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The Balance of Crew Rowing Boats

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Abstract

The purpose of this study was to examine the feasibility of a method to measure the rolling of rowing shells during normal performance, and the comparison of balance patterns for several crews of different experience levels. One novice eight, a club four and two National team eights were analyzed during regular training routines. The balance measurement tool, a Silva Level, did not interfere with crew performance and the video analysis allowed accurate measurements to 0.5 deg at a sampling rate of 30 Hz. Although the study was designed as a pilot project, the results showed clear tendencies. Balance improved with the experience level of the crews. Boats seemed to be more balanced at higher stroke rates. Surprisingly, all crews appear to learn more to the same side, which could be connected with the rigging of the boats. Also, balance can be improved through appropriate training.

Keywords: *Rowing, Balance Patterns, Learning Methods*

1. INTRODUCTION

Athletes who have never practiced rowing before are normally introduced to the sport of rowing using the following teaching methods. First, the beginner athletes are put on an ergometer or in a rowing tank before being allowed to take strokes in a boat. They are supposed to learn the correct movement patterns, as well as following others to perform in unison as a crew in a stable and safe environment. Next, the athletes take their first strokes in a stabilized boat on the water. To accomplish this, part of the crew will keep their blades flat on the water while sitting still (thereby stabilizing the boat), while the others try to accomplish correct blade placement on top of the already learned movement pattern. Finally, the athletes would be allowed to row together, executing the complete rowing stroke as a crew. This process seems to be well laid out and many coaches follow this method. The first step of this method is the easiest. Normally, it only takes minutes for people to perform the proper sequence of motions on an ergometer, especially when they have a model rower. Even the second step is normally accomplished in a short time. After the new rowers have grasped how and when they need to rotate the blade (according to the phase of the stroke), they will experience quite amazing boat movements due to their pulling. The last step of having the whole crew rowing together seems to be the most complicated, and even frustrating.

Although, the novice rowers look as if they know the proper sequence of body joint movements and blade control after practice on the ergometer and the stable boat, their actions become frantic and uncoordinated with their teammates, even destructive for the whole boat, when this last step is taken. When the beginner is put in the situation of having to do these basic movements with the additional tasks of balancing the boat and coordinating with other members of the crew, those previously learned basic movements tend to fall apart.

Current research in motor learning can help us explain this phenomenon. The dynamic systems theory suggests that rowing on the ergometer and rowing on the water are two different skills. One of the main distinctions between the two is the balance that is necessary for handling a rowing shell on the water.

One of the more recent theories to emerge is that of Dynamic Systems Theory, also known as Dynamic Pattern Theory. The underlying concept is that to achieve coordination, the central nervous system assembles dynamics; that is, equations of motion that govern coordination activity. Learning is then based on a self-organizing non-linear system that controls our movements (Kelso, Ding and Schöner, 1993).

In the case of a rowing crew, the boat and rowers would be considered a system that is seeking to coordinate itself. More specifically, at any point during the learning process, the system is governed by a well-defined coordination dynamics. This type of organization, is not limited to intrinsic coordination patterns that might arise from hard-wired neural circuitry. As a consequence, perceived, learned, or intended constraints not only affect the pattern being performed but also its dynamics, in particular its dynamic stability (Schöner et al., 1992). In rowing, these constraints would include the balance of the boat.

Regulatory features in the environmental context determine what and how body and limb movements must be performed to successfully achieve the goal of the action in the performance setting. Knowledge about the environmental regulatory features of the skill is an important component of skilled performance, and the acquisition of this knowledge is an essential part of the initial stage of learning. Practice should include a performance context situation in which the critical environmental regulatory features occur (Magill, 1998). In the case of a rowing crew system, the environmental regulators would include the other members of the crew and balance.

As Smith and Loschner (2002) note, the dynamical systems perspective on motor learning provides a relevant conceptual framework for the improvement of rowing performance. This perspective emphasizes the interaction of the learner with the biomechanical parameters of the motion – the forces and resulting kinematics. The learner relates to the laws of nature so these laws can be used to create the required organization for a closer approach to the movement goal.

From an ecological point of view, motor learning emerges from the interplay of constraints on action, which shape behaviour towards the optimal solution, and practice, conceived as an active exploration of the workspace to search this optimal solution (Nouritt, Deschamps, Lauriot, Caillou, and Belignieres, 2000). Lay, Sparrow, Hughes and O'Dwyer (2002) note that with practice at a gross motor task such as rowing, the timing and magnitude (coordination and control) of muscle contraction will become closer to optimal, thereby minimizing unnecessary muscle contractions and improving coordination. This is supported by the proposition that motor learning is associated with changes to movement control parameters that reflect the increased economy of energy expenditure in achieving the task goal (Sparrow et al., 1999, Lay et al., 2002). Again this is demonstrating the role of exploration in the self-organization of learning.

In summary, the Dynamic Systems Theory indicates that balance is an integral part of rowing technique. Poor balance and poor rowing technique influence each other directly. This leads to increased energy expenditure not only to control movement, but also to overcome larger water and wind resistance that is created by ineffective boat and oar movements (fin action relative to the water, blades touching the water in recovery).

Wagner, Bartmus, and deMares, (1993) used a three-axes gyro quantifying the specific balance of rowing. In pilot studies with two rowers in singles, they detected larger deviations in yawing and rolling for a beginner relative to an elite oarsman. These two motion components increased when the scullers rowed at an intensity of ~ 10 mmol/l lactate or when they changed hand positions pulling with their left before right hand instead of their normal technique. However, only two single rowers were analyzed, no 0 deg baseline was indicated and very limited values were given.

Nevertheless, balance seems to offer more insight into rowing technique. If balance plays a major role in the learning process of rowing, the following hypotheses can be formulated:

- Crews of various expertise levels (novice to national team) will show differences in their balance performance.
- A crew intending to improve during a training season will focus on balance as part of their overall performance improvement.
- A crew will show similar balance patterns at different stroke rates.
- As it relates to dynamic systems theory, balance may represent a collective variable useful as an indicator of overall crew/system performance.

2. DEFINITIONS AND METHODS

Rowing is a sport that requires repeating a highly coordinated movement cycle. The sequencing of the rowing stroke involves four major phases: the entry, drive, release, and the recovery. There are also two important positions: the catch and the finish. The catch is defined as the position where the handle is closest to the stern of the boat. The catch is part of the entry phase, in which the blade is placed into the water to start propelling the rower and boat. Following the entry, the rower continues the propelling during the drive. The blade leaves the water during the release and the rower prepares for the recovery where the blade is brought back to the next entry. During the release, the finish is the position where the handle is closest to the bow of the boat.

Wagner et al., (1993) state that stabilizing the balance or the rolling of the boat is a main task of the rowing motion, and coping with this problem facilitates the learning of additional elements of the rowing motion. The system consisting of rower(s), boat and oars is free to rotate around the X-axis and the effort to control this movement (to keep the balance) is important for the performance of the crew. To row effectively, athletes are required to maintain a postural balance keeping them upright in the boat. This increases in difficulty when the boat is moving around the X-axis. When there is rolling in a boat, the crewmembers will adjust their body positioning in an attempt to balance the boat. In addition, the oar and blade are often used for stabilizing (see Fig. 1).

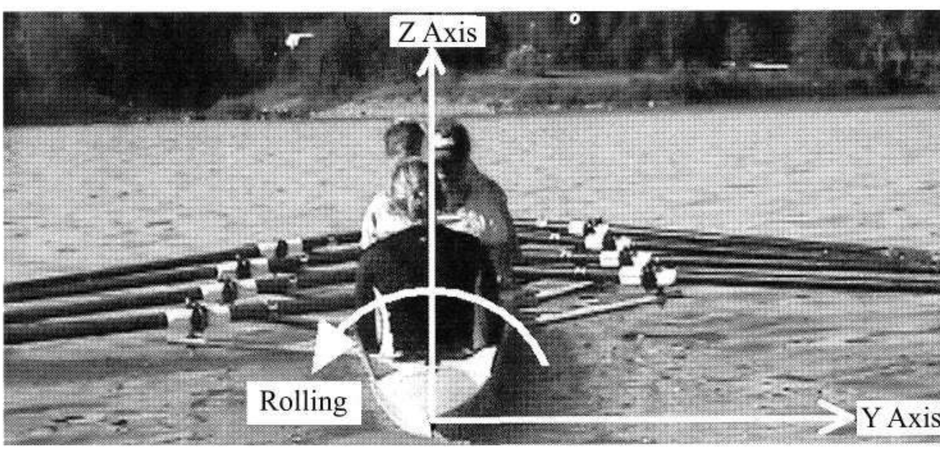


Figure 1.
Picture of best view (Y-Z plane) to see the rotation around X-axis. The X-axis points perpendicularly into the picture and one can easily see how the boat could roll to the left (port side) or right (starboard side).

In the study presented here, we used a very simple measurement method that was developed by McLaughlin (2004). The method does not interfere at all with the motion of the athletes and adds literally no weight to the boat. In addition, pilot studies with the Silva level (see Fig. 2) showed that the indicators work freely and fast enough (without delay) to use for data collection. For our tests, a single Silva level was attached on the stern deck of the boats. The level was calibrated on land using spirit levels. The 0 deg position was set when the boat and with it the footstretchers and the seats were leveled. The stern of the boat was then filmed with a video camera (For the trials with the Novice 8+, the Club 4+ and the W8+: Panasonic PV-704-K Camcorder, manual focus, 1/500s shutter speed; For the trials with the M8+: Sony DCR-TRV33 Digital Handycam; automatic focus) from a motorboat that followed directly behind the rowing shell. The camera's field of view focused on the level, and it was possible to see the stroke person's hands and handle to identify the frame of the catch position.

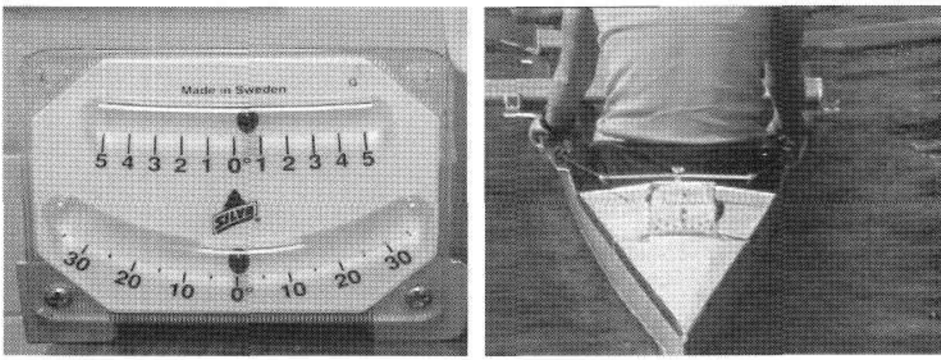


Figure 2.
(a) Silva Level used in measuring the balance along the X-axis of the boat. (b) Picture captured from video taken of the level on the stern deck of the boat for collecting balance data.

The value read from the level was rounded to the closest 0.5 degree. The numbers on the left side of the level were taken as positive (meaning the boat was rolling to port side) and the numbers on the right recorded as negative (boat rolling to starboard side). In addition, the frame numbers were noted down for the video picture where the rower reached the catch position. This information was used to identify the time of each catch.

Four different crews were studied regarding their performance of balancing their shells:

- Novice 8+ – a women's eight with coxswain (Abbreviation: 8+) of the University of Western Ontario novice program in their third week of learning (October 2003).
- Club 4– – a men's heavyweight four (Abbreviation: 4-) from the Western Middlesex Rowing Club (June 2003).
- W8+ – The Canadian National Team Women's eight (June and August 2003).
- M8+ – The Canadian National Team Men's eight (May 2004).

At the time of the study, no Club eights crew was available for testing. To include this experience level of athletes, a four crew was studied. All crews where observed during their normal training routines.

The crew 'W8+' was first examined in June 2004, shortly after their formation following their internal selection. The crew and their coach were informed about the results of this test. They then used the balance level in their training. The coach watched the indicator and gave the crew feedback during their technique training. The crew was then examined a second time in August. After having rowed together for almost three months, including several races on the World-Cup circuit.

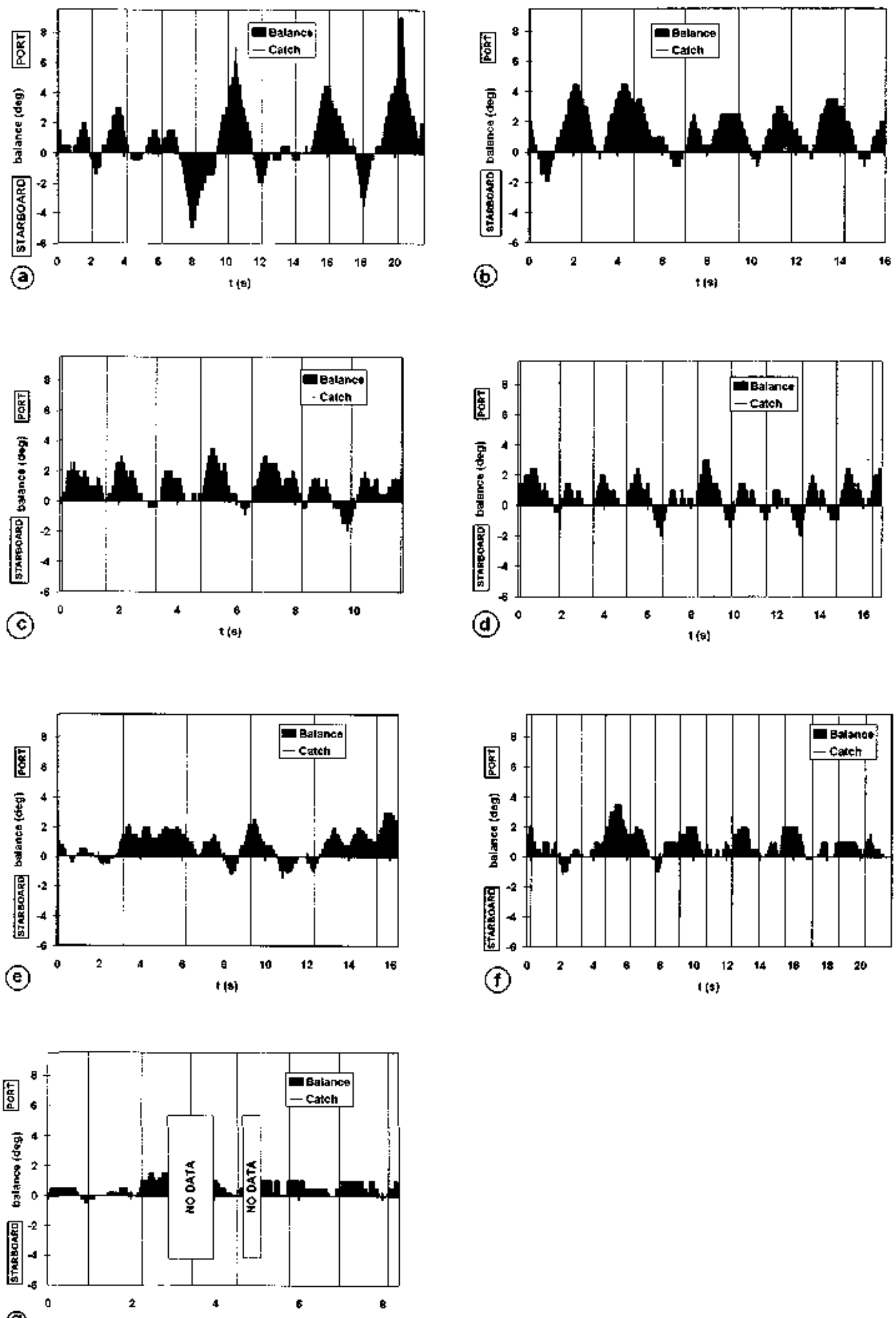
The crew 'M8+' was videotaped shortly after their internal selection while performing at different stroke rates. No feedback was given between the different training pieces.

This study was a pilot study with limited access to the different crews and the results can only show tendencies. While most of the boats are eights, the four was included as an example of a club level crew, as an intermediate experience level between the novice and elite crews. This study was intended to determine the feasibility of the measurement method and to produce some preliminary data.

3. RESULTS

From the balance data collected, graphs (Fig. 3 a-g) were plotted for all crews that show the angle of the boat in the Y-Z-plane (or 'balance' along the X-axis) over time. In addition, vertical lines indicate the catch position at the time of occurrence.

Fig. 3:
Balance Data of different crews. Note: Vertical Lines mark beginning of each stroke (=catch).



a) Novice 8+
b) Club 4-
c) National Team Women 8+ – June
d) National Team Women 8+ – August
e) National Team Men 8+ – Stroke rate 20 (1/min)
f) National Team Men 8+ – Stroke rate 38 (1/min)
g) National Team Men 8+ – Stroke rate 50 (1/min)

For each of the trials, the mean balance angle was calculated over the collected data. This data shows around which average balance position the boat seemed to roll predominantly and it will be called 'relative mean' for this reason. The absolute mean was also processed. The mean of all absolute values of data points gives an indication how much the boat rolled, independent of direction or side. The standard deviations for both of these measurements were calculated as well, which gives an indication how unsettled the boat was. All means and standard deviations for the balance data can be found in Table 1, as well as Figures 4 and 5.

Table 1
Relative and Absolute Means and Standard Deviations for Balance Data

Crew	Stroke Rate (1/min)	Mean (degrees)		Standard Deviations (degrees)	
		Relative	Absolute	Relative	Absolute
Novice 8+	29.8	0.87	1.73	2.22	1.63
Club 4-	25.4	1.50	1.75	1.52	1.22
W8+ (June)	36.2	0.94	1.24	1.14	0.81
W8+ (Aug)	36.6	0.64	0.99	1.05	0.74
M8+ (SR: 20)	19.6	0.80	1.05	1.00	0.73
M8+ (SR: 38)	38.4	0.81	0.86	0.73	0.67
M8+ (SR: 50)	50.2	0.52	0.55	0.45	0.42

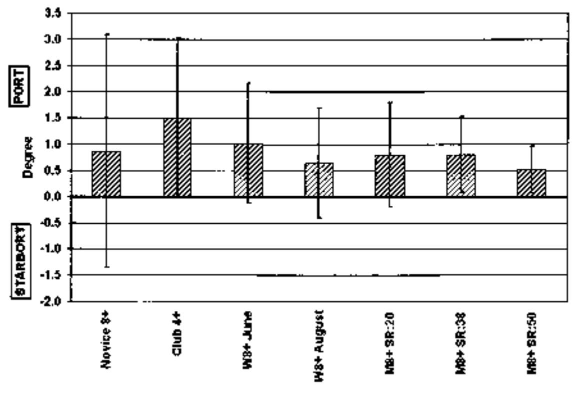


Figure 4
Relative Means with Standard Deviation Error Bars for Balance Data.

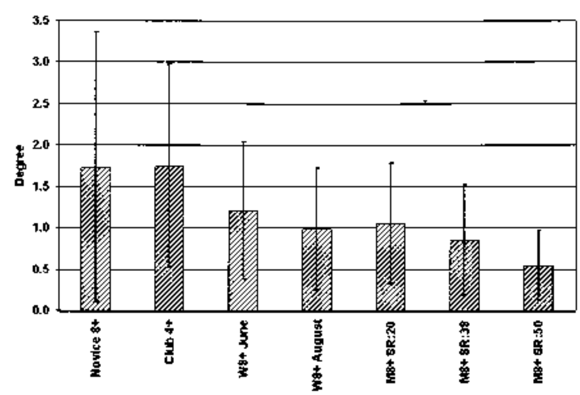


Figure 5
Absolute Means with Standard Deviation Error Bars for Balance Data.

4. DISCUSSION

The purpose of this study was to evaluate the feasibility of the measurement tool in normal rowing training and to compare different crews regarding their performance of balancing their boat. The results of this study are the first to analyze the rolling behaviour of crew boats and to quantify the movement of rowing shells around the X-axis. Since the measurement did not interfere in any way with the crew, the results can be viewed as representative of normal performances. Although the number of crews studied is very small, some tendencies can be pointed out.

To put the measured rolling angles in perspective, one must realize that if a sweep boat is 1 deg out of balance, the rowers on one side of the boat carry the hands at the end of the oars about 5 cm higher than the rowers on the other side. At a rolling angle of 2 deg, the difference is already 9 cm. These are significant differences to the optimal height the rowers carry their hands in a balanced boat. Coaches and athletes spend considerable time to rig the height of the oarlocks properly, and differences are measured in millimeters.

In addition, the rowers sit on seats that are connected with the boat. This means, any rolling of the boat is directly transferred to the seats. The rowers then shift their body through movements in the lower back to regain balance. This can lead to extended loads in the spine, which can lead to back injuries, especially when rowers apply force on the oar in the moment the boat is out of balance. A rolling boat can therefore lead to injuries.

The absolute mean (Fig. 5) as a measure of the overall rolling of the boat shows that balance improves with the experience of the crews. The mean values for the Novices and Club rowers are very similar, but the standard deviation of the Novice crew is much larger. The National Team women and men showed very similar values for balance and were both considerably better balanced than the Club or Novice crews.

The novice crew demonstrated the largest rolling movements around a comparatively low relative mean value (see Fig. 4 and Table 1). This indicates that the boat rolled quite symmetrically around the 0 deg position, but with large amplitudes. The Novices had a 46 % higher standard deviation in their relative rolling around their mean position. The Club crew had their boat rolling with 33 % larger amplitudes than the next best National Team crew.

At one point the novice crew was 9 deg off balance. At about 10 deg roll angle, the rigger of the boat would touch the water and the rowers on the particular side of the boat could not continue to move their oars. The handle of their oars would get stuck on the gunwale. Thus the Novice boat was rolling close to the maximum possible, as the crew was not able to control the boat effectively, rolling it with large amplitudes to both sides. Nevertheless, all crews showed some degree of rolling movements during rowing.

The National Team women's crew improved their balance with training. Two months of working on team unity, as well as receiving feedback about their balance produced an improvement of 20% in absolute rolling and although the swinging only advanced by 8%, the relative mean progressed by 32%.

The National Team men's crew kept their boat more balanced while increasing the stroke rate. At a stroke rate of 19.6 min^{-1}, the men displayed similar values to the women's crew the year before. However, balance increased dramatically with higher stroke rates. A similar effect can be observed on a bicycle, which is easier to balance at higher velocity, although one can only speculate about the reasons for this phenomenon in rowing.

These findings support modern learning theories. Beginner crews have a large problem with balance and need to experience this environment to learn coordinating their movements and incorporating balance accordingly. Even an experienced crew can improve when provided with proper information about their performance. A very interesting discovery was that the mean of the relative balance data for all crews was positive. This shows that all boats were "sitting on port side" (as rowers would say), meaning the boats were generally tilted to port side and rolled around this uneven position. Since all boats in this study had their stroke rower on port side, it could be that this seating order had an influence on the balance. The stroke rower is the person who sets the pace and controls the rhythm. Therefore, all rowers behind the stroke try to follow and match this person's cadence and try to equal the exerted power. It is then possible that as a result of watching and focusing on the stroke rower and their blade, the rest of the crew turn their heads to port side and shift their weight slightly to this side. This hypothesis was not examined in this study.

In summary, measuring balance in this simple way can provide interesting data not only for coaches, but also for researchers. The coach of the Canadian Women's National Team eight has already used this method. Though, it is an interesting question as to how much influence balance has on the overall performance of a crew. Although only a limited number of crews were analyzed, it seems clear that there are rolling movements in all boats. Using balance as a collective variable may be of value in determining how boats are rigged (the physical adjustment of boat parts to individual needs) and how rowing is taught.

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