Introduction to the Biomechanics of Rowing

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When two coaches observe a crew rowing, each will have a different frame of reference. One coach likes to observe the teamwork while the other watches for the power application by the rowers. What is the reason that the two coaches have different points on which to focus?

It may be that the two coaches have different concepts of what is the correct technique. It may also be the way the coaches look at the movements. One looks for the movement of the bodies while the other observes the movement of the blades. It could also be that the movements are just too quick and the coaches have no real point of reference.

One can learn to see a movement but the question really is which pattern of movement is the correct one? Which parts should be watched in which order and with what emphasis? Can one say that the faster rower utilises the best technique? Questions such as these are fundamental and apply directly to biomechanics. Biomechanics is the science that explores the human patterns of movement with application to physics.

Analysis based on physical laws as well as exact measurements have helped develop a stable base of biomechanical knowledge on rowing technique. It is relatively easy to acquire the basic knowledge necessary in biomechanics and be able to describe the biomechanical connections that the rowers can use in rowing practices. This article presents an overview of the biomechanics of rowing and provides suggestions to the coach to apply this information in practices.

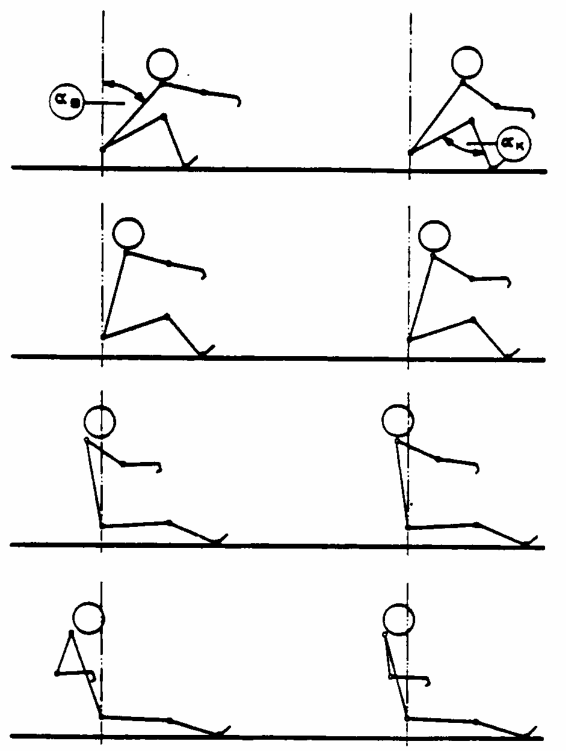
The Tasks of Biomechanics in Rowing

The goal in rowing is to make the unit (the rowers and the boat) cover the distance as fast as possible from the start to the finish. Physical performance is necessary to achieve this basic goal and the muscles of the human body produce the necessary energy. Biomechanics is interested in how the rower converts this physiological capacity into moving the boat. Biomechanics describes the movements first and then explains the movements; more specifically, which muscles and joints the rower uses and which forces have an effect on the body and to propel the boat.

There is a vast range of research in this field. The development of photography and video cameras have brought with them great progress in biomechanics. The coach now does not need to rely on his or her eyes only. In this way comparisons with other teams are now possible.

From simple analysis of photographs, the next level of rowing technique analysis can be reached with an improved means of filming, i.e., use of the video camera. Angles and lengths can be measured using sharply defined pictures from special viewpoints (90 degrees to the side or from above). Time can be very accurately measured by using advanced filming techniques. Careful identification of the joints of the body through a series of pictures can provide effective analysis. By taking each of these frames (pictures) and analysing them separately, you can calculate the actual change in the angles of the major body parts (see figure 1).

Figure 1: Determination of the important joints in several phases during the drive phase (please note the angle of the knee and the back).



The position of the oars and the blades provides another means of analysis. From the side of the crew, you can analyse the distance of the blade to the water at any point in the stroke (especially at the entry). Another popular type of analysis is to observe the position of the oar relative to the boat. By filming from a bridge, you can calculate the length of the stroke at the entry and the finish of the stroke and compare it to the orthogonal or perpendicular line to the boat (see figure 2). The centre of gravity (CG) can be calculated by analysing the sequence of the movement of the body joints. The movement of the CG horizontally and vertically during the stroke cycle is important for the forces exerted by the rower (see figure 3).

With somewhat more sophisticated equipment you can measure the forces on various parts of the boat, such as on the oarlock, on the footstretchers and on the blade (see figure 4). Great progress has been made in this means of analysis over the past several years.

Figure 2: Measurement of the length of the stroke from pictures made looking down from a bridge.

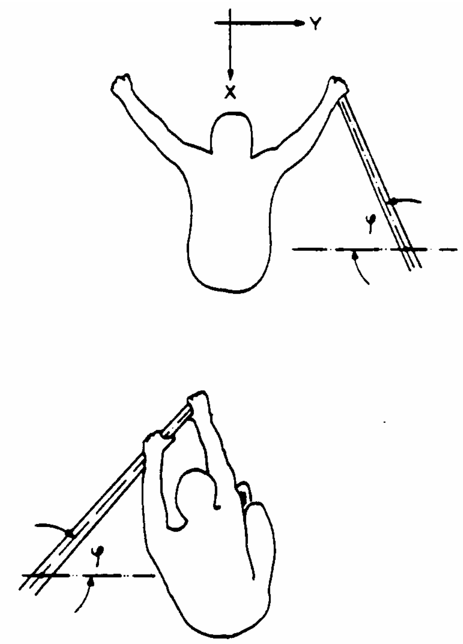


Figure 3: The movement of the centre of gravity (CG) during the recovery phase.

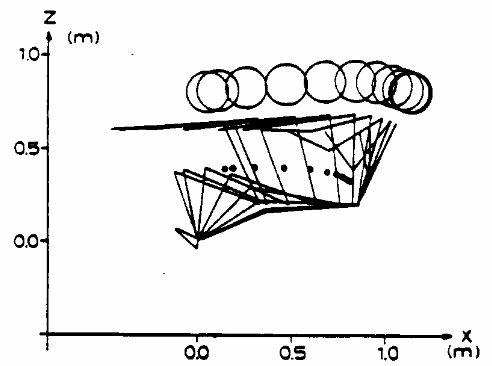
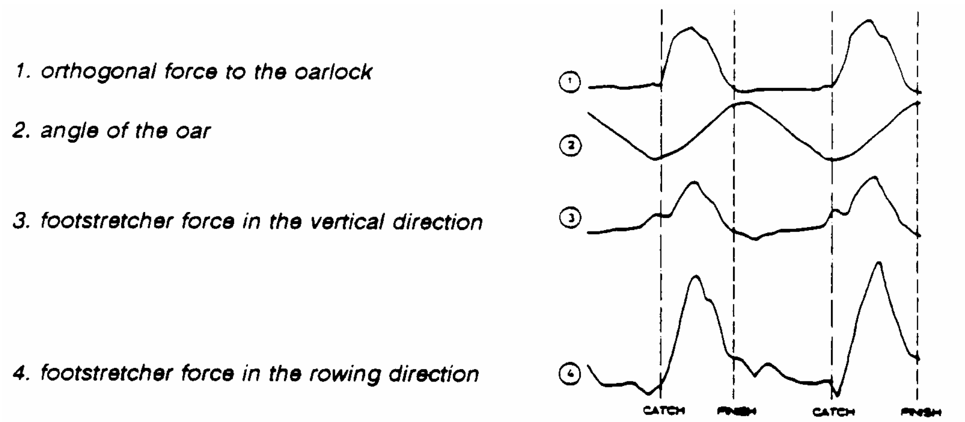


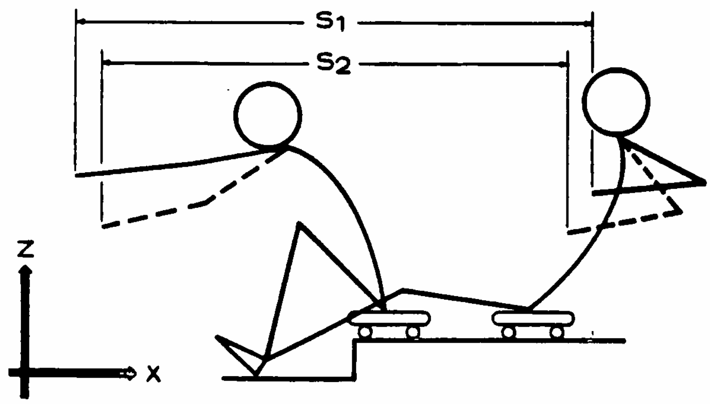
Figure 4: Measurement of parameters on the oarlock and on the footstretcher as viewed from the starboard side (from Haynes, 1988, p. 67).



Previously a coach could only rely on trial and error to apply rigging changes and the effects, if incorrectly applied, could ultimately hinder the rowers' performances during the year. Now the biomechanist can analyse these changes. Biomechanical research has also helped to eliminate the negative mechanical influences on the stroke. This allows analysis of the effects of CG movement by making changes in rigging (see figure 5). For example, how does lowering the height of the oarlock change the length of the stroke? The efficiency of drills and exercises for improving technique and the effectiveness of fitness training can also be analysed.

Beyond improvement in performance, biomechanic research has been able to analyse the loss of load to the human body. This research brought prophylaxis, or analysis to preserve health, to our attention. The load on the bones, tendons, ligaments and muscles can now be determined. Movements and techniques can be identified that do not injure the rowers. This is particularly true in the sport of gymnastics in recent years. Functional gymnastics refers to exercises that are adapted to the human body and its parts. This has shown not only that the position of the joints should receive attention but that the velocity of certain movements greatly influences the way the muscles and ligaments are loaded and, therefore, can respond in the correct manner.

Figure 5: The influence of the height of the oarlock (vertical distance between the oarlock and the seat) on the length of the stroke; a longer stroke (S1) using a higher oarlock and the same slide length.



Biomechanics research has found certain indicators that are essential to reach high levels of performance. As with other sports, rowing has certain basic body requirements which are necessary for high performance (i.e., body height, arm length, lean body mass, etc.). Such anthropomorphic analysis is made in countries where it is possible to select athletes for sports at an early age.

Practical Biomechanical Applications

The most important applications for the rowing coach in biomechanics are found in the biomechanics principles. They are the bases for the daily instruction by the coach. They determine the rowing technique that will help rowers attain the common goal of rowing faster. The latest research in the biomechanics of rowing follows.

The biomechanical principles show the complete framework for rowing technique. Nevertheless it is obvious that the coach has to adapt these principles to the particular situation, perhaps with the assistance of a biomechanist. Because principles are comprehensive laws, they apply to tall rowers as well as not so tall rowers, single scullers as well as for the sweep rower in the eight.

Principle Number 1

All movements have to be performed in a way that the rower is able to transfer his/her physiological performance into optimal propulsion.

With this first principle it becomes clear that, for rowing technique, only functional considerations have value. There is no need that the pattern of rowing be "beautiful." The rower must be able to 1.) produce the highest physiological performance and 2.) transform this performance into the best propulsion possible.

Principle Number 2

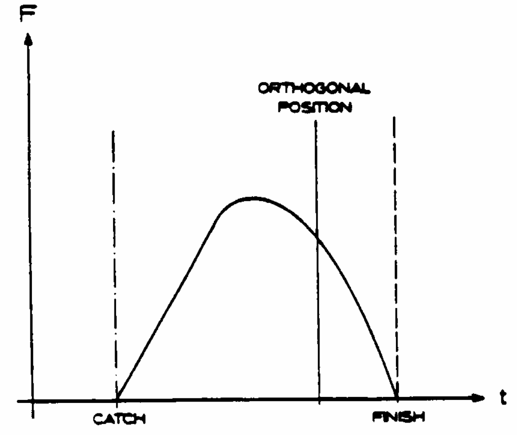
The long stroke is necessary to produce a high level of rowing performance.

The long stroke length, on the outboard of the oar, creates a large reaction force with the water on the blade and, thus, enables the rower to produce his/her best performance on the inboard portion of the oar. The following factors restrict the practical application on the length of the stroke: 1.) the physiological ability of the rower (the more powerful the rower is, the longer the stroke can be), 2.) the velocity of the boat (the faster the type of boat and the higher the level of proficiency, the longer the stroke can be), and 3.) the functional capability of the rower (depending on the body height of the rower and the geometry of the boat).

To produce a high level of performance means to generate a large force over a long distance in as little time as possible. This is a law of physics. In rowing there is a double relationship between performance and the necessary distances: 1.) within the boat, the rower can only attain his/her maximal physiological performance using as long a stroke as possible with the inboard portion of the oar; and 2.) outside of the boat, the necessary force, on the outboard portion of the oar, can only be generated through a long stroke length. A blade without movement relative to the water does not create any reaction force with the water. A common myth among coaches is that the blade is relatively fixed or "sticks" in the water. Research shows that the blade does move through the water more than commonly thought, similar to the hand of a swimmer moving through the water. This movement creates the force to propel the boat.

Research has shown that for all rowers the angle of the oar at the finish is very similar (Nolte, 1982). It is interesting to note that the body height does not matter in this case. Only the body width and the geometry of the boat can cause small differences. Therefore you can influence the length of the stroke only with the variation of the angle of the oar at the entry. In this situation it is important to know that, contrary to popular opinion, the most effective use of the rower's strength is in the early drive phase of the stroke, the angle created before the perpendicular point to the boat (Affeld, 1985, 2.4.4.). In short, the second principle says that a long stroke is important for high performance and this length is most effective in the early drive phase of the stroke (see figure 6).

Figure 6: The ideal course of the pull force of the rower (F = force, t = time) (Nolte, 1984, p. 203).



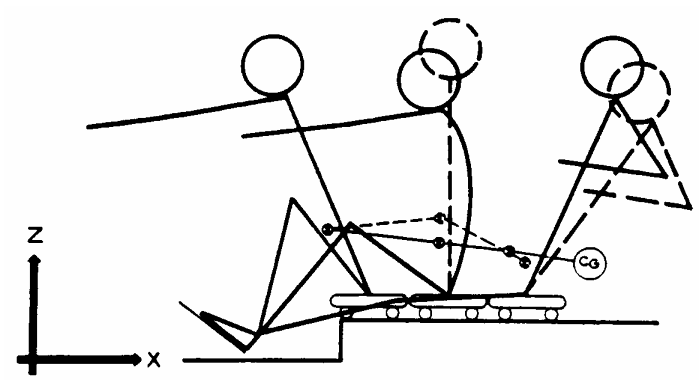
To produce force on the inboard section of the oar, the rower has to move his/her body weight. A considerable amount of power is necessary for this movement. From the total production of the physiological performance of the rower, the following has been determined: 1.) approximately 75 percent is used to pull the oar; 2.) approximately 9 percent is used to support the horizontal movement of the body weight; and 3.) approximately 16 percent of the whole performance is used for the vertical movement of the body (Nolte, 1984, p. 174).

Performance capacity that is used to move the body cannot propel the boat. These biomechanical reflections created the next two principles.

Principle Number 3

The movement of the rower has to be as horizontal as possible so that the vertical displacement of the centre of gravity is minimised without losing length in the stroke.

Figure 7: Comparison of the vertical displacement of the centre of gravity (CG) with the correct (the more horizontal CG - solid line) and incorrect (the CG that has vertical movement - dotted line) technique.



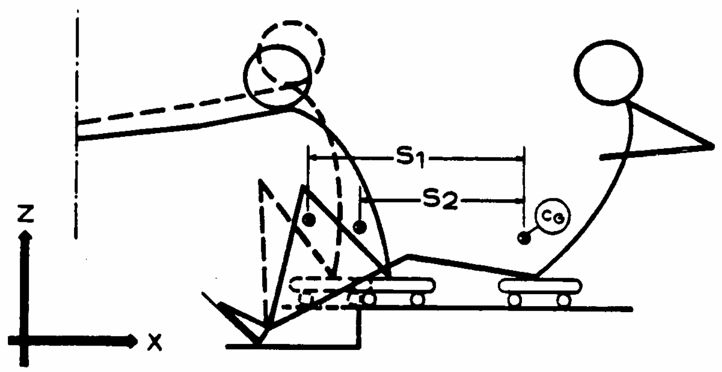
The flexion and extension of the legs, the swing of the upper body from the hips and the vertical movement of the hands and arms cause certain vertical displacements of body parts. With functional co-ordination and avoidance of unnecessary movements, the vertical displacement can be minimised. Biomechanical research shows clear evidence of this principle. The upper body leaning too far back and straightening up during the early drive are major errors. On the contrary, a position with a naturally round back along with minimal vertical movement by the hands are signs of a physically correct technique (see figure 7).

Principle Number 4

The horizontal velocity of the rower relative to the boat should be as small as possible. Ex: The displacement of the centre of gravity in the horizontal plane should be minimised without losing length in the stroke and there should be no lost time with stops or pauses.

This consideration can be followed in two main steps: 1.) the horizontal distance of the CG has to be minimised and 2.) the horizontal movements have to be performed with minimal changes in acceleration. Figure 8 shows schematically that you can have the same length of stroke with different horizontal movements by the CG. It is evident that the so-called Karl Adam technique which uses the extended tracks (Klavora, 1977) is incorrect.

Figure 8: Schematic representation of how to shorten the horizontal movement of the centre of gravity (S1 vs. S2) with slide length where the length of the stroke stays the same.



To this point we have only considered the performance effect the rower has on propelling the boat. This refers to the rower's effect to overcome the water resistance of the shell (not to mention the air resistance and elements of friction such as the wheels of the sliding seat). The water resistance of the boat grows proportionally with the square of the velocity. The changes of the velocity of the boat are considerable because of the differences in the stroke and recovery phases as well as the movements of the bodies of the rowers. Because of these changes in boat velocity, the resistance of a rowing boat is much greater than for a boat of constant speed. To show this, let's consider the following example:

A shell with a constant velocity of 5 meters per second (a men's pair with coxswain) produces a resistance of 100 Newtons. If the velocity is changed so that the boat goes the same average speed but spends approximately half the time at 4 m/sec and the other half at 6 m/sec, it has a 4 % greater resistance.

Normally the changes in boat velocity produced by the rowing stroke are even greater. Therefore it is quite important to consider anything that can reduce these changes. By selecting a rowing technique that minimises changes in boat velocity, the rower can be much more effective in moving the boat. The importance of principles 3 and 4 becomes even greater when you can save performance capacity by minimising the resistance of the boat.

Vertical movement of the centre of gravity produces a dipping of the boat and creates even greater resistance. Large and fast changes in the horizontal movement of body weight also increase the changes in the velocity of the boat. Attention to these principles in boat velocity movements in selecting a rowing technique will have positive effects on the performance of the crew.

Biomechanical Applications in Rowing Training

We have seen that the racing times in international competition for all boat classes have decreased in recent years. The physiological capacity of the rowers has not increased as much as have the improvements in times. Therefore, the development of rowing technique is considered one of the major reasons for this success and biomechanical analysis has assisted this development. The women's pair without coxswain from West Germany who won at the l990 World Championships is an example of a crew whose technique closely followed the principles of biomechanics. Their technique did not emphasise the excessive layback at the finish as employed by the Romanian women's crews, the previous winners of the event. Biomechanical principles applied by a larger group, such as an entire national rowing federation, can provide big advantages to the rowers. Over a longer period, it is possible to create consistently successful big boats, like the Italian men's lightweight eight and the West German men's open eight.

It is possible to reach the top levels of world class rowing only if you employ a sound rowing technique. An outstanding example of this is the 1990 Australian men's four without coxswain. This boat defeated many excellent past champions by using superb rowing technique and, in doing so, in the extremely fast time of five minutes, 52 seconds.

Biomechanics in the Future

Research in biomechanics is not finished. Basic research in specific analysis of rowing technique is on going. For example, additional research is necessary to determine at which point the effectiveness of the angle of the oar at the entry decreases. The measurement tools and analysis methods will be developed so that they can be used by coaches at all levels. The efficiency of an individual rower in a crew can be increased with dynamic measurement devices, such as force transducers, in the boat. In the end, the practical education of biomechanical concepts and the simplification of scientific research into language that can be understood by the coaches and the rowers is our goal.

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