Feedback Systems in Rowing

Arnold Baca, Philipp Kornfeind and Mario Heller
University of Vienna, arnold.baca@univie.ac.at

Abstract. On-land feedback devices using rowing ergometers provide an alternative for on-water systems. In order not to draw incorrect conclusions it is essential to compare the rowers' technique in the boat to that on the ergometer. Units for measuring reaction forces in the boat and at the ergometer have been constructed. Similarities in the reaction forces at the foot stretcher could be found for elite rowers.

1 Introduction

Technique analysis in rowing involves the consideration of fine details of the movement of the rower with regard to the boat. In addition to kinematic analyses the study of the kinetics of the boat-rower system provides valuable insights into strengths and weaknesses (e.g. peculiarities in motion coupling) (Spinks and Smith 1994; Badouin and Hawkins 2004). Feedback systems incorporated directly in the boat are used in elite rowing (Smith and Loschner 2002). Data are processed on-board and may be transmitted to a PC located on the coach's launch using wireless communication technologies (Collins and Anderson 2004).

Analyses of the rowing technique in the boat are difficult to realize and are very demanding in time and instrumentation. In many cases analyses are therefore based on rowing simulators (ergometers) on land (Page and Hawkins 2003; Loh, Bull, McGregor and Schroter 2004). In order not to draw incorrect conclusions from the training sessions on land it is essential to compare the rowers' technique in the boat to that on the ergometer (cf. Lamb 1989).

A specific setup has been developed to compare the dynamics. Units have been constructed to measure reaction forces at the foot stretcher in two dimensions and may be used in the boat as well as at the ergometer (Concept 2 Indoor Rower Model D) with or without slides (a construction that is attached to the legs of the ergometer, allowing the ergometer to roll back and forth during the rowing stroke). Reaction forces at both feet are acquired separately.

In addition to the forces at the foot stretcher the pulling forces also allow to draw conclusions on the rowing technique. In the case of ergometer measurements a force transducer is connected to the chain attached at the handle. In the boat, dynamometric oarlocks are used for this purpose. Data measured in the boat are recorded using a data logger or a Personal Digital Assistant (PDA).

A comparison of reaction forces at the foot stretcher has been performed for elite rowers. The methods applied and selected results (case study) are presented in the sequel.

2 Methods

Reaction forces at the foot stretcher are measured using two identical constructions (Fig. 1) based on load cells (HBM, type HLC220) and strain gages (HBM, type XY91-6/120). The (portable) units may easily be attached to the foot stretcher of the boat or of the ergometer. Forces are induced into a cover plate made of aluminum. Components vertical (load cell) and parallel to the platform (strain gages) can be acquired. From the data recorded the resulting force vector (magnitude, orientation) is calculated. The load cell acts as double bending beam, the strain gages have been applied to acquire parallel forces. To obtain an optimal position to mount the strain gages, stress calculations have been performed utilizing the software Ansys™. A CAD model of the load cell has been constructed in order to simulate the load cases in longitudinal direction. The local maxima of the material tensions resulting from these simulations were selected as positions for bonding the strain gages.

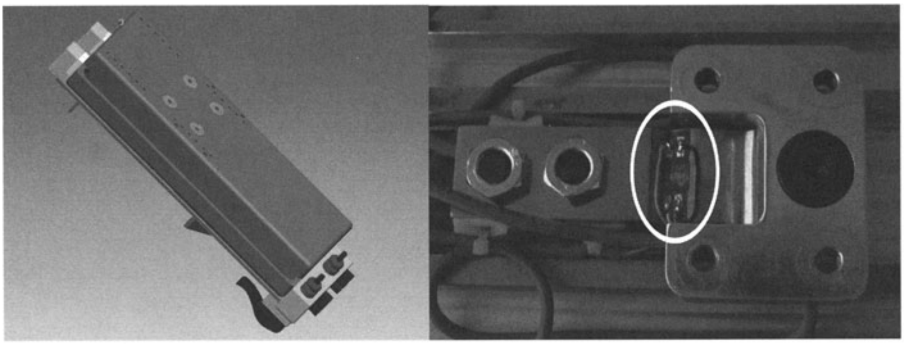

Fig. 1. Left: construction for measuring reaction forces at the foot stretcher, right: modified load cell with strain gages

The strain gages (2 measuring grids configured in a T-rosette arranged perpendicular to one another) have been configured as a full bridge. Because of their orientation in the circuit they compensate forces perpendicular to the load cell and simultaneously double the sensitivity in longitudinal direction. In order to condition and amplify the bridge signals a dual stage amplifier circuit was dimensioned, manufactured and integrated into the platform.

In the boat the platforms are mounted directly to the foot stretcher by screwed connections, in the case of the ergometer quick clamps at the lower side as well as fastening angles at the upper side are used for fixation (Fig. 2).

Fig. 2. Fixation of the platforms. Left: boat, right: ergometer

The linear relationship between force and output voltage was investigated by performing a comprehensive calibration procedure with static loads in both force axes (normal and parallel) in positive as well as negative direction. The measuring points obtained by this procedure yield a nearly plane grid, showing a high linearity (Fig. 3).

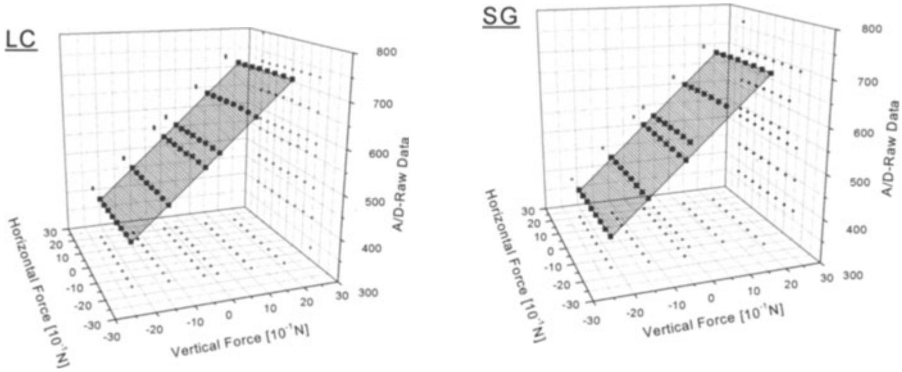

Fig. 3. Calibration. Left: perpendicular to platform (load cell – LC), right: parallel to platform (strain gages – SG)

However, the linear relationship observed is not necessarily sufficient for the dynamic case, since inertia properties of the system and moreover the frequency behavior may influence the signal. In order to analyze the dynamic behavior, comparative measurements were performed using the ergometer equipped with the platforms. The ergometer was put onto a force plate. A force transducer measuring the pulling force was attached to the chain of the handle.

If horizontal force components are considered only, the following equation can be set up

$$F_S = F_{GRF} - F_p, \tag{1}$$

where F_S is the horizontal reaction force at the foot stretcher, F_P the pulling force and F_{GRF} the horizontal ground reaction force in the direction of motion. A comparison of two different measuring systems is therefore possible.

A typical example for one stroke is shown in Fig. 4. Measured (F_{S*}) and calculated horizontal reaction forces (F_S) at the foot stretcher are shown. Note that F_{S*} is the sum of components normal (load cell) and parallel (strain gages) to the foot stretcher considering its angle with respect to the boat/ergometer. A correlation of r=0.99 was calculated between the values (200 samples per second) of F_S and F_{S*} for this stroke.

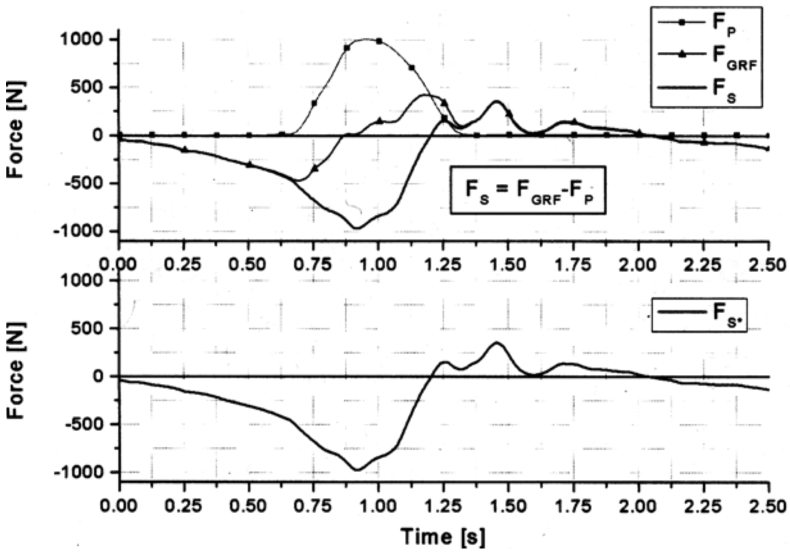

Fig. 4. Upper chart: pulling force (F_P), horizontal ground reaction force (F_{GRF}) and calculated horizontal reaction force at the foot stretcher (F_S). Lower chart: measured horizontal reaction force at the foot stretcher (F_{S*})

3 Case Study

Horizontal reaction force curves at the foot stretcher of an Austrian elite rower (national team) are presented in Fig. 5. All measurements have been performed on the same day. Remarkable asymmetries between left and right foot can be seen in all situations. In particular, the amplitudes of the right foot are higher during the pulling phase (negative forces). For the three successive strokes presented the quotients of the areas under the curves (negative parts only) of left and right foot are 0.68, 0.73 and 0.73 for the boat, 0.83, 0.82 and 0.80 for the ergometer with slides and 0.89, 0.91 and 0.90 for the ergometer without slides.

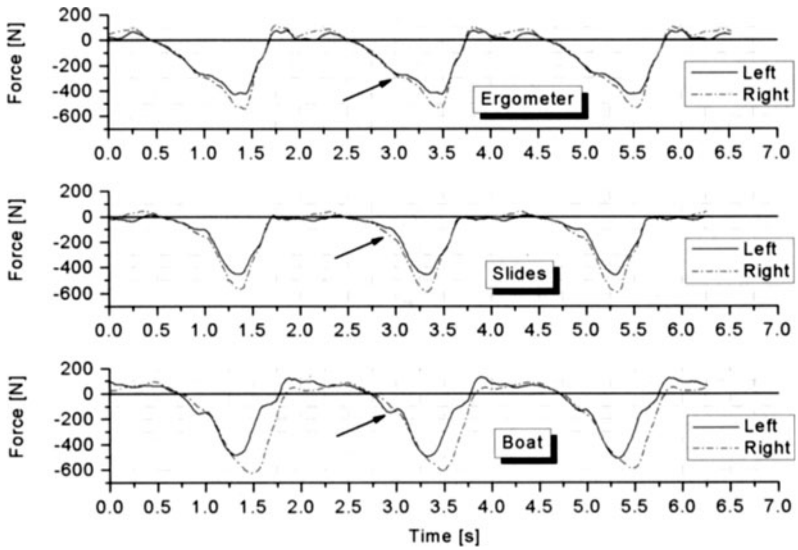

Fig. 5. Horizontal reaction forces at the foot stretcher from elite rower (3 strokes, 30 strokes per minute). Upper chart: ergometer without slides, middle chart: ergometer with slides, lower chart: boat

Moreover, a specific irregularity marking the start of the pulling phase (denoted by little arrows in Fig. 5) can bee seen in both ergometer conditions as well as in the boat. One possible reason for the strong occurrence of this irregularity might be that the upper body of the rower under investigation straightens up too early at the start of the pulling phase.

The rower may therefore benefit from feedback sessions on the ergometer. During these sessions knowledge-of-performance feedback is given. The time histories of the relevant kinetic parameters are displayed on a monitor in view of the rower during motion execution. The rower is thereby able to discover how changes in the movement pattern alter the shape of the curves.

4 Conclusions and Perspectives

Case studies indicate that peculiarities in the rowing pattern may also be observable when using rowing simulators. In these cases benefits are expected from the use of feedback systems based on ergometers.

The results also indicate that the ergometer with slides compares better to on-water rowing. This is not surprising, since on the ergometer with slides the rower has to accelerate/decelerate the ergometer whereas on the ergometer without slides he/she has to accelerate/decelerate his/her body. It should, however, be considered that many (elite) rowers are not used to exercise on ergometers with slides.

Upcoming experiments will also consider pulling forces for the comparisons.

A variant of the on-land feedback system for use in the boat assisting both coaches and athletes and a cascaded double ergometer system are under development.

Acknowledgements

We thank Armin Blaha and Emanuel Preuschl for their valuable contribution in constructing the foot stretcher dynamometer.

References

Baudouin, A. and Hawkins, D. (2004) Investigation of biomechanical factors affecting rowing performance. J. Biomech. 37, 7, 969-976.

Collins, D. J. and Anderson, R. (2004) The use of a wireless network to provide real-time augmented feedback for on-water rowing. In: *Proceedings of the American Society of Biomechanics 28th Annual Conference*, Portland, USA, pp. 590-591.

Lamb, D. H. (1989) A kinematic comparison of ergometer and on-water rowing. Am. J. Sports Med. 17, 3, 367-373.

Loh, J. M. H., Bull, A. M. J., McGregor, A. H. and Schroter, R. C. (2004) Instrumentation of a Concept II rowing ergometer for kinetic and kinematic data acquisition, In: M. Hubbard, R. D. Mehta and J. M. Pallis (Eds.), *The Engineering of Sport 5, Volume 2*. isea, Sheffield, pp. 173-179.

Page, P. N. and Hawkins, D. A. (2003) A real-time biomechanical feedback system for training rowers. Sports Eng. 6, 67-79.

Smith, R. M. and Loschner, C. (2002) Biomechanics feedback for rowing. J. Sport Sci. 20, 783-791.

Spinks, W. L. and Smith, R. M. (1994) The effects of kinematic information feedback on maximal rowing performance. J. Hum. Mov. Stud. 27, 17-35.