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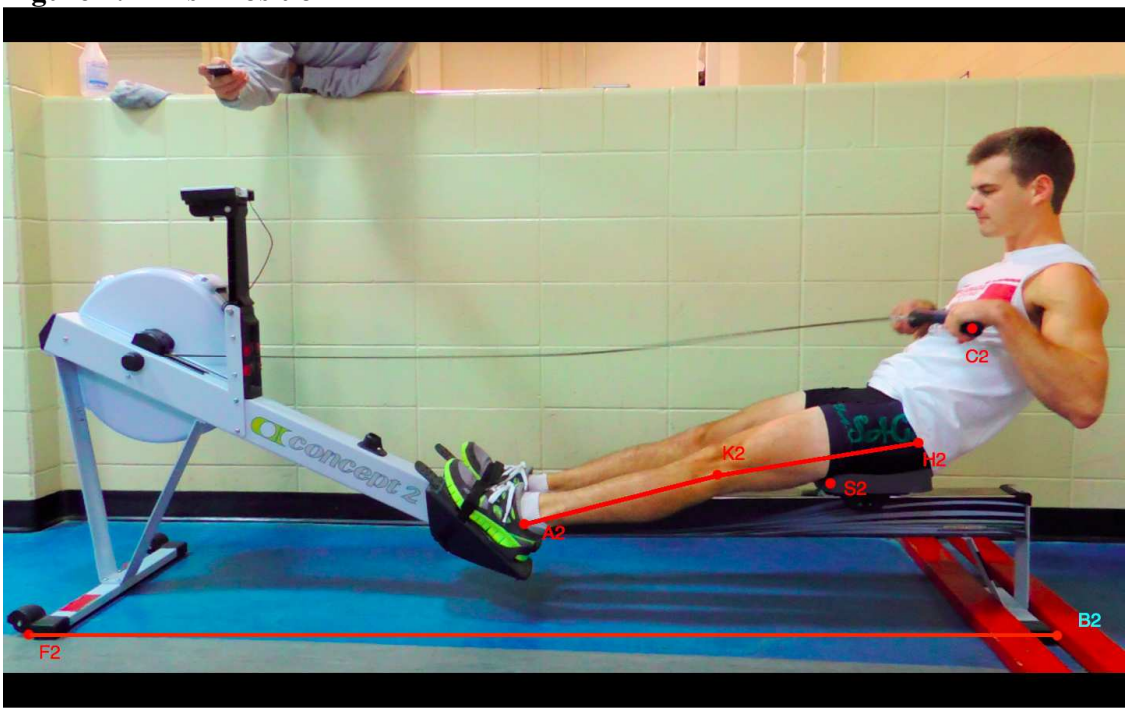
2D/3D Motion Analysis

The rowing ergometer stroke is a complex movement involving the entire body to effectively produce power (Torres-Moreno, Tanaka, & Penney, 2000). The movement must be performed sequentially with fluid flexion and extension of the legs, truck and arms (McGregor, Bull, & Byng-Maddick, 2004). The ergometer stroke involves physical strength, endurance, skill and coordination (McGregor, Bull, & Byng-Maddick, 2004). The topic of the rowing stroke on the ergometer became an idea for this project because I have coached rowing for the past few years and I was interested how to take quantitative analysis of the rowing stroke. I filmed Scott while rowing on an ergometer at 18 strokes per minute. The video matched the requirements for the project at 29.97 fps and 1920x1080 resolution. The quantitative measurements taken calculated from the video were the angle of the knees at the catch and finish position of the stroke. The length of the stroke measured by the handle in the catch position to the handle in the finish position. The distance the front of the seat travelled from the catch to the finish position. The last measurement is the average velocity of the handle and the average velocity of the seat during the rowing stroke. The first step was to take freeze frames of the rower in the catch and finish position of the stroke. Labelling the important points on the rower and machine for later measurements and calculations to be performed.

LABELLING POINT	WHAT THE POINT IS
H1/ H2	**HIP OF THE ROWER**
K1/K2	**KNEE OF THE ROWER**
A1/A2	**ANKLE OF THE ROWER**
S1/S2	**FRONT OF THE SEAT ON ERGONMETER**
C1/C2	**HANDLE OF THE ERGONMETER**
F1/F2	**FRONT OF THE ERGONMETER**
B1/B2	**BACK OF THE ERGONMETER**

Figure 1: Catch Position

Figure 2: Finish Position



Angles

The relative angle of the knee joint was taken using the values from Figure 1. The value of the relative angle of the knees at the catch shows the compression of the athlete in the catch position and their ability to maximum this part of the stroke for length (Cerne et al, 2013). The value of the relative angle of the knee at the finish is to make sure the rower is maximizing stroke length with the legs (Cerne et al, 2013). To calculate the angle of SKH the coordinates for the points are needed, once the coordinates are confirmed the lengths of the sides are calculated using:

Formula 1

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}.$$

After finding the lengths of the sides, the angles are calculating using two more formulas:

$$a^2 = b^2 + c^2 - 2bc\cos(\alpha)$$

$$\alpha = \arccos\left(\frac{b^2 + c^2 - a^2}{2bc}\right)$$

The charts below show the coordinates of the points used and the final values of the calculations.

Figure 3: The angle of the Knee Joint for Figure 1.

Point 1			Point 3			Point 1	
x1	671		x1	865		x1	671
y1	680		y1	573		y1	680
Point 2			Point 2			Point 3	
x2	662		x2	662		x2	865
y2	411		y2	411		y2	573
size	269.15052		size	259.717154		size	221.55135
cos 2 =	0.650		cos 1 =	0.453		cos 3 =	0.383
2 =	49.49		1 =	63.04		3 =	67.47	180.00

Point1= H1
Point2= K1
Point3= A1

Figure 4: The Angle of the Knee Joint for Figure 2.

Point 1			Point 3			Point 1	
x1	669		x1	1176		x1	669
y1	665		y1	559		y1	665
Point 2			Point 2			Point 3	
x2	917		x2	917		x2	1176
y2	601		y2	601		y2	559
size	256.12497		size	262.383307		size	517.96235
cos 2 =	-0.996		cos 1 =	0.999		cos 3 =	0.999
2 =	174.74		1 =	2.66		3 =	2.60	180.00

Point1= H2
Point2= K2
Point3= A2

From the calculations above it is determined that the angle of the knee joint in Figure 1 or the catch position is 49.49°. The angle of the knee joint in Figure 2 or the finish position of the stroke is 174.74°. The angles calculated above are conducive to maximizing the length of the rowing stroke.

Distance

The next step in the quantitative analysis is the distance travelled by the seat during the rowing stroke. The distance travelled could be determined by finding the difference between "S1" in Figure 1 and "S2" in Figure 2 using the coordinate points. The distance of the points is calibrated using the length of the ergometer. The Concept 2 Model D ergometer is 244cm long according to the official website (Concept 2, 2014) Therefore using the coordinates of F1/F2 and B1/B2, the difference in the number pixels between the "F" and "B" points could be used to determine the distance travelled by the seat during the stroke. Since the camera was placed on a steady surface solid surface for filming and the erg was secured in place it was confirmed the coordinates of F1=F2 and B1=B2. The same methodology is used to determine the distance travelled by the handle throughout the rowing stroke. The figures below show the values of the distance travelled based on the length of the ergometer.

Part 1: Distance Travelled by the Seat

The coordinates and distance between S1 and S2 is displayed in Figure 5 below. *Formula 1* from the angle section was used to figure out the distance between the points. 1318.0 pixels = 244cm Therefore $\frac{244cm}{1318.0pix.}\ x\ \frac{s}{283.0pix.} = 52.39cm = s$

The value of "s" is the distance between S1 and S2, and therefore is the distance travelled by the seat during the rowing stroke. The distance travelled is 52.39cm

Part 2: Length of the Rowing Stroke determined by Distance Travelled by Handle

The coordinates and the distance between C1 and C2 is displayed in Figure 6 below. *Formula 1* from the angle section was used to figure out the distance between the points. 1318.0 pixels = 244cm Therefore $\frac{244}{1318.0}\ x\ \frac{c}{900.6} = 166.72cm = c$

The value of "c" is distance between C1 and C2, and therefore is the distance travelled by the ergometer handle during the rowing stroke. The distance travelled is166.72cm.

Figure 5: Distance the Seat Travelled during the Rowing Stroke

	distance	x	y			
Point1		779	612			
Point2		1062	612			
	d=		283.0	pixel	52.39	cm
		1 pixel		0.185128	cm	
	calibration					
		x	y			
Point1		34	804			
Point2		1352	808			
	d=		1318.0	pixlu	244	cm

Figure 6: Distance the Handle Travelled during the Rowing Stroke

	distance	**x**	**y**		
Point1		345	481		
Point2		1243	413		
	d=		**900.6**	pixel	**166.72** cm
		1 pixel		0.185128 cm	
	calibration				
		x	**y**		
Point1		34	804		
Point2		1352	808		
	d=		**1318.0**	pixlu	244 cm

Average Velocity

The final measurement taken is the average velocity of the seat and the average velocity of the handle during the rowing stroke. The average velocity of the seat was determined using the distance travelled calculated in Part 1 of the distance section. Presented in Figure 5 above. The time elapsed is determined from a freeze frame of the catch position (Figure 7) till the seat stops moving (the time in Figure 10).

Figure 7: The Catch Position Start Time for Seat Average Velocity

Figure 8: When the seat stops moving. Stop time for average velocity of the seat.

Equation for speed:

$$Average\ Velocity = \frac{Distance\ Travelled}{Time} \qquad \frac{0.5239}{0.821} = 0.6381\text{m/s to the right}$$

The last step was to find the average velocity of the handle during the rowing stroke. The average velocity of the seat was determined using the distance the handle in Part 2 of the distance section. Presented in Figure 6. The time elapsed is determined from a freeze frame of the catch position (Figure 9) till the handle stops moving towards the body (the time in Figure 10).

$$Average\ Veloicty = \frac{Distance\ Travelled}{Time} \qquad \frac{1.6672}{1.024} = 1.628\text{m/s towards the body.}$$

Figure 9: Start Time for Average Velocity of the Handle

Figure 10: Finish Time for the Average Velocity of the Handle

References

Concept 2. (2014). *Model D*. From Concept 2 Indoor Rower: http://www.concept2.com/indoor-rowers/model-d

McGregor, A. H., Bull, A. M., & Byng-Maddick, R. (2004). A Comparison of Rowing Technique at Different Stroke Rates: A Description of Sequencing Force Production and Kinematics. *International Journal of Sports Medicine , 25*, 465-470.

Torres-Moreno, R., Tanaka, C., & Penney, K. L. (2000). Joint excursion, handle velocity, and applied force: a biomechanical analysis of ergonometric rowing.. *International Journal of Sports Medicine , 21* (1), 41-44.