ROWPERFECT ROWING SIMULATOR

The ROWPERFECT dynamic boat simulator, the innovative training tool for the new millennium

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1. Introduction

For many of us the main attraction in rowing is the permanent quest for the optimal combination of strength, endurance and perfect co-ordination. Experience teaches us that of these three factors the perfect co-ordination is the most difficult to train, and to acquire. It is therefore surprising that in winter time so many rowers should spend so much of their precious time to increase strength and/or endurance on machines which force them to change their co-ordination pattern between the main muscle groups used for rowing into a direction which is absolutely detrimental to good rowing.
It is the objective of this paper to show how this can be improved upon, and how land based training can be used to improve rather than to deteriorate technique, to optimise training and to synchronise crews.
In this paper I have tried to bundle the experience we have accumulated over the last decade in developing and using the ROWPERFECT dynamic boat simulator.
The paper is divided into the following chapters:

- Analysis of the dynamics of the rowing motion on the water and on land
- The ROWPERFECT as a dynamic boat simulator
- Training of technique, monitoring progress
- Synchronising crews
- Injury prevention.

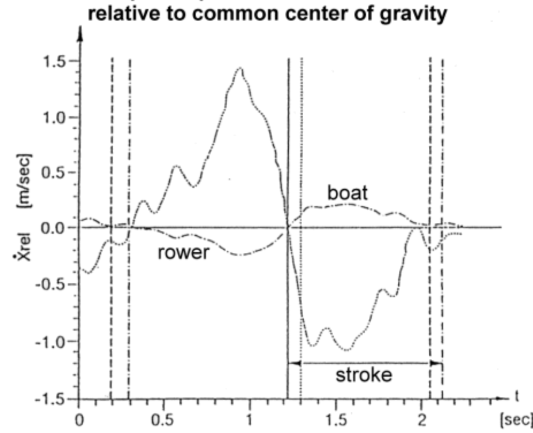
2. Analysis of the dynamics of the rowing motion on the water and on land

In the autumn of 1989, a critical young girl whom I trained as a sculler made some very clear observations which many of you might be familiar with, and which led to the development of the ROWPERFECT boat simulator.

Due to the days getting shorter, she had start doing a major part of her training on a rowing substitute called an "ergometer" of which her club had two types available, a Gjessing and a Concept II.
The first week she trained on the Gjessing, and her comment at the end of the week was:" This one is not like a boat. If I try to row on it like I should do in the boat, it is too hard for my knees at the catch". The second week she trained on the Concept II. In this case her comment was:
" This one is not like a boat either. If I try to row on it like I do in the boat, I feel slack at arms and back at the beginning of the stroke, and then, a little bit further I suddenly feel a sharp rise in force on arms and back, and it makes my back hurt "
As you all probably know by your own experience, her comments were true and accurate, and in line with similar remarks of Australian oarswomen and German oarsmen reported in the literature.

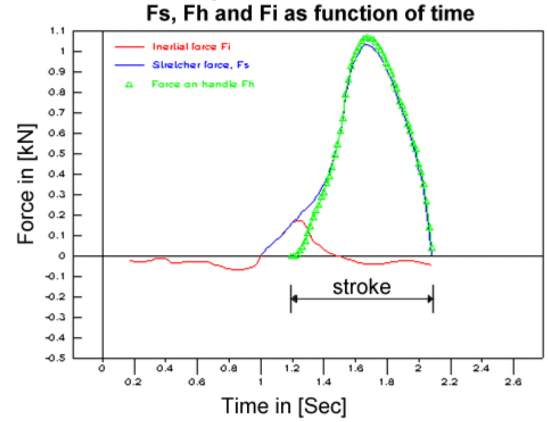
The reason of the difference in stroke perception between these machines and the boat lies in the difference in dynamic behaviour of the same.
A racing shell is floating freely on the water, and the oarsmen are moving freely along the length axis of the boat, the only fixed place of contact between them and the boat being the stretcher. This movement of the mass of the relatively heavy rowers relative to the very light rowing shell causes the speed of a racing shell to vary strongly within one stroke/recovery cycle. Extensive studies made by Dr. Volker Nolte show that the movement of the centre of gravity of boat and rower, relative to the common centre of gravity, are inversely proportional to their relative masses. (see Graph 1 taken from Nolte's thesis).

Graph 1. Speeds of boat and rower relative to common center of gravity



The difference in "feel "of the various boat types is caused by the fact that this mass proportion is different for the various types of boats. The heavier the boat, the more the rower has to accelerate and decelerate his body mass during the stroke/recovery cycle, and the more force he needs to do so. For the sculler of this example, body weight 85 kgs, boat weight 17 kgs, rowing at a stroke rate of 32 s.p.m. , the speed

Graph 2. Calculated forces Fs, Fh and Fi as function of time



fluctuation of the rowers mass, relative to the common centre of gravity, ranges from - 0,25 to + 0,22 m/sec (?= 0,47 m/s) over a stroke recovery cycle. By the same token, the boat moves, counterbalancing, from + 1,44 to - 1,10 m/sec. (Note that the speed differential between stretcher and rower in this case runs from +1,7 to - 1,3 m/sec. (?= 3,0 m/s)) For this pattern of movement, the relation between the (measured) force on the stretcher Fs, the force on the handle Fh, and the inertial force necessary to accelerate the mass of the rower relative to the common centre of gravity have been calculated. The result of this calculation is presented in Graph 2, whereby the force Fh exerted on the handle by the oarsman, is equal to the force on the stretcher Fs less the inertial force Fi used to decelerate/accelerate the body.
It can be clearly seen that the inertial force Fi is only a very small fraction of the total force on the stretcher, and that this force falls completely within the measured stretcher-force/time curve. Note also that the force on the handle Fh starts approximately 0,25 sec. after the body has started to decelerate. This case represents the "dynamic case".

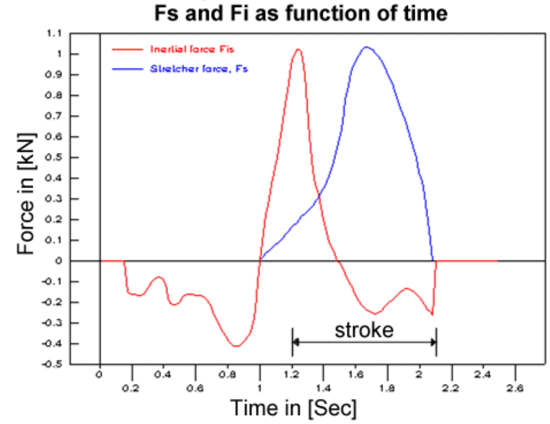
The ROWPERFECT boat simulator has been designed to simulate this dynamic case most accurately. The boat simulating part of it, the main frame with stretcher weighs around 17 kgs, and moves freely along the main bar. Therefore the

inertial forces exerted on the rower are very similar to those in the boat. This relative movement in the "dynamic case" is demonstrated.
What does this teach us about the degree of accuracy with which other "stationary" types of rowing machines are good boat simulators ?

Now assume that the 17 kg racing shell the sculler was rowing in, is suddenly kept stagnant. This is the "stationary" case.
This means that , whereas in the "dynamic" case the main part of the movement is done by the boat, or the boat simulating "floating" stretcher, it is now the oarsman who has to do all the movement relative to the environment.

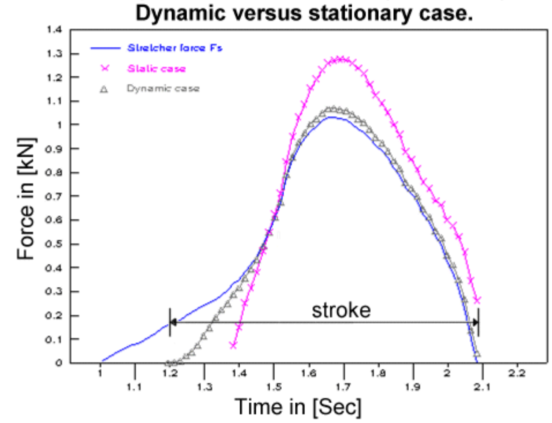
If he maintains the same pattern of movement with respect to the stretcher, then his movement relative to the environment is dramatically different. In stead of from a mere - 0,25 to + 0,22 m/sec in the "dynamic case" , his centre of gravity moves now from as fast as 1,7 m/sec towards the stretcher to 1,3 m/sec away from the stretcher.
Also for this "stationary" case the force/time profile necessary to maintain the same co-ordination pattern vis á vis the stretcher as in the "dynamic" case has been calculated for the same model sculler. The results of this calculation are presented in Graph 3.
From this graph it can be clearly seen that in this "stationary case", to maintain the same movement pattern relative to the stretcher, during the first four tenths of a second of the stroke, the oarsman would have to exert an inertial force to the stretcher far

Graph 3. Calculated forces Fs and Fi as function of time



greater than what he normally does in the boat, and in a much shorter time.
If the boat curve is close to the maximum he can do, which is normally the case, the above requirement is far greater than he is capable of.
What happens then, unavoidably, is that his co-ordination is going to shift in such a way that the maximum of the inertial forces on the stretcher falls within the limits of his physical capabilities (force- and time- wise) . How this is done exactly depends very much upon the individual.
Clear is that, on the basis of physical principles, one can expect that in the "stationary case", the force on the handle is small during the first phase of the stroke, comes approx. 0.2 seconds later and rises much

Graph 4. Forces on handle (theoretical) Dynamic versus stationary case.



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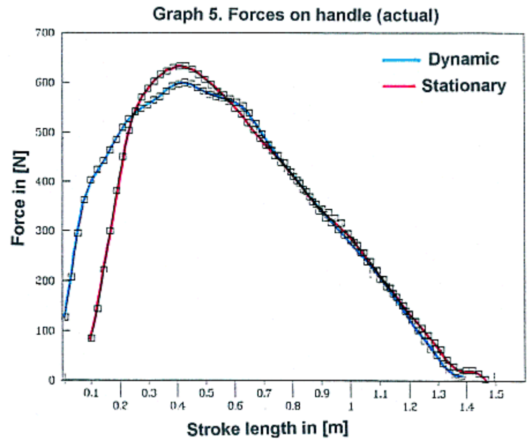
more steeply as compared to the "dynamic" case (see Graph 4, Ref.2).

Hence the feel of "slack" at the beginning of the stroke and the "thump" in the back a fraction of a second later on "stationary" ergometers. An example of two strokes with almost identical work, measured on the ROWPERFECT boat simulator with the sliding mechanism fixed ("stationary case") and floating ("dynamic case"), clearly shows that the actual situation is evidently in line with the theory. (Graph 5)
For this reason "stationary" ergometers are no good boat simulators, not suitable for training technique, and potentially dangerous for knees and backs.

3. The ROWPERFECT as a dynamic boat simulator

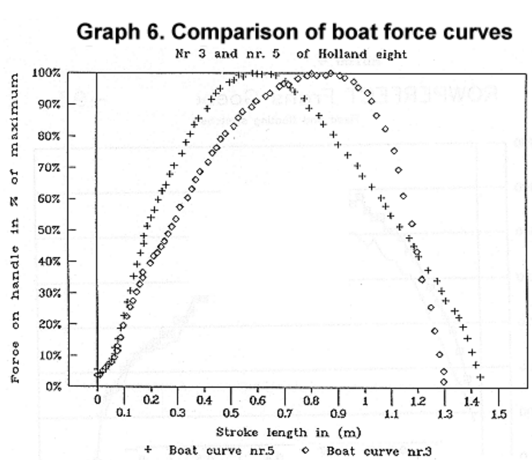
The ROWPERFECT dynamic boat simulator has been developed to eliminate the drawbacks of traditional "stationary" ergometers, and to provide a new tool for training not only strength and endurance, but technique as well. It's unique mass balanced double sliding action provides the best simulation of the dynamics of a rowing boat currently available.
In the summer of 1993, with the co-operation of the crew of the Olympic Dutch Holland Eight, a double blind experiment has been run to verify the validity of the ROWPERFECT as a dynamic boat simulator and to determine the degree of agreement between stroke force/length profiles



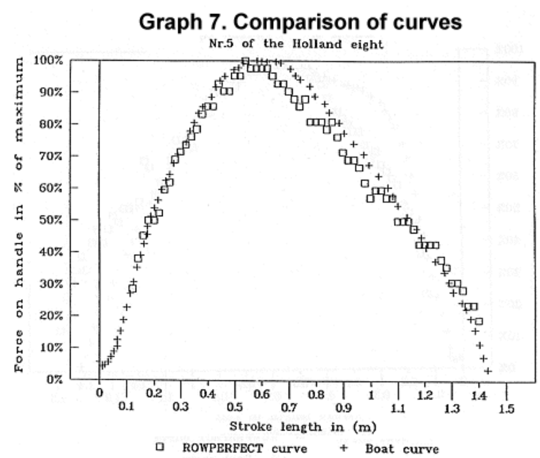
produced in the boat and on the ROWPERFECT dynamic boat simulator.

After an outing in the eight, the crew were asked to row on the boat simulator, at a stroke rate of approximately 30 s.p.m. at standard strokes. The boat simulator then was tuned to give the "feel" of the eight. To the opinion of the crew the best simulation was obtained using sprocket 1, and a disk which gave the fan a resistance factor of 26. With this tuning each member of the crew were asked to row at a stroke rate of 30 s.p.m. with their eyes closed, imagining they were rowing in the eight. It was shown that after a couple of strokes each individual reproduced his own curve with high accuracy. A surprisingly big difference however was found between the curves of the different individuals.

Two weeks later at an outing of the Holland Eight,



typical stroke profiles of the crew were recorded in the boat at a stroke rate of 33. Also these records were made without feed back to the oarsmen.
Also in this case big differences between the stroke profiles of different individuals were found. Graph 6 shows for example the curves of the nr.3 and the nr. 5 of the Holland Eight. However a very good similarity between the stroke profiles recorded in the boat and on the dynamic boat simulator has been found. The actual differences between the ROWPERFECT curve and



the boat curve per individual being much smaller than the difference between individuals, either in the boat or on the dynamic boat simulator. This is illustrated in Graph 7 , taken from Ref.4 , which shows the force-length profile of the Nr. 5 of the Olympic Holland Eight, both in the boat and on the ROWPERFECT dynamic boat simulator. From these experiments it can be concluded that there is a very good similarity between the force/length curves on the ROWPERFECT boat simulator and the curves made in the boat, the actual differences between boat and boat simulator per individual being much smaller than the difference between individuals, either in the boat or on the water. The conclusion therefore is that the ROWPERFECT dynamic boat simulator is a very useful tool for modifying stroke profiles and for eliminating stroke profile differences within a crew.

The stroke profiles recorded with the ROWPERFECT training system and software are fully representative for the ones measured in the boat.

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4. Training of technique, monitoring progress

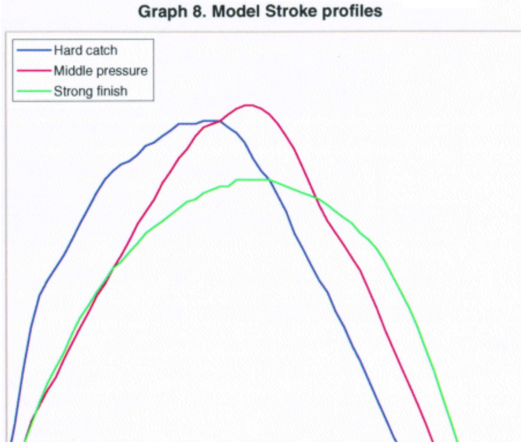
As will be clear from the foregoing, due to it's poor rowing dynamics, training during the winter season on "stationary" fixed stretcher type ergometers to increase strength and/or endurance, inevitably will induce a pattern of coordination into the rowing movement that is detrimental to good rowing, and leads to the development of bad rowing habits during the wintertime. These bad habits then have to be un-learnt in spring time, at the expense of a lot of extra time and effort, to restore the smooth action of controlled power and precise co-ordination necessary for good rowing

The way a rower normally learns to row, or to change a rowing motion, is a very indirect one, and generally goes roughly along the following lines:

- the coach tells the rower how to perform a certain movement
- the rower tries to do what he understood from what the coach explained
- the coach sees the result not being exactly what he wants, and tries to explain to the rower what he should do differently
- the rower tries to do what he understood from what the coach explained
- etc.

It is clear that this very indirect way makes it very difficult to optimise the stroke profile of a rower, and that finding an optimal stroke profile in this way is almost impossible.
This is even more so because a boat does not create a controlled test environment where effects of the order of magnitude we are looking for, are therefore not easily detected. The disturbing influence of wind, water, waves, balance, and timing of other crew members, tend to overshadow the effect that is being looked for.
It is known from litterature that from the point of view of the rower's metabolism some types of stroke profiles are more efficient than others.
In Ref. 3 and 4 Roth and Schwanitz reported that they found in a controlled test environment, that the rowers metabolism was operating at a higher efficiency if rowers rowed "middle pressure" strokes as opposed to "hard catch" and "strong finish" strokes. (Graph 8).

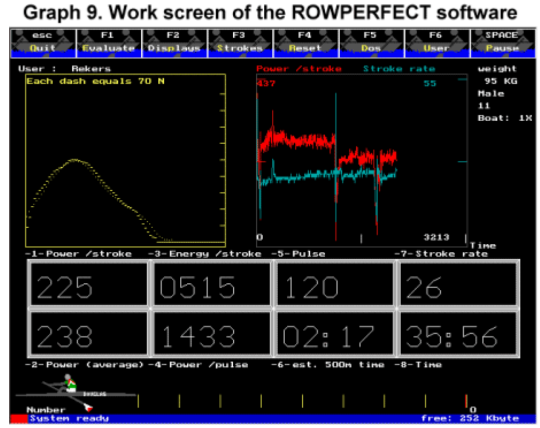
Graph 8. Model Stroke profiles



They found a difference in oxygen uptake under aerobic conditions for strokes at the same power from 3,3 l/min for a "middle pressure" stroke, 3,4 l/min for a "strong finish" stroke and 3,7 l/min for a "hard catch" stroke. This gives the trainer and coach a method for optimising performance of his rowers.
Therefore the modification of one's stroke profile can be highly desirable as it can be a very effective means of optimising one's performance.
As Holger Hill and co-workers (Ref.5) showed, a direct visual feedback of the force profile of every stroke is very effective for learning to modify one's stroke profile.
In the past however , measuring systems for measuring stroke profiles have only been available in the laboratory, and were very elaborate and very expensive, far out of reach for the average club or the individual rower.

The ROWPERFECT system is the worlds first training system that brings direct biofeedback optimising capabilities within reach of every rower, and therefore gives new and unprecedented possibilities for coaches and rowers for optimising training.
Since the development of the dynamic boat simulator with it's unique boat simulating characteristics, it is possible, for the first time, to improve technique, on land, during wintertime. Together with the interface and software the ROWPERFECT system provides the coaches and rowers with an unprecedented effective tool to improve technique , optimise performance and to monitor progress.
The user screen provides a stroke force/length curve, optionally with a reference curve, a graphical display of the progress of the training session and numerical performance indicators. (Graph 9)

Graph 9. Work screen of the ROWPERFECT software



At the completion of each stroke the screen shows a force/length curve. The shape of this force/length curve depends on technique, and gives a clear insight in the co-ordination between legs, back and arms during a stroke. This force/length curve therefore can be used to detect technical flaws and to diagnose the causes.

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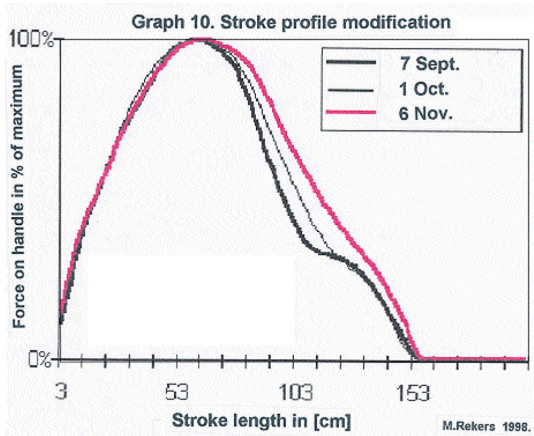
Immediate "biofeedback" to the rower is essential for changing the co-ordination pattern. It is achieved by showing an "ideal" reference stroke profile as a template, together with each actual stroke profile. For each stroke the rower can see the difference between his actual stroke profile and the target. This makes the learning process very efficient, allowing the rower to much more rapidly acquire a technical improvement than by any other means, and then to automate it.

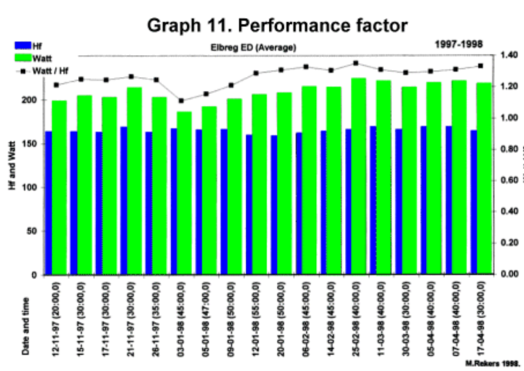
Graph 10 illustrates what can be achieved in terms of improvement of co-ordination in a short time. This graph shows how deficiencies in the force length curve of a novice sculler have been eliminated in a period as short as 2 months.

In the ROWPERFECT software, the conversion of power to virtual speed has a built- in weight correction factor. This weight correction factor takes the influence of the rowers' weight on the speed of the boat at a given power into account. Therefore in comparing results, it does not automatically favour the slow heavyweight at the expense of the more agile lightweigth, and thus is a better tool to select the real boat movers. Tests for the single scull mode with top clas female and male rowers, ranging in weight from 59 to 95 kgs, have shown that the times calculated by the ROWPERFECT system over a 2000 meter course are generally within a margin of a couple of seconds from the actual times rowed in the boat



under ideal conditions with near to perfect technique.

A special ROWPERFECT feature for monitoring progress is the Performance Factor.
If a pulse sensor unit is installed, the system uses the heart rate and the power generated by the rower to calculate the energy dissipated per heartbeat (Performance Factor). This information is essential for monitoring progress, and provides an early warning system for health problems or over-training.
An example thereof is given in graph 11.



This graph shows the performance of a novice girl during aerobic training on the ROWPERFECT. Below the horizontal axis are the date and the duration of the aerobic training in minutes, the right hand axis indicates the average power and the average heart frequency during the training, the right hand axis presents the Performance Factor.

During the first three weeks of December training had been interrupted due to a health problem. Clearly the dip in Performance Factor can be seen, and the graphs shows that in the second week of January recovery was complete.
A similar pattern with other rowers has been found in cases of anaemia and of over-training.

The performance factor is a very powerful tool for optimising the performance of a rower and a crew.
The gearing (in-board/out-board ratio) and stroke rate have a very strong influence on the efficiency of the rower's metabolism.

The power producing performance of rowers can to some extent be compared to that of automobile engines.

In automobile engines one can distinguish between the low-rating/high-torque diesel engines and high-rating/ low-torque petrol engines. The optimum performance of these two types of engines lies at different rpm's.

This is true for rowers as well. Like an engine, a rower has a certain combination of work per stroke and stroke rate where his body works at its highest efficiency. At too heavy a gearing, the rower will not be able to exhaust himself, because his muscles give-up prematurely, and at too light a gearing the rower cannot use the force of his muscles to it's full extent. His optimal performance lies somewhere in between. From our experience we know that the loss in performance of a rower or crew, when not geared correctly, may be as high as 10 % of the power output. To obtain the best possible performance, it is therefore of prime importance to determine the optimal gearing/stroke rate combination for a rower and a crew.

This can be done most efficiently on the ROWPERFECT dynamic boat simulator, by measuring the power output / stroke rate relation at various levels of gearing, and then transferring the same "feel" of gearing to the boat. The first rower who did this systematically, back in 1989, was Frans Göbel . During his preparation for his first world title in the lightweight single scull

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in Bled, he used the prototype of the ROWPERFECT for this purpose to his advantage. The following year he did the same on the first production model to win his second world title in Tasmania. Tests run with Greg Searle in the summer of 1998 showed that the optimum performance in the boat and on the dynamic boat simulator were obtained at an identical stroke rate and speed, showing that the ROWPERFECT results and the boat results are fully compatible and comparable.

5. Synchronising crews

For synchronising crews, the ROWPERFECT boat simulator is as effective as a Flight Simulator is for airline pilots. Like in the flight simulator the airline pilot can be trained in the very complex art of handling an aircraft without the risk of crashing, the boat simulator enables the rower to learn the very complicated pattern of co-ordination of movements and timing, essential for good rowing, not hindered by wind, waves and water, and not disturbing his fellow crew members.

It goes without saying that this is only true if the equipment which is used, truly simulates what happens in the boat in reality.

The ROWPERFECT boat simulator does exactly this.

The main problem for the apprentice crew and their coach is that in the boat all of the problems occur at the same time, and that the crew have to divide their time between co-ordination, timing , balancing and handling the oar.

On the boat simulator the co-ordination and timing can be handled as separate entities, enabling the crew members to concentrate on one issue at a time, making the learning process more efficient.

The process of synchronising of a crew can be divided into a number of phases:

- Learn the crew to all make the same stroke.
- Learn the crew to all do it at the same time.
- Acquire proficiency in handling the oar.

The boat simulator can play an important role in the first two phases of this process.

In the first phase the coach has to decide which type of stroke the crew is going to row. Depending upon the time that is available, the coach can decide to use either one of the following methods:

1. First determine the optimal stroke profile, as described in the previous chapter, and, once this is established, subsequently train the rowers to make that profile
2. Determine the average stroke profile which the crew makes, and have all the rowers copy the average

The first method can be used when sufficient time is available, generally at the beginning of the training season. This will eventually learn the rowers to row at their highest efficiency.

The second method could preferably be used for making combination crews in the season that have to be homogenised as rapidly as possible. With this method the individual adaptation required is minimal; efficiency may be sub-maximal .

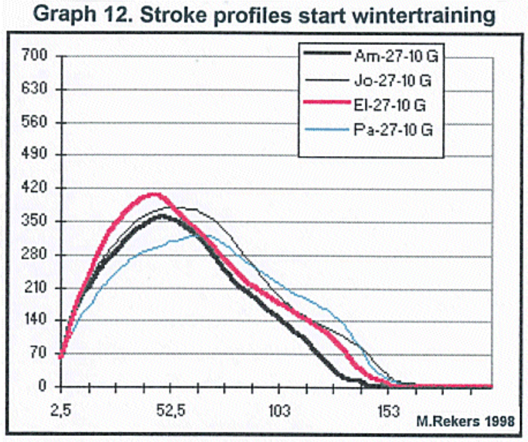
Training on the same stroke profile initially is most efficiently done during extensive endurance training, later to be extended to intensive endurance training and interval training.

The effect of such a training on crew homogeneity is shown in Graphs 12 and 13. In these graphs the development of the stroke profiles of a ladies novice four is shown. In their first year this crew had been very unsuccessfull . At the beginning of the winter training in October of their second rowing year, the force length curves of the four crew members are highly different. After 5 months, although different in strength, the stroke profiles have become highly homogeneous. At the first long distance race in the season it was shown that the crew had become the fastest in their category by far. Graphs 14 an 15 show comparable results of a novice men's crew.

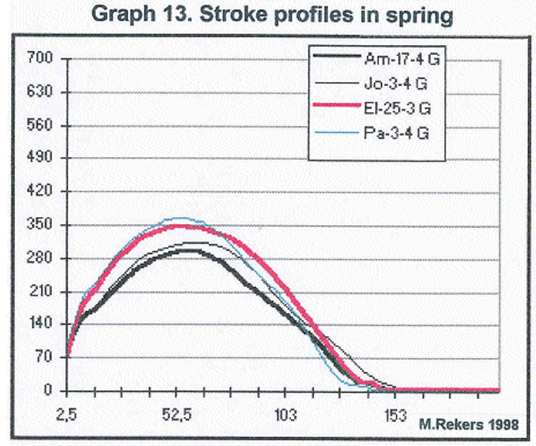
Similar results have been obtained over the last 5 years with the crews of Cambridge University Boat Club and with the Australian Lightweight coxless four.

Initially, training on a given stroke profile is done on an individual basis, to enable the rower to fully concentrate him- or her-self to the smooth co-ordination of movement. In a second phase when the required profile is being mastered, the dimension of inter-individual timing can be added to the training. As a unique feature of the ROWPERFECT boat simulator,

Graph 12. Stroke profiles start wintertraining



Graph 13. Stroke profiles in spring



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the moving slides of two (or more) units can mechanically be coupled to truly simulate the dynamics of crew boats. This gives the coaches and the rowers unprecedented possibilities for synchronisation of their crew during land training, not hindered by wind, current, waves, balance problems or problems of handling the oar.

Because the disturbing influence of these factors is totally absent, the crew can fully concentrate on co-ordination and timing. On the crew boat simulator, minor differences in co-ordination and timing between the crew members are much more clearly felt by the rowers than in the boat, greatly enhancing the synchronisation process.

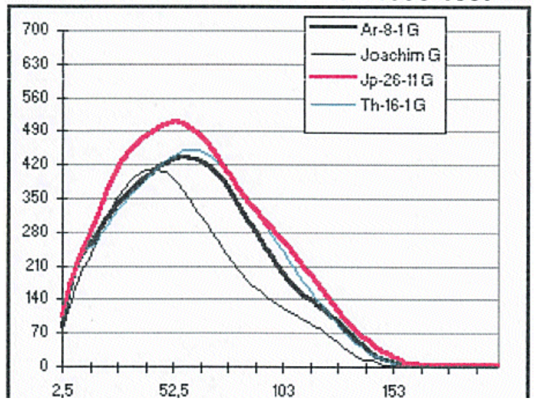
Good rowing provides immense satisfaction. Some aspects of it can be taught and learned more effectively on the ROWPERFECT dynamic boat simulator than in the boat.

Similar to a racing shell, the boat simulator is very sensitive to a proper co-ordination of movements. Good technique is rewarded, poor technique is exposed and can be effectively dealt with in an early stage.

6. Injury prevention

Traditionally in the past rowing always has been a relatively safe sport with a low incidence of injuries compared to other sports. Occasionally some back problems did occur, but a lot less frequent than at present, and primarily during winter time. Very often

Graph 14. Stroke profiles
Novice crew winter season 1996-1997

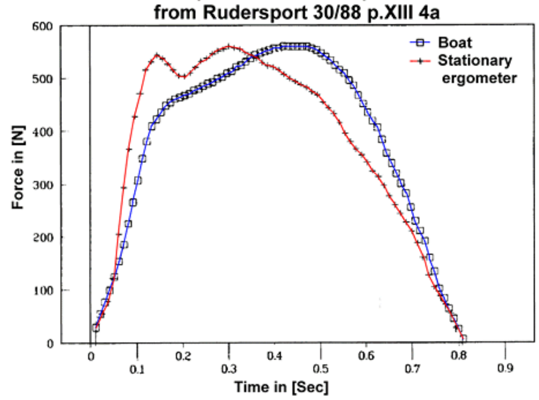


these problems could be related to land based exercise (such as weight lifting) and they tended to disappear when the rowing season started and more rowing in the boat was done.
Since fixed stretcher ergometers have become commonly used this situation has changed drastically. The main reasons for this are:

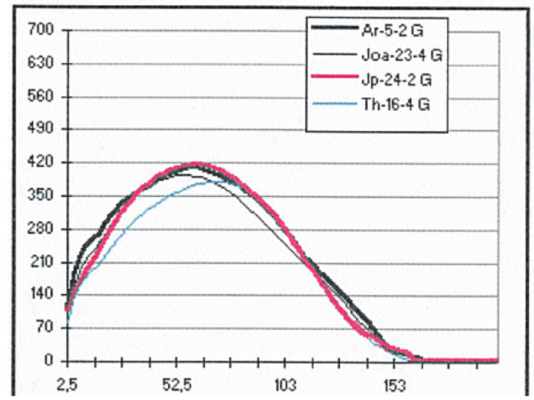
- The dynamic behaviour of these machines differs quite considerably from that of a light racing shell freely floating on the water; their dynamics rather resembles that of an infinitely heavy boat or of a rowing tank
- On these machines one can exhaust oneself to a much higher degree than in the boat. In the boat, loss of technique, due fatigue, will automatically limit the maximum attainable level of exhaustion; this protects the rower from himself (and from his coach)

As is mentioned in chapter 2, the difference in dynamics between a "fixed stretcher ergometer"

Graph 16. Force/time profiles
from Rudersport 30/88 p.XIII 4a



Graph 15. Stroke profiles
Same crew a few months later



and light racing shell forces the rower to adapt his co-ordination pattern. Graph 16 taken from Rudersport Ref. 4, shows a force/time curve of a fixed stretcher ergometer and of a boat.

The characteristic difference in force/time profiles, in line with the theory is clearly visible.
From this graph one can calculate that the gradient with which the force on the handle increases at the steepest part of the curve amounts to approx. 4.000 N/s in the boat, and 7.800 N/s on the fixed stretcher ergometer, so almost double.

Training on this type of equipment therefore means exerting , every stroke and again, a shockload on the lower back twice as big as in the boat.
A similar phenomenon occurs on these machines at the end of the stroke. The higher body velocity at the end of the stroke forces the rower to revert the majority of the motion of his upper body by using the big hip flexors, a known cause of back problems.

As far as knee problems is concerned the following: Because a "fixed stretcher" ergometer from a dynamic point of view behaves like boat which is infinitely heavy, at the end of the recovery/beginning of the stroke, the rower has to decelerate and accelerate his total body weight over a 5 to 7 times bigger speed differential then he has to do in the boat (see Graph 1). Especially at higher stroke rates during races and/or condition tests, over-compression of the knees on this type of machines is inevitable.

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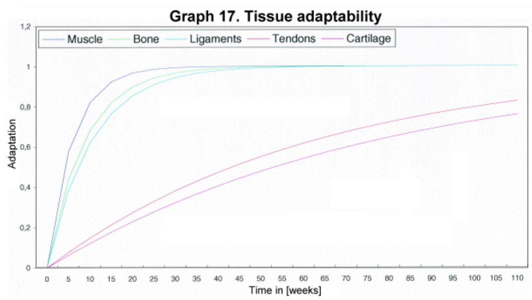
Because of their "stationary" behaviour, these machines create an inherent danger for the younger athlete without a previous sport career, using these machines for endurance training, condition tests or races.

Apart from the above physical/ mechanical aspects of injury prevention, also the physiological response of the organism on training is essential.

Essentially training is providing the body with stimuli to adapt . For an optimal effect of the training , the load to the organism should be kept within a certain band width of the maximum allowable load. Too low a load provides no training effect, too high a load can lead to injuries and over-training.

The speed with which the various tissues adapt to a higher load varies widely from one tissue to the other. This speed of adaptation is inversely proportional to the half-life of the cells of the tissue, being defined as the time required by the organism to replace half of the cells of a given tissue. In the sequence muscle > bone > ligaments > tendon > cartilage the half-life increases with over a factor 13 (from 4 wks for muscle to over 1 yr for cartilage). The speed of adaptation for the different types of tissue is illustrated in Graph 17. From this graph it can be seen that full adaptation for muscle tissue can be achieved in approx. 35 weeks, whereas for cartilage only a 75 % adaptation can be expected over a period of two years.



For the speed with which the load on the total organism can safely be increased, each and every moment the weakest tissue in the total chain is the rate determining step.

For many a young athlete, and especially for those young athletes without previous sports career, this weakest link becomes very soon the cartilage, because it adapts by far the slowest to a higher load. The second danger area in this respect are the tendons.
For injury prevention, avoiding peak loads is of crucial importance. By avoiding peak loads, and keeping below the maximum allowable load for the weakest category of tissue, a maximum total load of the organism and therefore a maximum training effect can be achieved safely.

From the above the following conclusions and recommendations can be made:

- *To prevent injuries, the maximum allowable load to the weakest link in the rowing organism may not repetitively be exceeded, and peak loads should be avoided.*
- *To avoid peak loads it is essential that equipment for training and condition testing truly simulates the dynamics of a light racing shell. (The most common "fixed stretcher " ergometers are not fit for this purpose).*
- *Certainly for the younger athlete without previous sport career , condition tests, selection tests and races on "fixed stretcher " ergometers have to be strongly discouraged.*
- *The elasticity of a suitable "dynamic" boat simulator should resemble the over-all elasticity of oar-rigger-boat main shoulder- stretcher as closely as possible.*
- *A suitable "dynamic" boat simulator should force the rower to maintain technique at higher levels of fatigue, to avoid overloading.*
- *To properly control the loads on the various parts and tissues of the athlete during training on "dynamic" boat simulators, it is recommended to have the athletes train on a prescribed stroke force/ length profile, which may not be exceeded.*
- *Peakloads in the boat can be avoided to a big extent, by synchronising the crew stroke profiles during wintertime on a suitable dynamic boat simulator. This prevents the individual rower from being forced to pull the boat all by himself for a split second.*
- *Having part of the crew making "power tens" with the others stabilising the boat should be forbidden.*

I am convinced that an important proportion of the injuries inflicted upon our oarsmen during wintertime is due to the repetitive shockloads generated by "fixed stretcher" ergometers during endurance training, condition tests, selection tests and races. This is true not only for injuries of the lower back, but of the knees and of the tendons as well.

A policy of some clubs where tests on these machines are part of the selection criteria, forces young rowers to during wintertime to accept the risk of injury, to prepare for these tests, and at the tests themselves to qualify. This often with the result that talented young athletes have to stop rowing prematurely by injuries that could have been prevented.

The ROWPERFECT dynamic boat simulator, the innovative training tool for the new millennium

7. Conclusions.

From the foregoing it can be concluded that:

- The dynamically balanced ROWPERFECT boat simulator is superior to stationary type ergometers in its boat simulating characteristics. This greatly reduces the risk of back and knee injuries.
- It enables the rowers to combine physical and technical training and to improve the technique of co-ordination of the main muscle groups that are used in rowing.
- The force/length curves made on the ROWPERFECT dynamic boat simulator coincide very well with similar curves made in the boat, and they give an immediate bio-feed back to the rowers. This makes it an essential tool for improving technique and for synchronising crews.
- The weight related power to speed conversion factor makes it a better tool to select real boat movers.

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