KINEMATIC AND KINETIC STUDIES ON MEASUREMENT OF ROWING TECHNIQUE

Lu Deming, Wang Yunde and Shi Jiping
China National Research Institute
of Sports Science

Introduction

China's rowing performance is good when compared with other Asian countries in Asia (e.g. Chinese athletes took away 7 of the 8 gold medals in the Xth Asian Games in 1986), but compared with world-class teams, there is still a long way to go. In the 1987 World Championships China won only bronze in the women's coxless four, and was only fourth of women's sculling in the World Youth Championships.

In order to solve the problems in rowing technique, training and athletes-selection, a research group was set up and a series of studies were conducted on the rowing technique of elite Chinese rowers from national and some provincial teams. As a consequence, technical data, pictures and suggestions were provided, which have made contributions to the improvement of China's rowing performance.

Methods

A 1PL high-speed camera was used to take technical pictures of China's most elite rowers during training and competitions. Shooting distance was 35-100m with frequency of 50 frames/s. The pictures were then analyzed with the help of GP-2000 film-analyzer and computer. As a result, graphs of boat speed, as well as diagrams of movement of the body joints, and rowing technical pictures were developed.

A test of the synchrony of the high speed camera and the telemetered anthropometric and force data was conducted prior to the beginning of the data collection. Data were collected in the following manner. A self-produced force measuring cell was fixed in the oarlock and a subminiature transmitter (200 g.), installed in the boat and NRT-4A receiver (set on land) produced by NEC Co. of Japan was used for recording force signals. The rowing angle signals were transmitted by a heart-rate transmitter designed by the China National Research Institute of Sports Science and received by a conventional radio. All signals were then recorded by a 7-channel tape-recorder manufactured by Japan Teac Company. The telemetry system and high-speed camera were operated by a synchronizing controller, with received signals loaded into computer. Technical pictures were also loaded into computer after analysis. Finally, synchronous analytical illustrations were drawn with the processed kinematic and kinetic data for comparative study.

Results and Analysis

Boat Speed

Times of different phases during a stroke and relative boat displacement and speed were analyzed respectively, based on the data collected from training before the Xth Asian Games in August, 1986 and from the National Championships in October of the same year.

For simpler analysis, the boat speed curve during one stroke was divided into 7 phases (Figure 1) and marked by 8 vertical lines. Each of the lines was defined as follows (left to right),

1) Start lifting oar, blade begins to drop,
2) First water contact, the moment blade contacts water,
3) Start pulling oar, blade stops dropping and speeds to stern,
4) Oar being perpendicular to the boat, the oar comes to orthogonal position to the longitudinal axis of the boat,
5) Start pressing oar, blade begins to rise,
6) Last water contact, the moment blade leaves water,
7) Start pushing oar, blade comes to bow,
8) Start lifting oar, ...

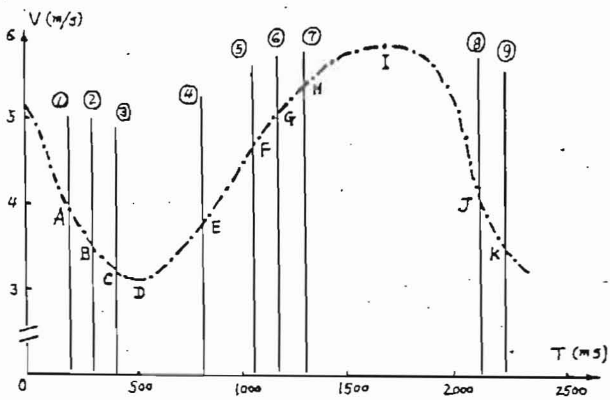


Fig. 1 Curve of Boat-Velecity

(1) Start Lifting Oar (2) First Water Contact
(3) Start Pulling Oar (4) Oar Being Vertical to the Boat
(5) Start Pressing Oar (6) Last Water Contact
(7) Start Pushing Oar (8) Start Lifting Oar

Stroke Time and Boat Displacement

The average stroke time value of Liu Qun (man's sculling), Chen Changfeng and Han YaQing (woman's sculling) was 2.06 (Table 1). The boat displacement per stroke by Liu was 9.14 m, while that by Chen and Han was averaging 8.61 m (Table 2).

Tab. 1 Time(sec.) for Each Phase and Its Percentage of Full Stroke

Phase / Name	Lift	Pull	Press	Push	Total
Liu	0.23 11.0	0.71 34.0	0.31 15.1	0.82 39.2	2.06
Chen	0.20 9.7	0.56 27.8	0.28 13.9	0.99 48.6	2.03
Han	0.25 12.2	0.54 25.7	0.23 10.3	1.07 51.3	2.09
Average	0.23 11.0	0.60 29.2	0.27 13.3	0.96 46.5	2.06

Tab. 2 Boat Displacement(m) in Each Phase and Its Percentage of Full Stroke

Phase / Name	Lift		Pull		Press		Push		Total
Liu	0.77	8.2	2.99	31.8	1.38	14.6	4.27	45.4	9.41
Chen	0.71	8.4	2.10	24.9	1.15	13.7	4.46	53.0	8.42
Han	0.80	9.1	1.86	21.1	1.07	12.1	5.03	57.7	8.80
Average	0.76	8.6	2.32	25.9	1.20	13.5	4.60	52.0	8.87

In China, a full stroke cycle is usually divided into four phases, lift, pull, press and push. The time for each phase and its percentage of full stroke time are shown in Table 1. The boat displacement in each phase and its percentage of full stroke displacement are shown in Table 2.

Taking the orthogonal position of the oar to the longitudinal axis of the boat as the dividing line, the pull phase was again divided into two sub-phases—the front half and the rear half. The average ratio of stroke time between the front half and the rear half of the three rowers was 74:26 s, while that of boat displacement was 70:30 m.

Parameters Describing Features of Boat Speed

The average boat speed per stroke was 4.57 m/s for Liu, and 4.18 m/s for Chen and Han. When evaluated in relation to the four stroke phases, lift, pull, press and push, the boat is slowest in the lift phase and fastest in the push phase (Table 3).

Tab. 3 Boat Speed (m/sec.) of the Four Stroke Phases

Phase / Name	Lift	Pull	Press	Push	Average
Liu Qun	3.42	4.24	4.44	5.22	4.57
Chen Changfeng	3.60	3.72	4.09	4.52	4.15
Han Yaqin	3.14	3.47	4.71	4.74	4.21
Average	3.39	3.81	4.41	4.83	4.31

In this study it was found that there were four parameters that described both technical features of the boat speed curve, and qualities of rowing technique.

The Maximum Difference (Max D), refers to the difference between the maximum (point I) and the minimum (point D) boat speed within one stroke (Figure 1).

It is shown in Table 4 that the average Max D of the three rowers was 2.16 m/s. Generally speaking, the lower the Max D value is, the less changeable will be the boat speed. Thus, if we cover the same distance with the same average velocity, those with less boat speed change will consume less energy. In consequence, the athlete will be less fatigued. This is of great significance to long-distance events such as 2000 m rowing.

Tab. 4 Parameters Describing Features of Boat Speed(m/sec.)

Item / Name	Aver.	Lowest Speed During Pull	Highest Speed During Pull	Start Speed of Push	Highest Speed During Push	Max D	Min D	Pul D	Push D
Lin	4.57	3.51	4.91	4.89	5.66	2.15	0.44	1.40	0.77
Chen	4.15	3.04	4.35	4.11	5.17	2.13	0.71	1.31	1.06
Han	4.21	2.97	4.49	4.50	5.16	2.19	0.82	1.52	0.66
Average	4.31	3.17	4.58	4.50	5.33	2.16	0.66	1.41	0.83

The Minimum Difference (Min D), refers to the difference between the time of first water contact (point B) and the time of minimum (point D) boat speed (Figure 1). It describes the slowdown of the boat beginning at the moment of first water contact. Obviously, the lower this value, the better the acceleration. It means a very quick "catch water" phase which will increase impetus to the boat. This parameter can be used to determine the quality of "catch water."

The pulling Difference (Pul D), refers to the time difference between the minimum (Point D) and the maximum (Point F) boat speed during pull (Figure 1). It describes the quality of pull. When under same conditions, the higher the Pul D value, the better are the pulling results. It is then a significant parameter in determining the quality of pull technique.

The Pushing Difference (Push D), refers to the difference between starting Push (point H) and the maximum (point I) boat speed (Figure 1). It describes the acceleration of the boat caused by the back sliding of the rower during recovery. A higher Push D value reflects a faster body movement towards the stern. West German scholars have stated that this recovery motion should be smooth and even., the key point during recovery was to keep the speed. Thus the recovery should neither be too fast nor too slow, a sudden acceleration or deceleration should specially be prevented.

Types of Speed Curves and Their Relation to Technique

Based on studies of 52 speed curves by national and local elite rowers, it was found that all the curves may generally be divided into two groups, the "single peak" and the "double peak." In the "single peak" curve, there is only one peak during a stroke cycle (Figure 2), meaning that the boat speed is stable and less energy is consumed during work. But in the "double peak" curve, a little hump appears at the beginning of the speed curve (Figure 3). This little hump coincides with the "press" phase, indicating that it is the result from a slow press movement, that is, the athlete is unable to pull the oar while pressing. This kind of curve reflects a rather changeable boat speed which consumes more energy than the "single peak" curve. Most Chinese rowers at the Xth Asian Games were found to have "double peak" curves. This may have something to do with the old concept of "lift, pull, press and push." Yet many young athletes, such as (gold medals winner of four important competitions) Li Zhongping (men's scull) and Cao Mianying (woman's scull), have "single peak" speed curves.

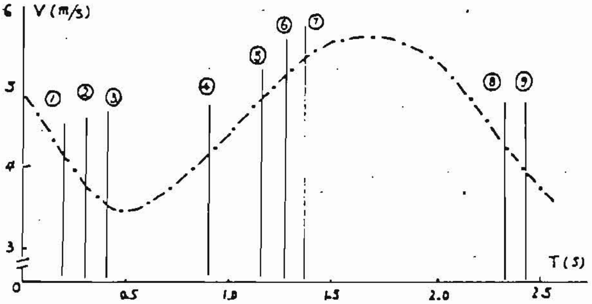


Fig.2 "Single Peak" Curve of Boat Speed

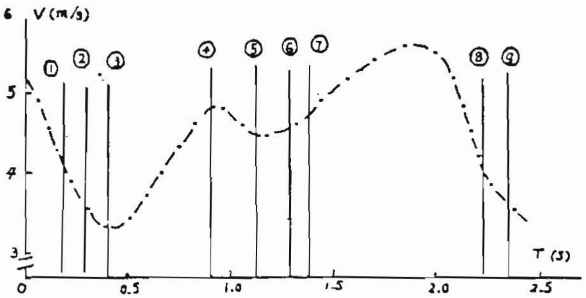
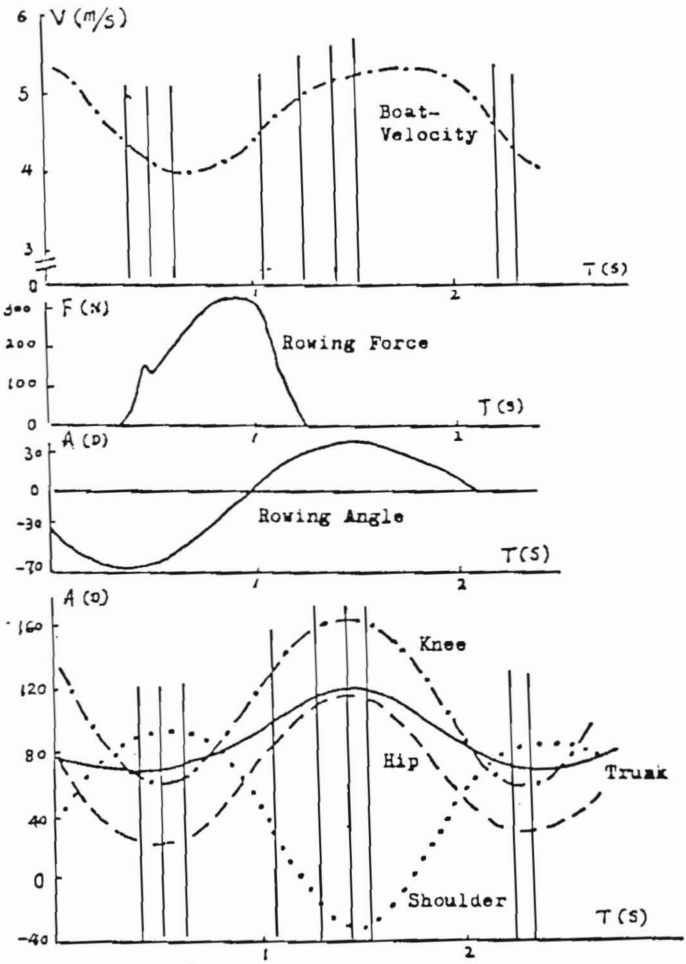


Fig.3 "Double Peaks" Curve of Boat Speed

Force, Rowing Angle and Features of Body Movement

Some elite rowers from Anhui Provincial Team and Niedersachsen Team of West Germany were measured last April in Hefei city, China. Among the scull rowers Li Zhongping, Zhu Daofa (Anhyui Team) and Reinker (Niedersachsen Team), were the best and had different technical styles. They were chosen for technical analysis. Synchronous analytic curves of boat speed, rowing force, rowing angle and body movements were drawn.

If we define the angle between oar and the longitudinal axis of the boat as zero degree ($= 0^{o}$); the angle between first water contact and orthogonal position of the oar as the front angle (the negative angle); and the angle between the orthogonal position of the oar and last water contact is the rear angle (the positive angle).



, Fig.4 Synchronized Analytical Curves of Boat-Velocity, Rowing Force, Rowing Angle and Angle of Body Joints (Li Zhongping)

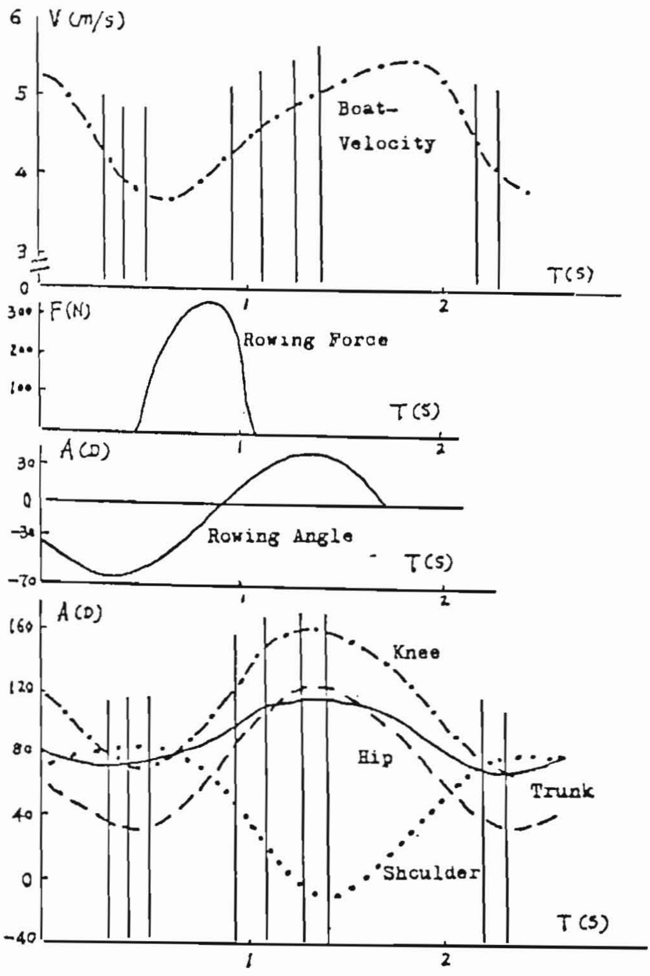


Fig.5 Synchronized Analytical Curves of Boat-Velocity, Rowing Force, Rowing Angle and Angle of Body Joints (Reinker)

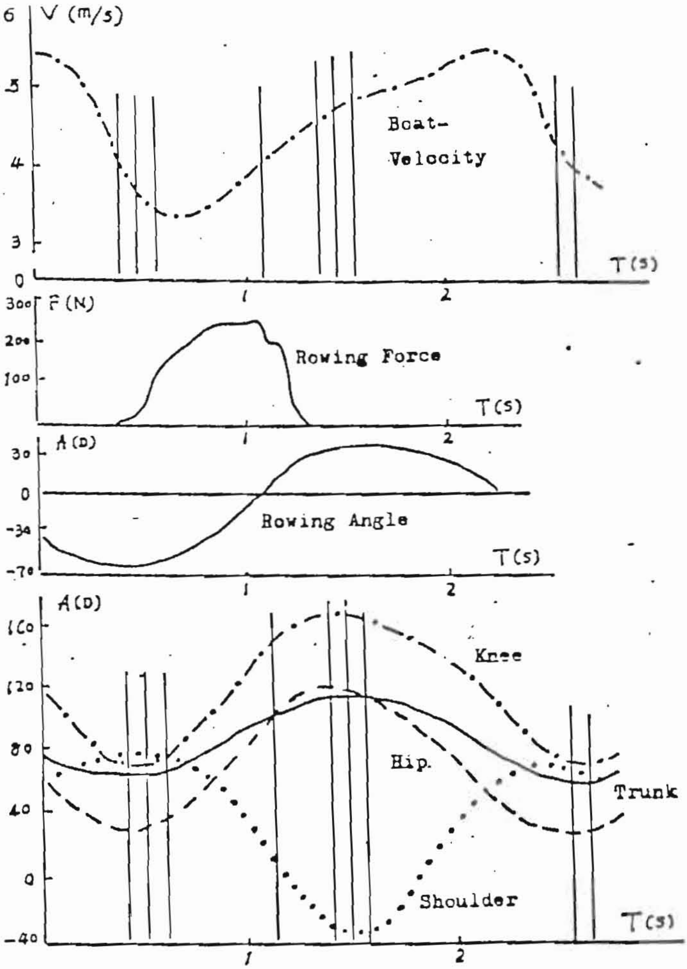


Fig.6 Synchronized Analytical Curves of Boat-Velocity, Rowing Force, Rowing Angle and Angle of Body Joints

(Zhu Daofa)

The following features were found from Figures 4,5,6:

a) Force curve rises sharply shortly after the blade drops into the water, but the boat speed curve demounts at the same time;

b) The peak of force curve appears before ;

c) When the force curve decreases to zero degrees, the speed curve continues;

d) Over 80% of the work during pull through is applied in the phase of front angle (Table 5), thus the first half of pull movement is of great importance.

Tab. 5 Work Applied by Force

Work / Name	Total Work (J)	Work Appl. Bef. ψ=0° (J)	%
Li Zhongping	328.1	267.4	81.5%
Reinker	258.2	213.4	82.7%
Zhu Daofa	246.7	211.8	85.9%
Average	277.7	230.9	33.4%

2.2 The Force Curve

The greatest average force of the three athletes was 304.8 (N) (Table 6). The highest force of Li Zhongping and Reinker was similar to that illustrated by Felix Angst et. al. (1987) in Figure 7 while that of Zhu Daofa was a bit lower (Table 6). Force courses of the three were also obviously different. Li and Zhu's curves had a flat surface with a wider and smoother peak, while that of Reinker was very sharp with a narrower peak. The former reflected a longer time of work applied by force, which could be called "Smooth Force," and the later meant a shorter work time by applied force, which could be regarded as "Sudden Force." The "Smooth Force' curve was similar to the standard force curve illustrated by Felix Angst (2) and were better than the "Sudden Force" curve. For example, although Li's greatest force was not as high as that of Reinker, his work time of the applied by force was longer. So Li applied a higher total impulse to the boat than Reinker (Table 6).

Tab. 6 The highest Force adn Impulse

Item / Name	Fmax(N)	∫F bt(N/sec.)
Li Zhongping	323.5	221.6
Reinker	330.9	172.8
Zhu Daofa	255.1	165.4
Average	304.8	186.6

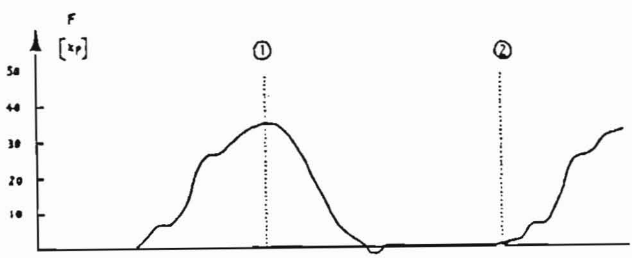


Fig.7 Curve of Rowing Force

The Rowing Angle

The average entire rowing angle of the three rowers was around 100 degrees, of which the front angle (before φ = 0°) was some 63 degrees and the rear angle (after φ = 0°) was some 37 degrees. The ratio between the two was approximately 2.1.

Features of Body Movements

It is common knowledge that the force applied to the boat comes from body movements, that is, the movements of body segments and joints. In this study, the inclination of the upper body, angular displacement of the hip, knee and shoulder joints were measured with the aid of a film-analyzer. Consequently, motion curves were drawn (Figures 4,5,6) to define the features of body movements.

a) The hip and knee joints moved synchronously;
b) The angles of hip and knee joints were smallest at first water contact and largest at last water contact;
c) The upper body inclined synchronously with the hip and knee joints, yet the angle of inclination was not as great;
d) The shoulder joints also moved synchronously with the hip and knee joints.

The Hand Curve

The movement of the blade is determined by the movements of hand, thus it is the important to carry out studies on hand curve. A Th. Korner, head coach of the GDR national rowing team, stated at the 7th FISA Coaches' Conference that "Comparisons between hand curves of oarsmen with different qualifications indicate a flat lifting surface as ideal course" (3), both world-class oarsmen J. Landvoigt of GDR and I. McNuff of Great Britain had hand curves typical of a"flat lifting surface." (Figure 8)

Figure 9 illustrates the hand curves of some elite Chinese rowers Li Zhongping, Cao Mianying and Liu Qun. It is clear that the course of the hand of Li Zhongping is similar to the "ideal course" described by Th. Korner, while those of Cao Mianying and Liu Qun were too strong downwards at the last phase, which weakens the striking effects.

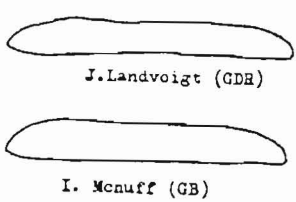


Fig.8 Course of Hand Curses With Flat Lifting Surface

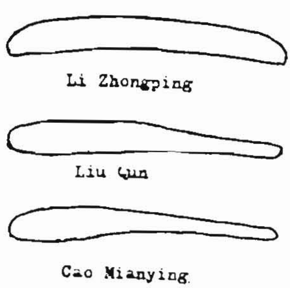


Fig.9 Course of Hand Curves of Some Chinese rowers

Recommendation on Improvement of Old Technical Conception

A. Hotz and J. Weinech pointed out in the book, "Optional Learning of Motion" (1983) that "The improvement of the quality of motion (and so of efficacy) is close to the improvement of the motional conception" (Hotz, 1983). In China, a full stroke cycle was usually divided into four phases "lift, pull, press and push." With this kind of technical conception in mind, the oarsmen would only pay attention to lifting and pressing the oar at water contacts, but neglected the pulling motion at the same time. Thus, the horizontal speed of blade at water contact was slower than the boat speed, which caused resistance.

Table 7 shows the horizontal speed of the blade at the moment of first water contact by 5 Chinese scull oarsmen. The average speed was 2.08 m/s. The highest was 2.88 m/s by Li Zhongping, and the lowest was 1.26 m/s by Liu Qun. The boat speed of all of them was over 3 m/s at first water contact, but none of the blade speeds were that fast. Only when the blade speed was higher than the boat speed was there motive power, otherwise there was resistance which lowered the boat speed. It would be the same case if one only pressed the oar at the moment of last water contact without pulling.

Thus is the recommendation that the former four-phases rowing cycle "lift, pull, press and push" be replaced by a new one "pull-lift, pull, pull-press, and push."

Conclusions

1. The four parameters of maximum difference (Max D), minimum difference (Min D), Pulling Difference (Pul D) and Pushing Difference (Push D) and the two types of curves of single peak and double peaks are defined in this study. These curves can be used as reference indexes for rowing technique description.

2. The ratio of front angle of the oar (the oar to a line perpendicular to the boat rear angle) was 2:1. More than 80% of rowing work is done when the oar is in a front angle. Therefore, the front angle is the more important phase during a stroke.

3. There are two types of force curve, the Smooth Force and the Sudden Force. The former type is better for a stable boat speed and saves strength.

4. Courses of the hand of many elite Chinese rowers do not have as flat a lifting surface as those of world class rowers. Instead they have too strong a downwards direction during last phase.

5. A new four-phase stroke cycle consisting of "pull-lift, pull, pull-press and push" is recommended to replace the old one of "lift, pull, press and push."

References

Angst, Felix, Gerber, Hans, Stussi, Edgar (1985). *Physical and biomechanical foundations of the rowing motion.*

Angst, Felix (1984) *Biomechanics as a help in learning and training the rowing technique.*

Angst, Felix (1980) *Biomechanics as a help for the practical work of the rowing coach.*

Hotz, A., Weineck, J. (1983) *Optimal learning of motion.*