Comparative Analysis of Rigging Set-Up and Success Amongst Single Scullers at the 2016, 2017 and 2018 FISA World Championships (Rowing)

Lewis, Z.R.[1] & Purcer, M.[2]
[1]Brock University, St. Catharines, Ontario
[2]Master Coach Developer, Purcerverance

Abstract

The aim of this study was to examine the relationship between multiple components of the drive portion of the rowing stroke, directly affected by rigging set-up, and rowing performance. One-hundred and forty-two (*m*=70, *f*=72) world class single scullers were selected for analysis from the Senior, Under-23 and Junior categories. Subjects' blade slip and drive time were measured and their stroke ratios and stroke arc placement were calculated accordingly. Rowing performance was assessed using finish position from the A and B finals of the 2016, 2017 and 2018 FISA World Championship regattas. While rigging itself is not a primary determinant of rowing performance, results of the current study indicate that there is a correlation between finish position and both drive time and blade slip. Rowers who are rigged to maximize individual positive blade slip and minimize drive time achieve greater amounts of success.

Keywords: kinematics, blade slip, drive time, rigging, rowing performance

Introduction

Rowing as a sport, is a demanding physical and psychological ordeal. The Fédération Internationale des Sociétés d'Aviron (FISA) format, 2000m races, are remarkable physiological events that require competitors to utilize all anaerobic and aerobic reserves and leave competitors totally exhausted and gasping for air. Time required to complete a set distance is rowing's ultimate measure of performance (Sanderson and Martindale, 1986; Lazauskas, 1997), consequently a high mean velocity is imperative. This study examines the efficiency of the oar blade movement in the water relative to the performance at World Rowing Championships Regattas. Video analysis of the blade movement using methods identified by Purcer (2016) to determine rigging efficiency is compared to athlete performance.

Although races may cover 2km in distance, the winning crew is often decided by fractions of a second. At the Rio Olympic Games in 2016, twelve-out-of-fourteen races were decided by less than two seconds and the mean time difference between the top two boats in every category was 1.3s. With races regularly decided by such small margins the understanding of the effects of physical, biomechanical and mechanical factors of rowing performance is integral for success.

Sanderson and Martindale (1986) stated that rowing performance is affected by three factors. The first factor affecting performance is the power generated by the rower. While the power output produce by rowers varies by age and weight class, Smith and Spinks (1995) were able to differentiate between rowers of different abilities based on propulsive power output per kilogram of body mass, suggesting that power output increases with training and experience. The second factor affecting performance is the power required to move the boat against drag forces. The possibilities for lowering this amount of required power are limited by FISA's boat design regulations. Seiler (2006) notes that, after centuries of competitive rowing, the only substantial change in boat design has been gradual reduction of weight, with minimal changes in measurement. The third factor hypothesized to affect rowing performance is the efficiency of power utilization, which can be directly affected by technique or rigging of the boat.

Variables in rigging set-up have been around since the early days of rowing but it was not until the 1960's that boat builders provided coaches with the ability to change rigging dimensions easily (Purcer, 2014). Since that time coaches have sought to adjust the dimensions of rigging to maximize the performance of their crews. As performance is based on so many factors, rigging efficiency is often lost as an aspect because it is difficult to measure. This paper provides a link between performance and rigging efficiency with the analysis of the dimensions of blade slip, drive time and stroke arc placement.

Methods

Participants and Protocol

One-hundred and forty-two (70 males, 72 females) were investigated in this study. All participants were experiences rowers and were selected by their respective national rowing federations to represent their country at either the Senior, Senior B (Under-23) or Junior (U19) categories of competition. Video recordings of the single scull (1x) finals[1] for the top twelve athletes in each category from the 2016 World Rowing Championships (Rotterdam, Netherlands), 2017 World Championships (Sarasota, USA), 2018 World Rowing Championships Plovdiv, Bulgaria), taken from approximately the 1200m mark of the race were used to analyze oar blade movement in the water. This location was selected as the majority of athletes would be at race pace and not yet commencing their finishing sprint. A location within the first or last 500m was not desirable for analysis, as these quarters of the race are often executed as a speed quicker than the crew's average race pace (Kleshnev, 2001; Secher, Espersen, Binkhorst, Andersen, & Rube, 1982). The 1200m location also provided a point in the race where competitors would be separated to provide an unobstructed camera view across the course in order to video athletes in the far lanes. The single sculls events were selected due to the number of events within the regatta and the ease of analyzing only one blade per boat.

The rowing stroke consists of a cyclic series of events that includes: the entry (or catch), the drive phase, the release (or finish) and the recovery. The entry occurs as the blade of the oar enters the water just after it approaches the bow of the boat. The act of the submerged blade pulling through the water toward the stern of the boat is known at the drive phase. The release occurs at the end of the drive as the blade is lifted from the water and is followed by the recovery as the blade arcs through the air from the stern to the bow of the boat. The current investigation focuses primarily on components of the drive phase where the results of rigging changes are most readily observed by coaches and felt by athletes alike.

Equipment and data processing

Rowing kinematics were examined from video footage taken of each rower while competing at the aforementioned regatta. The footage was captured from the sideline using a JVC video camera Everio 1080p (GZ-R30 BU) (Japan) positioned directly perpendicular to the direction of the race course on the rowers' port, right hand, side. Video was recorded at the 1200m point during their respective races. Digital copies of these recordings were then examined using video analysis software Dartfish Team-Pro (version 8.0, Switzerland).

Kinematic measurements and determination of variables

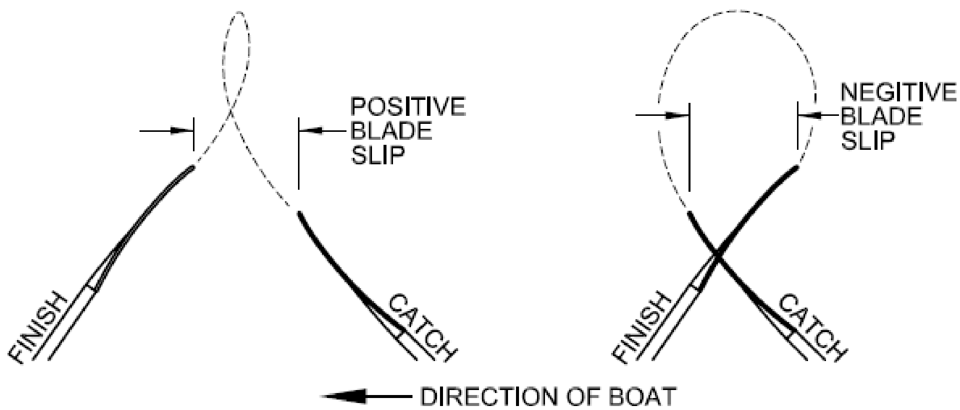
Kinematic measurements for three dimensions were analyzed for each of the top twelve scullers in the twelve races selected for analysis. Blade slip and drive time were measured as outlined by Purcer (2016) in the Analyze Performance - Rigging section of the RCA Performance Coach manual. In addition, an estimate of the stroke arc placement was captured as a third measure of effective rigging.

Blade slip is the distance the tip of the blade travels in the water parallel to the boat during the drive phase of the stroke (Purcer, 2016). This distance can be in the positive direction

[1] Note: Semi-final races were used to analyze the top twelve finalists for Sr. B categories as video of the final races was not available.

meaning the tip of the blade moves in the same direction as the boat or the negative direction moving opposite to the movement of the boat. Figure 1 is a graphic representation of both positive and negative blade slip.

Figure 1. Blade Slip. Positive (toward bow) and negative (towards stern).



Blade slip is a measurement of effective rigging and assesses the connection and interaction the blade has with the water. Positive blade slip indicates that the stroke arc position, length and the force on the surface of the blade balance with the athlete's applied power, stroke position and stroke length. Negative blade slip (although common in sweep rowing) is a result of shorter or improperly stroke position and/or a rigging setup that allows the athlete to apply grater force on the blade than required to move the boat at speed. The blade slip distance, positive or negative is a diagnostic dimension of effective rigging and good rowing technique.

Drive Time is the length of time the blade is in the drive phase of the stroke. The time is measured from the catch, the instant the blade becomes fully buried to the point at the finish when the blade has released from the water and is feathered (Purcer, 2014). The length of the drive phase of each stroke has been shown to directly relate to shell velocity (Soper & Hume, 2004) and shorter drive times directly correlated to increased boat efficiency (Kleshnev, 1999).

Stroke arc placement is the geometric location between the catch and finish angles of the oar during the stroke. The approximate placement of the stroke arc in the water relative to the boat was measured to compare with athlete performance as criteria of effective rigging. The measurement was taken as a function of time for a relative comparison between boats and it is understood not a reflection of the oar stroke angles as the boat accelerates during the drive phase. The drive phase was divided into two categories: drive before the pin (identified as oars being perpendicular with the shell) and the total drive phase. Placement percentage of blade before the pin was calculated and refers to the percentage of the drive sequence that the rower's oar was in the water before reaching a perpendicular position with the shell. This percentage provides a competitive measurement for the stroke arc location relative to the boat.

Stroke ratio was also calculated for the current investigation. Stroke ratio is a measure of the recovery time to the time the blades are in the drive phase of the stroke cycle (Herberger, 1974) and it is considered essential to "balance a crew's length of stroke and load ratio (time in water) with the needed recovery time (rest) on the slide" (Purcer, 2014, p.292). Purcer (2014) also notes that excessively high or low stroke ratios are inefficient and may suggest inadequate load, length or stroke positions of a crew. The following equation was used to calculate stroke ratio:

$$Stroke\ Ratio\ = \frac{\frac{60}{Rate\ -\ D_t}}{D_t}$$

where rate is the number of stroke taken per minute by a crew and drive time is D_t.

Statistical Analysis

Data collected through measurements and calculation for this study was grouped related to the performance (finish position) of the athletes in each category. Results of the twelve data points related to the top twelve finish positions was grouped and Table A shows the mean values for each of the analysis categories.

Blade slip and drive time data of the top twelve finishers in each category was analyzed to provide mean and standard deviation values. Additionally, mean values for stroke rate, stroke ratio, stroke arc placement (before the pin) mean values were calculated for the competitors in the twelve races. Results of the data analysis are presented in Table A.

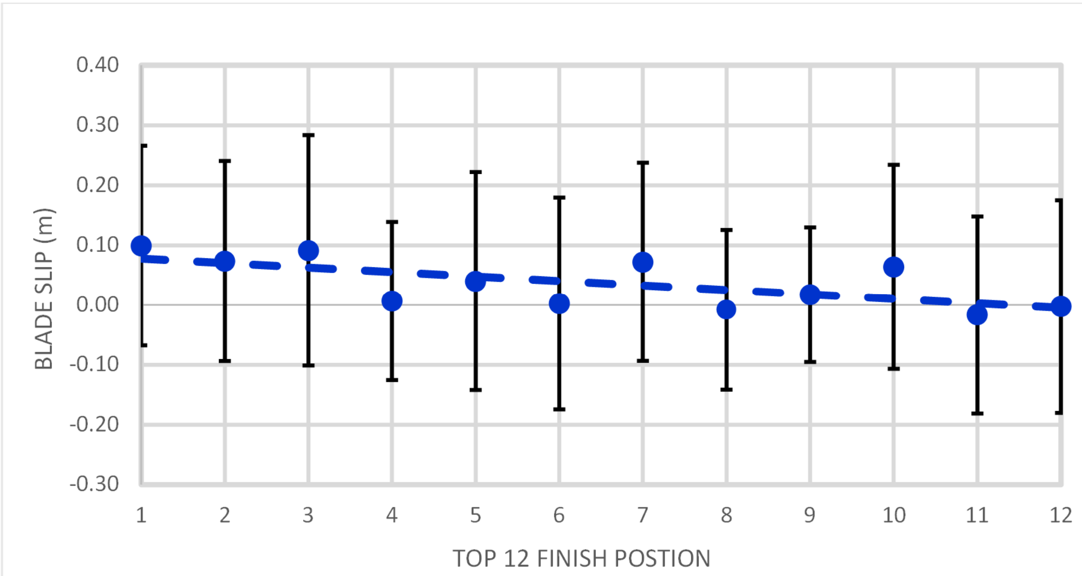
Results

Table A: Combined Measurements - Based on Performance Finish Position

Finish Place	Blade Slip (m)	Blade Slip (ST DEV)	Drive Time (SEC)	DRIVE TIME (ST DEV)	Stroke Rate (spm)	Ratio	Stroke Arc (BEFORE PIN)
1	0.10	0.19	0.82	0.09	32.5	1.25	67%
2	0.03	0.18	0.81	0.07	32.3	1.30	66%
3	0.04	0.09	0.82	0.07	32.4	1.26	69%
4	0.01	0.14	0.83	0.06	32.4	1.23	64%
5	0.07	0.21	0.84	0.08	32.0	1.25	67%
6	0.01	0.17	0.84	0.07	31.4	1.28	63%
7	0.06	0.17	0.86	0.06	30.6	1.28	66%
8	-0.04	0.12	0.84	0.14	31.6	1.25	65%
9	-0.02	0.12	0.84	0.05	31.7	1.26	67%
10	0.09	0.16	0.88	0.07	31.5	1.16	67%
11	-0.09	0.13	0.85	0.07	31.3	1.27	64%
12	-0.04	0.20	0.85	0.11	31.1	1.26	64%

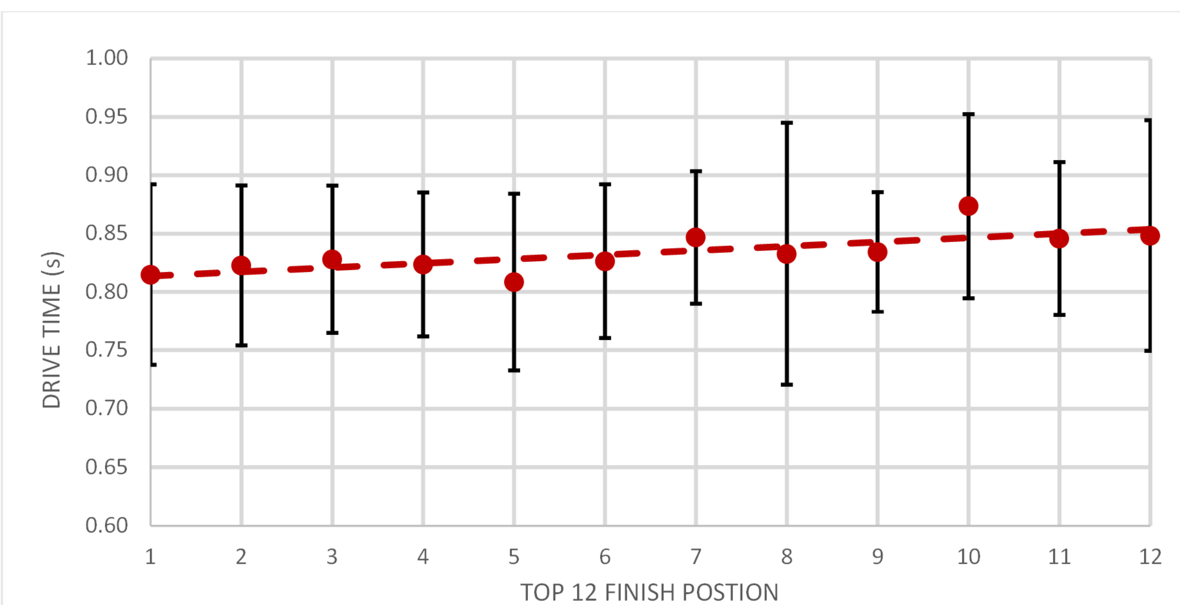
Blade slip data for the top twelve finish positions in each of the twelve races provided an analysis for comparison related to performance. The mean and standard deviation values of the twelve athletes in each of the categories is shown in Figure 2. The graphic shows the average value for the top twelve finishers in each of the twelve categories. The 142 data points provide limited examination; however, the data appears to show a trend based on the finish position. The trend line shows a relationship between finish position (performance) and blade slip indicating that better performance correlates with a higher positive blade slip.

Figure 2: Combined mean blade slip for all races analyzed relative to finish placing.



Drive time data was collected similar to blade slip and Figure 3 displays the mean and standard deviation for the twelve finishers in positions one to twelve. The data supports Kleshnev (1999) that correlates increased efficiency with drive time. The trend line shown on Figure 3 shows that lower drive times correlate with higher performance.

Figure 3: Combined mean drive time for all races analyzed relative to finish placing.



Discussion

The primary aim of this study was to examine the relationship between measurements of effective rigging and performance. Each individual athlete possesses a power and stroke length that through effective rigging can maximize boat speed as a function of performance. Effective rigging is a result of the factors of proper rigging load and stroke arc length and arc placement relative to the boat and to the athlete. Kinesthetic analysis of blade slip, drive time and stroke arc placement provide insight to effective rigging and although there are many factors that contribute to the performance rigging setup provides an opportunity for efficiency to maximize success.

It is understood that there are many factors of performance and rigging is only a small part. Rigging adjustments provide coaches an opportunity to change the load, length of arc and placement of the stroke. Coaches have long sought a method of determining the ideal dimensions to maximize performance of their crews. The analysis of blade slip, drive time and stoke arc placement provide a tool for coaches to measure and determine effective rigging. Through the kinesthetic analysis of rigging, coaches will be able to fine tune and adjust load and length dimensions to maximize crew performance.

The current study concludes that there is a strong relationships between some aspects of rigging and performance at the highest level. The findings indicate a direction correlation between both drive time and blade slip on how athletes placed while rowing at World Championships events. Drive time is negatively related to placing whereby the faster an athlete gets their blade through the water on every stoke the more likely they are to place better. Additionally, blade slip was positively related to overall placing. This indicates that as the athlete's boat travelled relative to their entry point of their oar each stroke, they were more likely to be successful relative to the competition.

Both blade slip and drive time can be altered by changing an athletes rigging either during training or prior to competition. With so many athletes on the world stage competing at such similar physiological abilities, particularly in the lightweight categories, this study highlights the importance and reinforces the role effective rigging can play on a crew's success.

Effective rigging is influenced by the athlete's applied power, length of reach (work distance), stroke rate, athlete's skill (bladework), and the environmental conditions of wind and water which effect the speed of the boat. Experienced athletes and certainly crews competing at the World Championships should be analyzed. Effective rigging provides the greatest boat movement in the least amount of time during the drive phase of the stroke.

An athlete's ability to apply force is relative to the speed of contraction of the muscle. Higher muscle contractile speeds limit the athlete's ability to apply force. Drive time at practice intensities 60 to 80 percent of race intensity and speeds with rates between 18 and 26 storks per minute relate to substantially slower contraction rates. At race rate and speed the stroke drive time is substantially faster and the amount of force applied to the oar handle and subsequently to the face of the blade is relative to boat speed. The important aspect to this is that rigging analysis is specific to the athlete and the boat speed.

Environmental factors such as wind and water conditions can affect the boat speed and therefore effect the results of the rigging analysis. Boat speeds affect the drive time and therefore athletes rowing into a head wind with reduced boat speed could experience reduced blade slip measurements.

The analysis of the stroke arc position suggests that the majority of athletes' rowing at this level have two thirds of their stroke (measured by time) before the pin (perpendicular). At this level of rowing most coaches are highly qualified to assess rigging and there are certainly a variety of tools available. The importance of stroke position cannot be overstated as an element of effective rigging. The catch angle and stroke arc length are important dimensions for coaches to measure and adjust to maximize effective rigging.

An analysis of stroke ratio reveals that although the average stroke ratio for competitors by finish placing is between 1.20 and 1.25 there are stroke ratios as high as 1.85 and low as 0.96. Stroke ratio is an important aspect as it allows the athletes a recovery period between the drive phase of each stroke.

A review of the stroke rate similar to stroke ratio provided additional insight to athlete performance. Stroke rate is related to drive time and stroke ratio and athletes able to row with lower drive times.

It is also agreed that athletes are able to be successful at the highest level with rigging that is less than efficient. One example is Zoe McBride of New Zealand winning the Lightweight Women's Single at the 2017 World Rowing Championships. Zoe's blade slip measured at negative 0.17 meters, over 0.20m less than the average for other athletes in the race. Zoe rowed the final race at a higher stroke rate than other athletes and had a significantly lower drive time (0.67 sec) about a tenth (0.10) of a second lower than the average of the other competitors in her race. The assessment of Zoe's rigging from the low drive time and sternward arc position suggests a 'light' rigging load. The light load along with the position of the stroke could account for the negative blade slip. Finally, although the rigging appears to be less than efficient based on blade slip and stroke position, Zoe was able to race with a very low drive time and higher rate and win the race.

Going forward coaches and athletes alike should pay considerable attention to their respective rigging to ensure best possible results. Modern technology has evolved to allow simple and efficient rigging analysis by a camera with video analysis software capable of tracking time and measuring distance on the video. Cell phones or tablets with video analysis software are capable of a simple review of blade slip, drive time and stroke position. It should be noted that camera placement must be perpendicular to the path of the shell when capturing the blade movement to maximize the accuracy of the analysis. Additionally, capturing the blade in the center of the frame is equally important to provide accurate measurements.

Conclusion

Consistent with Barrett and Manning's (2004) findings, the current study concludes that rowing performance is maximized when rigging is specifically tuned to match the athlete's size and strength. The findings of the current investigation unsurprisingly suggest that rowers who are rigged to maximize blade slip and minimize drive time, were more likely to achieve success. Furthermore, this study identifies the dimensions of blade slip, drive time and stroke arc placement as a measure of rigging efficiency. The aim of this study was to examine the relationship between multiple components of the drive portion of the rowing stroke, directly affected by rigging set-up, and rowing performance.

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