technical skill can apply more force with the big blades since these oars do not react so sensitively.

- ***Inconsistency:*** Development teams are inconsistent from race to race. Therefore, it's very difficult to judge where the differences come from.

Rowing with the big blades also raises some problems. It's even more important to work on rowing technique, since the oars are more forgiving. Otherwise, novices may not learn good technique and may not reach their rowing potential. Some coaches might be carried away with their novice crews by overemphasising the rough power before the rowing technique is well developed. In addition, the big blades increase the load on the lower back in particular during the first part of the stroke, which means without proper rigging and technique, more injuries are possible.

Conclusions

The new blades generated a lot of excitement in the rowing world. Several issues of *FISA Coach* included articles about the blades - no other topic has received as much attention. Some coaches were so excited about the hatchet oars that they wanted to prohibit their use, but none of the national or international governing bodies banned them. A development like the big blade can only help rowing over the long run, and a ban would have been a step in the wrong direction. Consider that we would still be rowing with heavier, more expensive and more fragile wooden oars if boat builders hadn't developed the plastic ones.

Likewise, there's no need to overreact and replace all Macon blades. The new oars do not increase the speed of a boat so dramatically that everyone needs them to stay competitive. The vast majority of high school, university and club races are decided by more than the difference the big blades could make. Most of the crews could probably improve their times more with proper physical and technical rowing training. It's also important to consider that the big blades can increase the possibility of injury and complicate learning technique, which is especially critical for masters and beginners. The decision whether to buy big blades should be based on common sense.

If you have a team that depends on every little advantage to stay competitive (a national team or a crew that has legitimate hopes for a championship) you should get the newest oars. All the other teams should consider very seriously whether they really need to spend additional money on new oars. If your rowing program plans to buy new oars anyway, then you should certainly buy the newest type of blades.

Further Reading

Affeld, K. and K. Schichl. Untersuchungen der Kräfte am Ruderblatt mithilfe eines Mechanischen Simulators. (Translation: Analysis of the Forces on the Rowing Blade with a Mechanical Simulator). Report from the Technische Universität Berlin, 1985.

Borrmann, Hugo, eds. Ruder. Boot und Bootshaus. (Translation: Oar, Boat and Boathouse). Berlin, 1941.

Counsilman, J.E. The Application of Bernoulli's Principle to Human Propulsion in Water. Indiana, 1972.

Nolte, Volker. Die Effektivität des Ruderschlages. (Translation: The Efficiency of the Rowing Stroke). Berlin, 1984.

Editor's note: FISA wishes to thank USRowing for its permission to republish this article, which originally appeared in the July/August 1993 issue of American Rowing *magazine.*

Training in High Altitude from 1800 to 2000 meters

Authors: Ulrich Hartmann and Alois Mader (GER)

General Conditions at High Altitude

At the altitude of 1800 meters the air pressure decreases from 760 mm Hg (mercury) at sea level to 595 mm Hg (St. Moritz is 610 to 615 mm Hg). The oxygen partial pressure in the arterial system decreases by about 20 mm Hg. The consequence of this is that the body at high altitude is offered less oxygen at the same cardiac output and respiratory minute volume when compared to sea level. After 23 to 25 days these negative effects can be compensated for in accordance with the correct amount and intensity of training. When the body is adapted to a higher oxygen transport capacity, this profit is the main positive effect in the form of a capacity reserve.

At high altitude the respiratory work is also reduced because of the decreased pressure. This results in a higher respiratory minute volume. The adaptation to higher breathing work during intensive loads in training is also of advantage during the forthcoming competition phase.

At high altitude the water-vapour pressure in the air decreases to 55% of the sea level value. The air gets drier, and this - in combination with a high amount of physical work - leads to an irritation of the respiratory tract and is followed by a high fluid elimination. At the same time with increasing altitude, the air temperature decreases. One thousand meters' difference in altitude leads to decrease in the temperature by about 6.5°C. The solar radiation is more intense because of the direct ultraviolet rays. This has an activating effect on the sympathetic tone.

Time Course and Physiological Reaction of Adaptation

1) Early transition/adaptation period (duration 3 to 5 days).

Reaction: Increasing respiratory work with the aim to compensate for the lack of oxygen pressure.

- Decrease of PCO_2,
- Alcalosis with impairment of the peripheral 0_2 utilisation.

Objective consequences caused by haematological research results:

- Concentration and decrease of blood volume (increase of haemoglobin by about 1-1.5%, increase of haematocrit to the value of 50 or more in men, and 47 or more in women),

- Reduced cardiac output during rest and also during submaximal load,
- During maximal load, increased cardiac output,
- Decreasing oxygen uptake by about 13% caused by reduction of the cardiac output,
- Increased heart rate (HR), as compared to the same load at sea level,
- Excretion of stress hormones (adrenaline, noradrenaline and corticosteroids, changes in electrolytes, minerals, etc.)

Subjective consequences:

- Subjective feeling of a high physiological load range caused by the increased sympathetic tone. The consequences could be a hidden effect of overtraining with long lasting decrease of power output.

2) Normal training phase after passing the early transition/adaptation period (4th/5th until 10th/12th day):

- Physiological load range and endurance trainability return to normal levels,
- Adaptation and normalisation of the work of the cardiac system to the conditions of high altitude,
- Blood volume returns to normal levels,
- Start of an intensive phase of erythropoesis. Taking iron, vitamin C and vitamin B_{12} supplements could be helpful,
- Normalisation of stress hormone excretion and acid-base-equilibrium,
- Because of the reduced buffer capacity for lactate, it is not effective to do training with high intensity during this phase of altitude training,

3) Late adaptation period, connected with higher intensity (13th/14th to l8th/l9th day):

- More intensive loads are possible, but without provocation of an "early top form."

4) Late transition period (19th/20th day):

- Reduced intensity with medium amount (active regeneration/"super-compensation").

5) Active regeneration (2 1/2 days), connected with early transition (maximal 3 to 5 days):

- Adaptation to sea level and climate (see below). Nearly normal training process, like at sea level. Addition of some high intensive loads is possible.

6) Competition phase (6th to 20th day after high altitude training camp):

As far as the problem of the maximally advanced form after high altitude training is concerned, the opinions are divided. They vary from the 9th to the 23rd day. According to our results, an optimum of physiological power output can be assumed between the 10th and 13th day. In accordance with scientific and theoretical results, during the following 10 days a decrease in the physiological effects can be assumed. This can not be verified by practical reasons or with experiments.

Implications for Training and General Framework Training Plan

1) Early Transition/Adaptation Period:

Because of physiological and psychological reasons there should be a load with high intensity just before going to altitude. During the first days at altitude the training dose should be long distance/steady state, or an aerobic training at a low intensity should be conducted. There should be a framework of training for each type of boat. The maximum of training is long distance training of a normal or somewhat reduced volume when compared to sea level. Once or twice per week there should be a strength-endurance training session at low intensity and with long recovery intervals between the repetitions. On the third or fourth day at altitude, half a day of rest should be planned. This early adaptation period should be a type of training between normal and regeneration training.

2) Normal training phase after passing the early transition/adaptation period:

As the load capacity normalises there is also a normalisation of the training process with two or three sessions per day. Too many intensive training loads should be avoided. A strength-endurance training at nearly the same intensity compared to sea level can take place. Monitoring of training should be exact and individualised.

3) Late adaptation period:

At the end of the high altitude training camp, more intensive load, such as going for distances, time relation distances and ergometer tests, are possible. Reaching for an early top form should be avoided by setting individual intensities for training sessions and by individually monitoring the training process. The intensive loads at the end of the altitude camp should be regarded as a stimulus to develop anaerobic capacity.

4) Late transition period:

The last two days at altitude are to be regarded as days of active regeneration (phase of "super-compensation"). During these days the return back to sea level will take place.

5) Active regeneration phase, connected with early transition phase at sea level:

During the first two or three days at sea level a reduced performance capacity should be expected. Four or 5 days after the altitude camp, an individually increased high intensive load should take place. The same load can be repeated some days later. After this, a nearly normal competition state can be expected.

Processes of Monitoring Training

Ergometer testing as an objective method of performance at the beginning and the end of the training camp is highly recommended. If possible, a spiroergometry test should also take place. Control of urea as an indicator of overtraining at least every three days is useful as additional support. Registration and monitoring of heart rate during training is important for individual reaction to training intensity.

Measurement of lactate to determine the intensity of training and the athlete's maximum load tolerance is also extremely helpful.

If possible, one should check the level of creatine kinase as an indicator of muscular damages after intensive work on the water and after intensive strength training. Controlling the levels of haemoglobin and haematocrit as an indicator of the water content of the body is useful as well.

Other Comments

The training at high altitude can only be long distance/steady state training. Basic technical improvements (e.g., during racing or in the range of high stroke rates) cannot be safely attempted because of the need for high intensity. These have to be trained during the year and in the course of other training measures.

There are indications that those athletes who have been at altitude before adapt much faster than others. From the theoretical point of view a high altitude camp three times per year should be optimal. The result of this is the repeated stimulus which causes the excretion of erythropoetin which is followed by the development of a higher amount of red blood cells and connected to a higher blood volume.

The precondition for a positive training adaptation at high altitude is health and a good, trained condition in the athlete. Infections which are developing or latent (especially in the area of the teeth) have to be under medical control early enough and, in any case, before the high altitude camp.

References

1. Astrand P.O.: Die körperliche Leistungsfähigkeit in der Höhe. In: Hollmann, W. (eds.): Zentrale Themen der Sportmedizin. Springer, Berlin-Heidelberg-New York, 3rd edition 1986.

2. Feth, W.: Materialien zum Höhentraining. Beiheft Leistungssport No. 5, 9, 399(1979).

3. Fischer, H.G., U. Hartmann, R. Becker, R Komanns, A. Mader, W. Hollmann: The excretion of l7 ketosteroids and l7 hydroxycorticosteroids in night urine of elite rowers during altitude training. Int. J. Sports Med., 13, 1, 1992. S. 15-20.

4. Hartmann, U.: Querschnittuntersuchungen an Leistungsruderern im Flachland und Längsschnittunter-suchungen an Eliteruderern in der Höhe mittels eines zweistufigen Tests auf einem GJESSING-Ruderergometer. Hartung-Gorre Verlag, Konstanz 1987.

5. Luft, U.C.: Die Höhenanpassung. Ergebn. Physiol. 44, 256 (1941).

6. Mader, A., U. Hartmann, H. Fischer, G. Reinhards, W. Hollmann: Magnesiumsubstitution im Höhentraining der Rudernationalmannschaft in Vorbereitung auf die Olympischen Spiele - Ergebnisse einer kontrollierten Studie. In: Magnesium-Bulletin 12, 3, 1990. S. 69-78.

7. Mader, A., U. Hartmann, W. Hollmann: Einfluss eines Höhentrainings auf die kardiopulmonale Leistungsfähigkeit in Meereshöhe. In: Hollmann, W. (eds.): Zentrale Themen der Sportmedizin. Springer; Berlin-Heidelberg-New York, 3rd edition, 1986.

Rigging Tables - Olympic Games
Lake Lanier, Atlanta, USA
July 1996

EVENT & PLACE	COUNTRY	BOAT BUILDER	SPREAD SPAN (cm)	OAR/SCULL BUILDER	OAR/SCULL LENGTH (cm)	INBOARD LENGTH (cm)
H2-						
1	GBR	Ayling	85.5	CII	377.0	115.5
2	AUS	Empacher	85.5	Croker	376.0	116.5
3	FRA	Empacher	86.0	CII	376.0	116.0
4	ITA	Empacher	86.5	CII	379.5	116.5
5	NZL	Empacher	86.0	CII	377.0	115.5
6	CRO	Empacher	86.5	CII	376.0	116.5
F2-						
1	AUS	Sykes	86.0	CII	373.0	117.0
2	USA	Empacher	85.5	CII	373.0	117.0
3	FRA	BBG	86.25	CII	376.0	117.0
4	GER	Empacher	86.5	CII	376.0	116.5
5	CAN	Hudson	87.0	CII	376.0	117.0
6	RUS	Empacher	87.5	CII	373.5	117.0
H2X						
1	ITA	Empacher	159.0	CII	292.0	89.0
2	NOR	Empacher	158.0	CII	291.0	87.5
3	FRA	Empacher	159.0	CII	291.0	88.0
4	DEN	Empacher	158.0	CII	291.0	87.5
5	AUT	Empacher	158.0	CII	291.5	87.0
6	GER	Empacher	159.0	CII	291.0	88.0
F2X						
1	CAN	Hudson	159.0	CII	291.0	89.0
2	CHN	Empacher	158.0	CII	290.0	87.0
3	NED	Stampfli	158.0	CII	291.0	88.5
4	AUS	Sykes	158.0	Croker	289.0	89.0
5	GER	Empacher	159.0	CII	289.0	88.0
6	NZL	Martin Marine	158.0	CII	289/288	88.5
H4-						
1	AUS	Empacher	85.0	CII	378.0	115.5
2	FRA	Empacher	84.5	CII	376.5	115.0
3	GBR	Sims	85.0	CII	376.0	116.5
4	SLO	Empacher	84.5	CII	376.0	114.5
5	ROM	Empacher	84.5	CII	378.0	114.0
6	ITA	Empacher	84.0	CII	379.0	114.0
F1X						
1	BLR	Empacher	160.0	Empacher	288.0	88.0
2	CAN	Hudson	158.5	Croker	290.0	88.0
3	DEN	Empacher	160.0	CII	291.0	88.5
4	SWE	Bootsbau Berlin	158.5	CII	291.0	88.5
5	GBR	Sims	159.0	CII	286.0	86.0
6	USA	Van Deusen	160.0	CII	287.0	88.0

EVENT & PLACE	COUNTRY	BOAT BUILDER	SPREAD SPAN (cm)	OAR/SCULL BUILDER	OAR LENGTH (cm)	INBOARD LENGTH (cm)
H1X						
1	SUI	W/M	159.0	CII	291.0	88.5
2	CAN	Empacher	160.0	CII	293.0	89.0
3	GER	Empacher	159.0	CII	291.0	87.5
4	SLO	Empacher	161.0	CII	291.5	89.0
5	CZE	Empacher	158.0	Empacher	294.5	87.5
6	NOR	Empacher	160.0	CII	292.0	88.5
HPL2X						
1	SUI	Filippi	159.5	CII	290.0	88.0
2	NED	Stampfli	159.0	Empacher	291.0	89.0
3	AUS	Sykes	158.0	CII	289.0	88.5
4	ESP	Empacher	157.0	CII	290.0	88.0
5	AUT	Empacher	158.0	Empacher	290.0	88.5
6	SWE	Stampfli	159.0	CII	290.0	87.0
FPL2X						
1	ROM	Empacher	158.0	CII	292.0	88.5
2	USA	Empacher	159.0	Dreher	288.5	88.5
3	AUT	Empacher	158.0	Empacher	288.0	88.5
4	ITA	Empacher	159.0	CII	289.0	89.0
5	DEN	Stampfli	158.5	CII	290.0	88.0
6	NED	Empacher	159.0	CII	289.0	88.0
HPL4-						
1	DEN	Empacher	85.0	CII	376.0	116.0
2	CAN	Hudson	85.0	CII	376.0	115.0
3	USA	Vespoli	84.5	CII	376.0	114.5
4	IRL	Stampfli	85.0	CII	376.5	115.0
5	GER	Empacher	85.0	CII	376.0	115.0
6	AUS	Empacher	85.0	CII	374.0	115.0
F4X						
1	GER	BBG	160.0	CII	291.0	88.0
2	UKR	Empacher	158.5	UKR	291.0	88.0
3	CAN	Hudson	158.0	CII	291.0	88.0
4	DEN	Stampfli	157.0	CII	291.0	87.5
5	CHN	Empacher	158.0	CII	290.0	87.0
6	NED	Stampfli	157.0	CII	291.0	87.5
H4X						
1	GER	Empacher	159.0	CII	293.0	88.5
2	USA	Empacher	158.0	Dimano	291.0	87.5
3	AUS	Sykes	158.5	Empacher	293.0	88.5
4	ITA	Filippi	158.0	CII	291.0	88.5
5	SUI	Filippi	157.5	CII	291.0	87.0
6	SWE	Stampfli	157.5	CII	291.0	87.5
F8+						
1	ROM	Empacher	84.0	CII	376.0	113.5
2	CAN	Empacher	85.0	CII	376.0	115.0
3	BLR	Empacher	85.0	CII	371.0	116.0
4	USA	Empacher	84.5	CII	373.0	115.0
5	AUS	Empacher	85.0	CII	374.0	
6	NED	Empacher	86.5	CII	376.0	115.0

EVENT & PLACE	COUNTRY	BOAT BUILDER	SPREAD SPAN (cm)	OAR/SCULL BUILDER	OAR LENGTH (cm)	INBOARD LENGTH (cm)
H8+						
1	NED	Empacher	83.5	CII	376.0	113.0
2	GER	Empacher	84.0	CII	377.0	114.5
3	RUS	Empacher	84.25	CII	376.0	114.0
4	CAN	Empacher	83.5	CII	379.0	113.5
5	USA	Empacher	83.0	CII	379.5	113.0
6	AUS	Empacher	83.5	CII	378.0	114.0

Rigging Tables -
FISA World Rowing Championships

Strathclyde, Scotland
August 1996

EVENT & PLACE	COUNTRY	BOAT BUILDER	SPREAD SPAN (cm)	OAR/SCULL BUILDER	OAR/SCULL LENGTH (cm)	INBOARD LENGTH (cm)
H2+						
1	FRA	Empacher	86.0	CII	376.0	116.0
2	ROM	Empacher	86.5	CII	376.0	116.5
3	NED	Empacher	87.5	CII	354.5	117.0
4	ITA	Empacher	87.0	CII	379.5	118.0
5	GBR	Empacher	87.0	CII	376.0	116.5
6	GRE	Empacher	87.0	CII	374.5	116.5
H4+						
1	ROM	Amilibia	84.5	CII	376.0	115.5
2	CZE	Empacher	85.3	CII	376.0	115.0
3	RUS	Empacher	86.0	CII	378.0	116.0
4	GBR	Sims	85.5	CII	376.0	115.5
5	FRA	Empacher	85.5	CII	376.0	115.0
6	YUG	Empacher	85.5	CII	376.0	115.0
F4-						
1	USA	Empacher	85.0	CII	377.0	116.0
2	ROM	Empacher	85.5	CII	376.0	116.0
3	GER	Empacher	85.5	CII	373.5	116.0
4	DEN	Sims	84.5	CII	376.0	116.0
5	CAN	Sims	86.0	CII	374.0	116.0
6	CHN	Empacher	85.5	CII	374.5	115.0
HPL2-						
1	DEN	Empacher	86.25	CII	376.5	117.5
2	IRL	Stampfli	86.75	CII	376.0	117.0
3	GER	Empacher	86.5	CII	376.0	116.5
4	ITA	Filippi	86.5	CII	371.5	114.0
5	FRA	Empacher	86.5	CII	376.0	116.5
6	AUS	Sykes	86.5	CII	376.0	117.0
HPL1X						
1	DEN	W/M	160.0	CII	290.0	89.0
2	CZE	W/M	158.0	CII	291.5	88.5
3	FIN	Empacher	159.5	CII	291.0	88.0
4	USA	Empacher	158.0	CII	291.0	89.0
5	SVK	W/M	160.0	Havel	291.0	89.0
6	RUS	Empacher	160.0	Moskva	288.0	88.0
HPL4X						
1	ITA	Filippi	161.0	CII	291.0	88.0

2	GER	Empacher	160.0	CII	291.0	88.0
3	FRA	Filippi	158.0	CII	292.0	87.5
4	IRL	Stampfli	159.0	CII	290.0	88.0
5	CZE	Empacher	158.0	CII	291.0	88.5
6	GBR	Sims	158.5	CII	291.0	88.0
HPL8+						
1	GER	Empacher	84.5	CII	376.0	114.0
2	DEN	Empacher	83.5	CII	376.0	116.0
3	CAN	Sims	84.0	CII	376.0	115.0
4	GBR	Sims	84.0	CII	375.0	115.0
5	NED	Empacher	85.0	CII	376.5	115.5
6	ITA	Empacher	83.5	CII	377.0	114.0
FLP2-						
1	USA	Empacher	86.0	Dreher	372.0	115.5
2	GBR	Empacher	85.75	CII	371.5	115.5
3	ROM	Empacher	88.0	CII	376.5	118.0
4	GER	Empacher	87.0	CII	376.0	117.0
5	AUS	Sykes	86.5	Croker	370.0	117.0
6	ZIM	Janousek	84.5	CII	373.0	115.0
FPL4-						
1	CHN	Empacher	84.5	CII	369.5	114.0
2	GBR	Janousek	85.0	CII	372.0	115.0
3	USA	Empacher	85.5	Dreher	372.0	115.0
4	JPN	Sims	86.0	CII	372.0	117.0
5	CAN	Sims	86.0	CII	373.0	116.0
6	GER	Empacher	84.0	CII	372.0	114.0
FPL1X						
1	ROM	Empacher	160.5	CII	291.5	90.0
2	FRA	Van Deusen	160.0	CII	291.0	89.5
3	USA	Empacher	160.0	CII	287.0	88.0
4	NED	Douglas	160.0	CII	289.0	90.5
5	DEN	Empacher	161.0	Empacher	289.0	88.0
6	GBR	Douglas	161.0	CII	290.0	89.0
JH2-						
1	CAN	Hudson	86.5	CII	376.0	117.0
2	GER	Empacher	86.5	CII	376.0	117.0
3	SLO	Empacher	89.5	CII	376.5	116.0
4	FRA	Filippi	85.0	CII	376.0	116.7
5	CRO	Empacher	86.0	CII	377.0	116.7
6	AUS	Sykes	86.0	CII	375.0	116.5
JH2+						
1	RUS	Empacher	86.5	Moskva	376.0	117.0
2	ITA	Empacher	87.75	CII	376.0	117.0
3	GER	Empacher	86.0	CII	376.0	117.0
4	GRE	Empacher	87.0	CII	374.0	117.0
5	GBR	Ayling	87.5	CII	376.0	117.0
6	CRO	Empacher	88.5	CII	373.0	117.7
JH4-						
1	SLO	Empacher	85.25	CII	376.5	115.0
2	AUS	Empacher	84.5	Croker	375.5	114.5
3	GER	BBG	87.0	CII	376.0	116.0
4	ITA	Filippi	85.0	CII	376.0	115.5

5	GBR	Empacher	85.0	CII	375.0	115.0
6	FRA	Filippi	84.0	CII	376.0	116.0
JH4+						
1	ROM	Empacher	85.5	Empacher	378.0	115.5
2	FRA	Filippi	84.0	CII	376.5	117.0
3	POL	Empacher	86.5	CII	377.0	116.5
4	ITA	Filippi	85.5	CII	377.0	116.0
5	GER	Empacher	85.0	CII	376.0	115.5
6	RUS	Empacher	85.0	CII	375.0	115.0
JH1X						
1	AUS	Sims	160.0	Croker	290.0	88.0
2	BLR	Empacher	160.0	CII	291.0	88.0
3	GRE	Empacher	161.0	CII	289.0	88.0
4	UKR	Empacher	158.5	UKR	291.0	88.2
5	RUS	Hi-Tech Racing	159.0	CII	291.0	88.0
6	BEL	W/M	160.0	CII	291.0	89.5
JH2X						
1	AUS	Sims	157.5	Croker	291.0	88.0
2	YUG	Empacher	158.5	Braca	291.0	88.0
3	SUI	Empacher	158.5	CII	291.0	88.6
4	ESP	Empacher	158.0	CII	291.0	88.0
5	SWE	Stampfli	162.0	CII	291.0	89.0
6	SLO	Empacher	160.0	CII	292.0	89.0
JH4X						
1	DEN	Empacher	158.0	Empacher	292.0	88.0
2	FRA	Filippi	158.0	CII	291.0	89.0
3	ITA	Filippi	159.0	CII	291.0	89.0
4	NOR	Empacher	159.0	CII	292.0	87.7
5	NED	Empacher	158.5	Empacher	289.0	87.0
6	SLO	Empacher	158.0	CII	291.0	88.0
JH8+						
1	ROM	Empacher	84.25	Empacher	378.0	113
2	GER	Empacher	85.0	CII	376.0	115
3	GBR	Empacher	83.45	CII	376.0	113.5
4	USA	Resolute	84.0	CII	376.0	113
5	RUS	Empacher	83.0	TMK	375.5	113
6	CZE	Empacher	84.0	CII	376.0	114.5
JF2-						
1	GER	Empacher	87.0	CII	376.0	117.5
2	RUS	Janousek	87.0	CII	371.0	116.5
3	AUS	KIRS	86.0	Croker	370.0	116.0
4	CHN	Empacher	87.0	CII	376.5	116.0
5	USA	Empacher	87.0	CII	373.0	117.0
6	GBR	Janousek	86.5	CII	371.0	116.5
JF4-						
1	GER	BBG	85.5	FES	376.0	115.5
2	ROM	Amilibia	85.5	Empacher	376.0	115.5
3	NZL	Sims	85.5	Croker	373.0	116.0
4	RUS	Sims	85.0	CII	371.0	115.0
5	BUL	Empacher	86.0	CII	374.0	116.0
6	GBR	Empacher	85.5	CII	371.0	115.3

JF1X						
1	SLO	Filippi	160.0	CII	290.0	89.5
2	GER	Empacher	159.0	CII	298.0	88.0
3	RUS	Empacher	159.0	Dzin	288.0	86.5
4	LAT	Latvi Jas	159.0	Empacher	290.5	87.0
5	SWE	Stampfli	159.0	CII	291.0	88.5
6	ITA	Filippi	160.0	CII	289.0	87.5
JF2X						
1	POL	Empacher	159.0	CII	291.0	88.0
2	AUT	Filippi	160.0	CII	289.0	88.5
3	GER	Empacher	159.0	CII	298.0	88.5
4	CHN	Empacher	159.0	CII	294.0	86.5
5	ITA	Filippi	159.0	CII	289.0	88.5
6	FRA	Empacher	159.0	CII	289.0	89.0
JF4X						
1	NED	Empacher	159.5	CII	288.0	89.5
2	GER	BBG	159.0	CII	298.0	88.0
3	SUI	Empacher	156.5	CII	289.0	87.7
4	GBR	Sims	157.0	CII	287.0	87.5
5	UKR	Empacher	160.0	UKR	290.0	88.0
6	RUS	Empacher	159.0	Moskva	288.0	87.0
JF8+						
1	GER	BBG	85.5	CII	376.0	116.0
2	ROM	Empacher	84.0	Empacher	378.0	115.0
3	DEN	Sims	85.0	CII	376.0	117.0
4	USA	Empacher	84.0	CII	373.0	114.0
5	CZE	Empacher	86.0	CII	373.0	116.0
6	UKR	Stampfli	85.0	UKR	377.0	116.0