TOPICS IN EXERCISE SCIENCE AND KINESIOLOGY

Rowing Ergometer Kinematics of Collegiate Female Rowers

Process of Science

Christina LeMunyon, Drake University, Des Moines, Iowa, USA; Biology Department.
Kevin Carlson, Drake University, Des Moines, Iowa, USA; Biology Department.

Abstract

- The purpose was to quantify rowing kinematics of female rowers and compare how rowing mechanics concurred with the rowing style taught by the coaching staff.
- Rowing kinematics at various paces were captured using Xsens motion capture hardware and processing software.
- **Point of application 1:** Lack of knee extension at the end of the drive phase limited the knee range of motion and time for force development.
- **Point of application 2:** Elbow flexion and hip extension occurred too early in the stroke leading to poor skeletal segmental interactions.
- **Point of application 3:** It was determined that the rowers examined in this study did not use the Rosenberg style fully.
- **Key Words:** ergometer, coaching, wearable devices/technology

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Introduction

Not unlike many technique dependent motor skills, the teaching and execution of the rowing stroke have differing approaches. The science and art of coaching requires the ability to discern mechanical differences of technique and how best to teach the athlete its respective implementation. The rowing stroke consists of a sequence of events defined as the: catch, drive, finish, and recovery. While all components of rowing mechanics are important, the drive phase is considered the most important phase. The drive phase is analyzed to determine how the boat is accelerated through the water or how the seat is driven backwards on the ergometer. Regardless if rowing takes place on the water or on an ergometer, there are two lines of thought relative to the initiation and subsequent joint actions of the drive phase. The first approach presents that knee extension should initiate the drive phase and is the main source of power generation (Rosenberg style). One contrasting viewpoint suggests that synchronous efforts between the legs and trunk should initiate the drive phase (German Democratic Republic-DDR style). Our goal was to describe drive phase kinematics and how they comply with what is taught by the coaching staff, which is the Rosenburg style. Gaining an understanding in the kinematics may help to provide insight into skill acquisition by the athletes. The avatar and data created via motion capture software could also be used as a teaching tool.

Methods and Results

Subjects (Mean age = 20; Mean body mass = 57kg; Mean height = 167cm) were identified by the coaching staff as athletes who were struggling with the instructed Rosenburg rowing style. Full-body (17 sensors) inertial motion capture was measured using an Xsens system (Xsens Awinda, Xsens Technologies BV, Enschede, Netherlands) sampled at 60 Hz, processed and analyzed by the matching software Xsens MVN Analyze 2018 (Xsens Awinda, Xsens Technologies BV, Enschede, Netherlands). Rowing was performed at stroke rates of 22, 24, 26, 28, and 30 strokes per minute (spm). Stroke rates were verified using the PM5 Monitor on the Concept 2 Model D rowing ergometer. Varying stroke rates were used to determine if changes in kinematics occurred across rates. Administration of stroke rates was done in an ascending order with no rest between rates. Each stroke rate was maintained for 3 minutes with the middle 30 seconds having motion capture completed. This time frame accounted from approximately ½ of the number of strokes for each administered stroke rate. For example, rowing at 22 strokes per minute allowed us to analyze 11 strokes. Data from each stroke was gleaned from the motion capture software and averaged across all of the strokes to determine a mean value. Each subject spent approximately 16-18 minutes rowing on the ergometer, including the warm-up. These stroke rates were consistent with the stroke rates maintained during training and competition. Instantaneous, bilateral joint angles for the hip and elbow when the knee reached maximum knee extension during the drive phase were examined. The drive phase initiated at the maximum knee flexion angle at the conclusion of the recovery and terminated at maximum knee extension. Data was compared to the stroke mechanics as instructed by the Rosenberg style. Subjects did not reach full knee extension during the drive phase, which indicates their knees remained flexed at the end of the drive phase, contrary to the Rosenburg style. In addition, at the point of maximum knee extension, the elbows were already in a flexed position, contrary to the Rosenberg style. Increasing stroke rate led to an increase in premature elbow flexion relative to when full knee extension was achieved. For the hip and knee joint actions, bilateral (L-R) symmetry was observed.

1. Point of application

Neither subject reached full knee extension during the rowing cycle, which indicates their knees remained flexed at the end of the drive phase. This limits the knee extension range of motion and the time in which skeletal muscle forces and positive work can be generated. For example, subject 1 had a knee flexion angle of 9.01° for the right and 10.30° for the left while rowing at 22 strokes per minute, whereas subject 2 had a minimum right knee angle of 7.78° and a left angle of 10.54° at 22 strokes per minute. **Knee flexion values at the end of the drive phase continued to increase as the rate of rowing increased (the knee became more flexed at the end of the drive phase). This continued to limit the range of motion and the time through which musculoskeletal force and positive work could be generated as described by the Rosenberg**

Subject 1	RIGHT JOINT ANGLES (M±SD)			LEFT JOINT ANGLES (M±SD)		
Stroke Rate	Knee (Flexion)	Hip (Flexion)	Elbow (Flexion)	Knee (Flexion)	Hip (Flexion)	Elbow (Flexion)
22 spm	9.01° (0.42)	6.31° (2.06)	65.09° (10.26)	10.30° (0.48)	5.74° (2.18)	81.16° (12.41)
24	12.29 (1.63)	11.75 (0.29)	50.66 (7.30)	10.07 (0.89)	9.31 (0.34)	61.08 (11.35)
26	15.89 (1.03)	12.50 (2.07)	49.85 (9.67)	13.27 (0.44)	10.67 (2.11)	64.39 (13.95)
28	17.26 (0.79)	13.56 (1.12)	45.47 (7.79)	15.69 (1.18)	11.86 (1.83)	53.73 (5.42)
30	19.34 (0.54)	15.26 (0.84)	54.22 (2.72)	14.17 (0.41)	12.54 (1.84)	55.59 (2.26)
Subject 2	RIGHT JOINT ANGLES (M±SD)			LEFT JOINT ANGLES (M±SD)		
Stroke Rate	Knee (Flexion)	Hip (Flexion)	Elbow (Flexion)	Knee (Flexion)	Hip (Flexion)	Elbow (Flexion)
22 spm	7.78° (0.24)	24.25° (0.63)	76.03° (12.78)	10.54° (0.36)	24.89° (1.04)	71.56° (13.99)
24	9.71 (1.06)	27.32 (0.77)	79.53 (5.55)	12.69 (0.34)	27.76 (1.28)	72.01 (4.87)
26	14.19 (1.47)	39.31 (3.02)	63.11 (5.45)	16.49 (1.31)	40.15 (2.95)	48.23 (7.25)
28	14.23 (0.44)	42.57 (3.70)	58.64 (11.95)	18.68 (0.66)	44.25 (3.42)	39.68 (16.03)
30	15.66 (3.28)	47.29 (2.16)	57.50 (4.81)	21.71 (3.02)	52.01 (2.91)	34.36 (7.09)

Table 1. Average joint angle (deg) of the hip and elbow at greatest knee extension during the drive phase.

2. Point of application

Regardless of which body segment begins the drive phase, the elbows should remain at or near full extension until the knees and trunk have completed their respective ranges of motion. Subjects were early in their initiation of elbow flexion, as the knee had yet to reach full extension before the elbows were beginning to flex (see Table 2). **This movement pattern would diminish the ability to transfer energy from one joint/segment to the next as appropriately described by Knudson's "Segmental Interaction Principle".** The **Hip** showed a position of flexion for both subjects when maximum knee extension was reached (see Table 1). If the Rosenberg style were implemented, then one would expect the hip to not have reached its most extended position when the knee reached its maximum extension.

Subject 1	RIGHT KNEE (M±SD)	LEFT KNEE (M±SD)
Stroke Rate	Flexion	Flexion
22 spm	42.61° (1.61)	43.40° (2.57)
24	45.86 (3.46)	46.32 (1.59)
26	49.82 (1.93)	49.04 (2.46)
28	53.00 (7.47)	50.74 (9.30)
30	55.37 (5.18)	54.23 (5.03)
Subject 2	RIGHT KNEE (M±SD)	LEFT KNEE (M±SD)
Stroke Rate	Flexion	Flexion
22 spm	63.21 ° (13.48)	64.33° (13.46)
24	58.94 (20.55)	61.23 (20.02)
26	74.43 (9.06)	80.32 (6.66)
28	79.20 (5.74)	83.49 (5.94)
30	63.97 (8.32)	68.27(6.95)

Table 2: Right and left knee joint angle (deg) when the elbow begins to flex during the drive phase.

3. Point of application

The Drake University rowing team coaching staff subscribes to the Rosenberg style of rowing technique and instruction. The Rosenberg style, named after Allen Rosenberg, is the most traditional style and inherits technique introduced in the early 20th century. This style is characterized by large forward declination of the trunk at the beginning of the stroke, then strong leg extension without significant trunk activation. It was determined that the rowers examined in this study did not use the Rosenberg style relative to knee motion as the knee did not reach full extension and elbow flexion was begun prematurely relative to knee position (Table 3). The coaching staff and athletes were able to utilize the motion capture avatar that is generated via Xsens software and numerical data to provide visual feedback to the student-athlete. This information may also allow the coaching staff to explore the utilization of different coaching cues to reinforce athlete learning. Due to short time of the drive phase (<1 s) and the fast movement of big muscle groups, rowers cannot change movement pattern during the drive. They can only evaluate their movement after completion of each stroke and make corrections for the next one. Inertial motion capture is a relatively quick and user-friendly tool to assist with

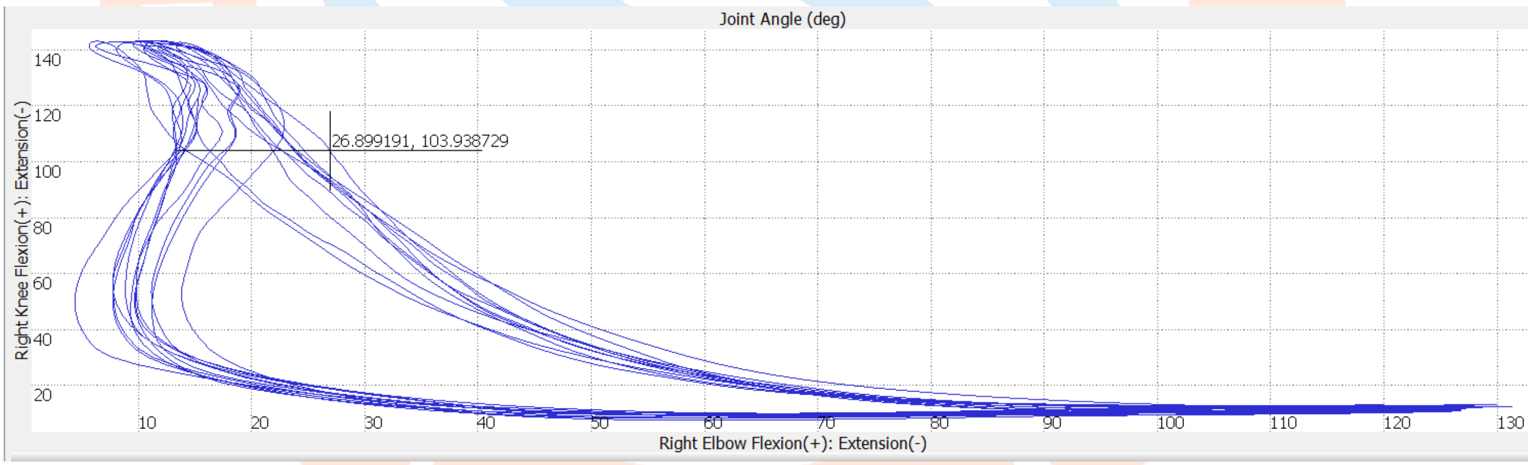

Figure 1: Coordination plot (Angle-Angle diagram) showing right elbow flexion/extension vs. right knee flexion/extension.

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Equipment Utilized

- Concept 2 Model D rowing ergometer
- Xsens inertial measurement units (IMUs)