



Pacing Profiles in World Championship 2000m Rowing: Explored through k-Shape Clustering

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Outline

- ▶ World Championship 2000m Rowing Data
- ▶ k-Shape Clustering
- ▶ Factors associated with Pacing Profiles
- ▶ Limitations and Future Work

Data

www.worldrowing.com:

- ▶ Olympics
- ▶ Paralympics
- ▶ **World Championships**
- ▶ World Cups
- ▶ Continental
- ▶ Under 23
- ▶ Junior
- ▶ Continental

Data: www.worldrowing.com



WCH Sarasota-Bradenton, USA 24 September - 1 October 2017

10 Media Start List **LM4-**
(Event) Lightweight Men's Four **X**
Start Time: 13:36 27 SEP 2017 Race 125

REVISED 25 SEP 14:07

World Champ Best:	DEN	JØRGENSEN / LARSEN / BARSOE / JØRGENSEN	Amsterdam (NED) 2014	World Championships	5:43.16
World Best Time:	DEN	JØRGENSEN / LARSEN / BARSOE / JØRGENSEN	Amsterdam (NED) 2014	World Championships	5:43.16
World Champion:	SUI	TRAMER / SCHAUERICH / NEPMANN / DVN	Augsburg (GER) 2015	World Championships	5:56.31

Rank	City Code	Name	Date of Birth
1	USA	(0) FOSTER Thomas	19 MAR 1984
		(2) DAVIS Nicholas	26 AUG 1987
		(3) SMITH David	17 FEB 1986
		(4) NEILS Andrew	27 JUN 1985
2	CHN	(0) LI Xiaoning	13 MAR 1987
		(2) WANG Tian	24 FEB 1989
		(3) YU Chenggang	23 FEB 1984
		(4) ZHAO Jinglin	18 APR 1990
3	GER	(0) STÖCKER Frank	23 JUL 1992
		(2) KESSELER Sven	22 MAR 1991
		(3) KOCH Jonathan	23 OCT 1990
		(4) PESCHEL Julius	31 OCT 1990
4	HUN	(0) PÁLA Balazs	01 DEC 1994
		(2) GIBSON Peter	20 MAR 1984
		(3) YAMAS Benue	02 JUN 1992
		(4) RIPPESCH Peter	25 SEP 1991
5	RUS	(0) TELITSYN Maksim	20 DEC 1990
		(2) BOGDANOV Aleksandr	25 OCT 1994
		(3) CHAIKIN Alexander	22 APR 1989
		(4) WELIN Andrey	18 JUN 1992
6	ITA	(0) DUCHINI Federico	19 JUL 1993
		(2) BARBARO Leone	20 OCT 1990
		(3) TEDESCO Lorenzo	20 DEC 1990
		(4) SPILGHI Piero	03 JUN 1994



Media Start List



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10 RACE DATA **LM4-**
(Event) Lightweight Men's Four **X**
Start Time: 13:36 27 SEP 2017 Race 125

Dist. (m)	USA		CHN		GER		HUN		RUS		ITA	
	Speed (km/h)	Stroke (m)	Speed (km/h)	Stroke (m)	Speed (km/h)	Stroke (m)	Speed (km/h)	Stroke (m)	Speed (km/h)	Stroke (m)	Speed (km/h)	Stroke (m)
25	6.6	44.0	6.3	50.7	6.1	48.0	6.9	45.0	6.1	48.0	6.5	50.0
50	6.6	46.0	6.8	51.0	6.9	47.0	6.3	45.0	6.9	47.0	6.9	50.0
75	6.6	46.0	6.6	50.6	6.7	47.0	6.5	45.0	6.9	46.0	6.1	49.0
100	6.6	44.0	6.6	49.0	6.6	46.0	6.7	44.0	6.9	45.0	6.1	46.0
150	6.6	44.0	6.9	47.0	6.9	46.0	6.9	46.0	6.9	45.0	6.1	47.0
190	6.6	43.0	6.9	45.0	6.9	45.0	6.6	43.0	6.9	42.0	6.1	46.0
195	6.6	42.0	6.9	44.0	6.9	45.0	6.5	43.0	6.9	41.0	6.0	45.0
200	6.6	40.0	6.6	43.0	6.6	44.0	6.5	43.0	6.9	40.0	6.0	44.0
250	6.6	38.0	6.6	42.0	6.6	42.0	6.6	42.0	6.9	40.0	6.0	43.0
290	6.6	38.0	6.7	41.0	6.7	43.0	6.6	42.0	6.7	40.0	6.0	43.0
330	6.6	38.0	6.7	40.0	6.6	43.0	6.6	42.0	6.7	39.0	6.0	42.0
360	6.6	38.0	6.6	40.0	6.6	43.0	6.5	42.0	6.6	38.0	6.0	42.0
390	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
420	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
450	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
480	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
510	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
540	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
570	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
600	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
630	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
660	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
690	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
720	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
750	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
780	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
810	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
840	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
870	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
900	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
930	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
960	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
990	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0
1020	6.6	38.0	6.6	40.0	6.6	43.0	6.5	41.0	6.6	38.0	6.0	41.0



Race Data



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10 Results **LM4-**
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Rank	City Code	Name	500m	1000m	1500m	2000m	Prog. Code
1	ITA	(0) DUCHINI Federico	1:29.28 (1)	2:58.20 (1)	4:29.64 (1)	6:01.82 (1)	FA
		(2) BARBARO Leone	1:29.92 (1)	1:31.64 (1)	1:32.18 (1)	1:32.18 (1)	FA
		(3) TEDESCO Lorenzo					
		(4) SPILGHI Piero					
2	RUS	(0) TELITSYN Maksim	1:29.97 (4)	3:01.10 (2)	4:33.58 (2)	6:07.05 (2)	FA
		(2) BOGDANOV Aleksandr	1:31.19 (2)	1:32.48 (2)	1:33.46 (2)	1:33.46 (2)	
		(3) CHAIKIN Alexander	1:39.9	2.90	3.95	5.23	
		(4) WELIN Andrey					
3	GER	(0) STÖCKER Frank	1:29.49 (2)	3:01.64 (3)	4:35.06 (3)	6:09.27 (3)	FA
		(2) KESSELER Sven	1:31.95 (3)	1:33.62 (3)	1:34.21 (3)	1:34.21 (3)	
		(3) KOCH Jonathan	1.21	3.24	5.42	7.45	
		(4) PESCHEL Julius					
4	CHN	(0) LI Xiaoning	1:29.68 (3)	3:02.48 (4)	4:36.82 (4)	6:10.95 (4)	FA
		(2) WANG Tian	1:32.82 (4)	1:34.14 (4)	1:34.23 (4)	1:34.23 (4)	
		(3) YU Chenggang	1.38	4.28	6.94	9.13	
		(4) ZHAO Jinglin					
5	USA	(0) FOSTER Thomas	1:34.03 (6)	3:11.11 (5)	4:47.80 (5)	6:28.63 (5)	FA
		(2) DAVIS Nicholas	1:36.43 (5)	1:36.78 (5)	1:36.78 (5)	1:36.78 (5)	
		(3) SMITH David	6.55	12.91	18.26	24.81	
		(4) NEILS Andrew					
6	HUN	(0) PÁLA Balazs	1:33.15 (5)	3:13.06 (6)	4:50.50 (6)	6:46.17 (6)	FA
		(2) GIBSON Peter	1:35.41 (6)	1:40.98 (6)	1:46.82 (6)	1:46.82 (6)	
		(3) YAMAS Benue	4.87	16.38	20.91	44.35	
		(4) RIPPESCH Peter					

Progression System: Remaining Crews to Final A (1-→FA)



Results



Data: www.worldrowing.com

1. Scrape PDF files from World Championships
2. For each race, extract data from the 3 PDFs
3. Join the race data from the 3 PDFs
4. Combine all races into one file
5. Make code and data available on github!

github.com/danichusfu/rowing_pacing_profiles

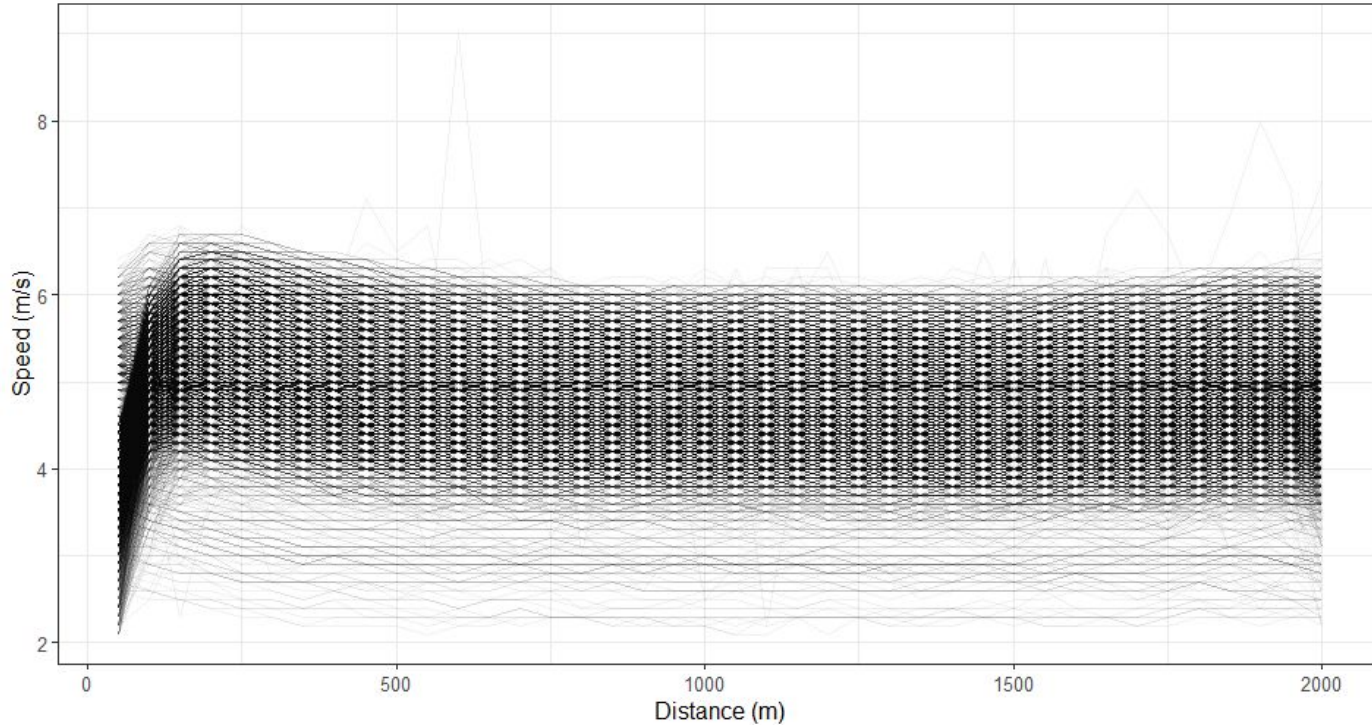
Goals!

- ▶ Identify the pacing profiles being used by each boat in World Championship 2000m Rowing
- ▶ Identify which race factors are associated with exhibiting a pacing profile

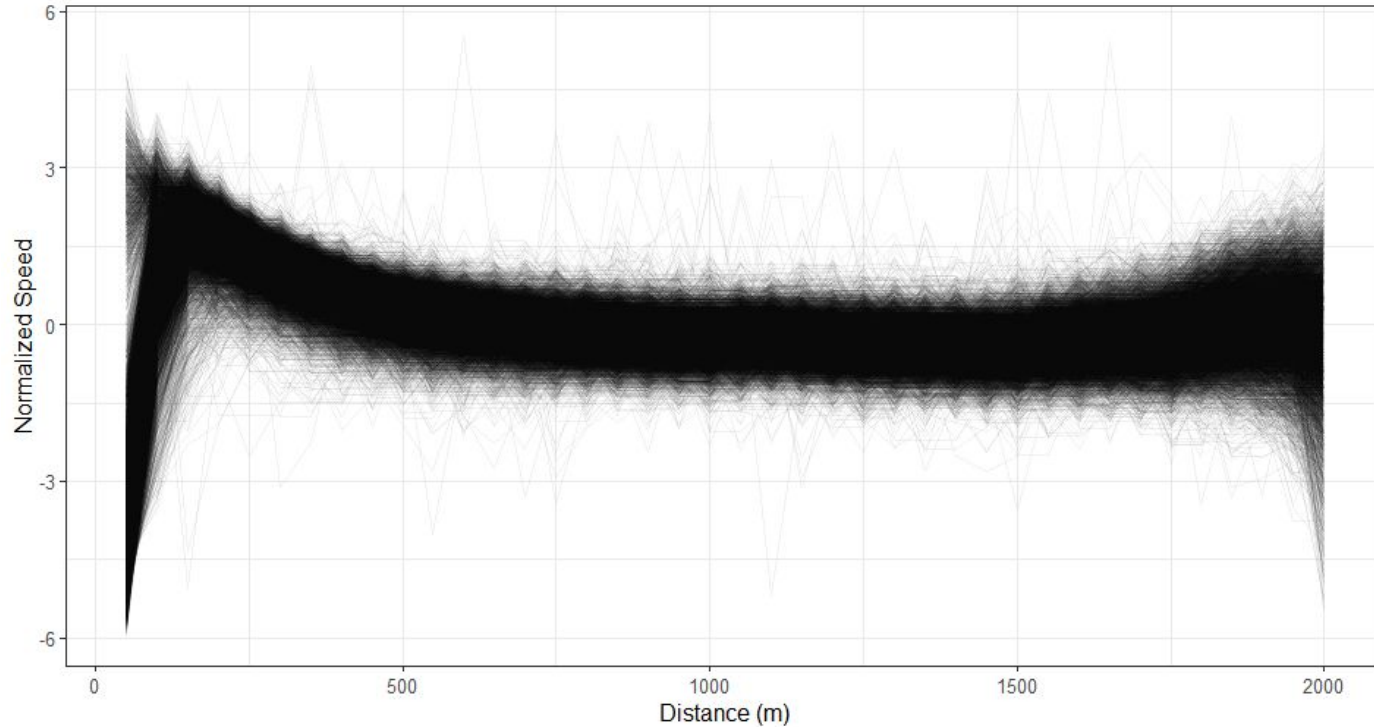
Identification of Pacing Profiles

- ▶ Cluster boats based on their average speed at each 50m split
- ▶ Problems:
 - Magnitudes of average speed depend on factors such as boat size, weight class, age group and gender
 - Longitudinal data

Raw Speed Curves



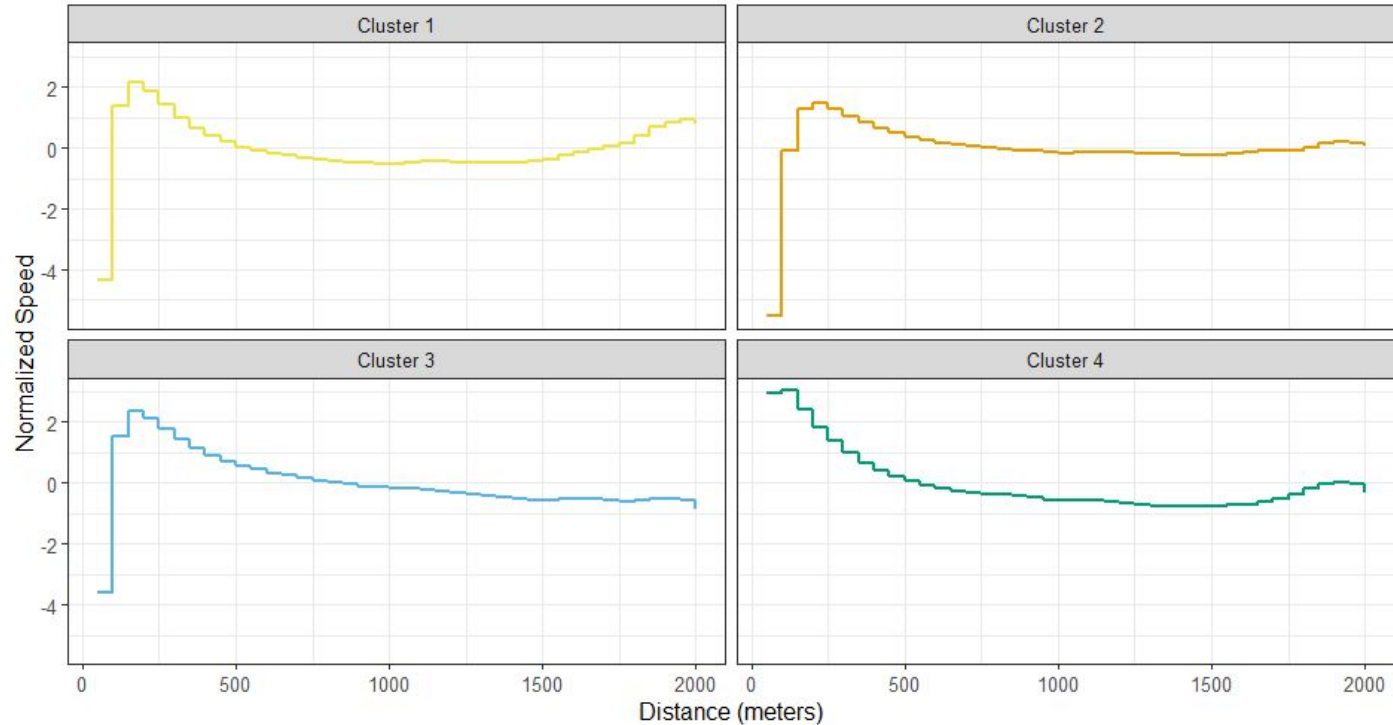
Normalized Speed Curves



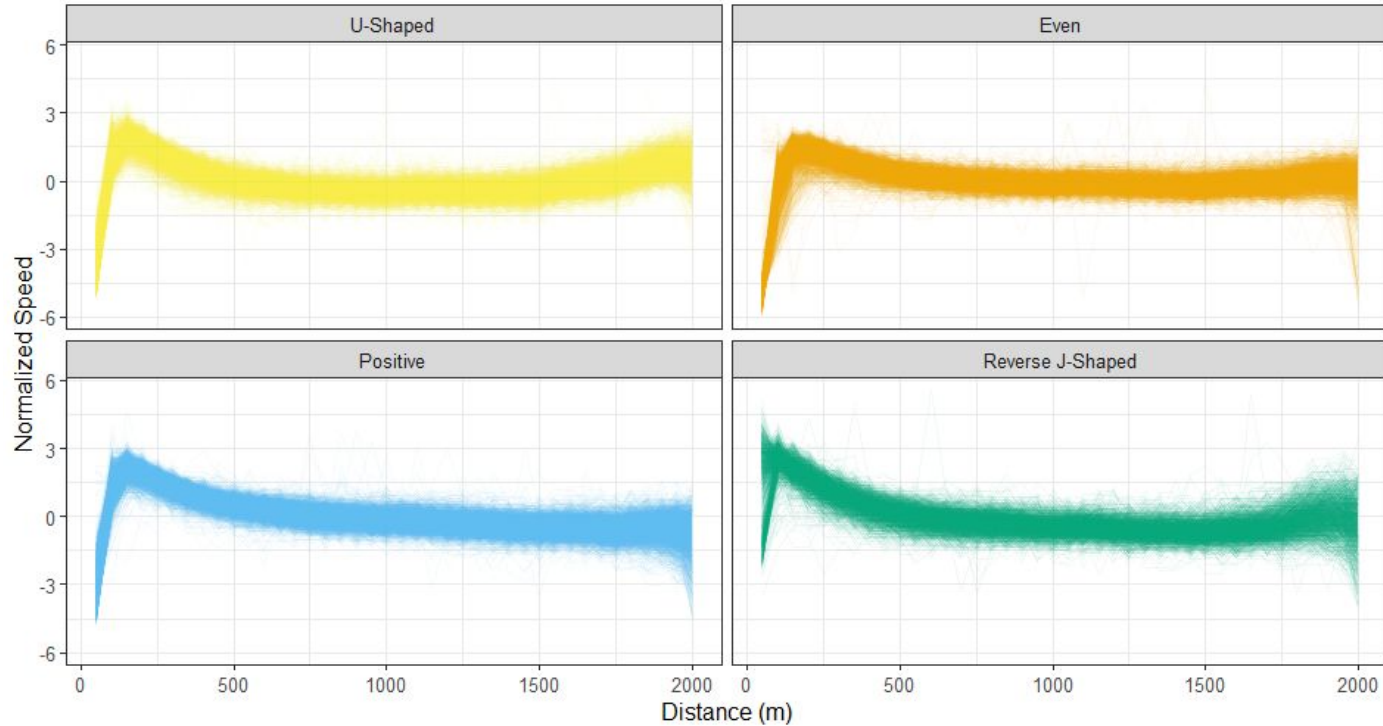
k-Shape Clustering

- ▶ Iterative process to minimize distance for an observation to a cluster centroid
- ▶ Uses Shape-based distance (SBD) (Paparrizos and Gravano 2016) as an alternative to Dynamic Time Warping (DTW)
- ▶ SBD is computationally more efficient than DTW
 - $O(m \log(m))$ to $O(m^2)$
- ▶ Small sacrifice in accuracy in experimental settings

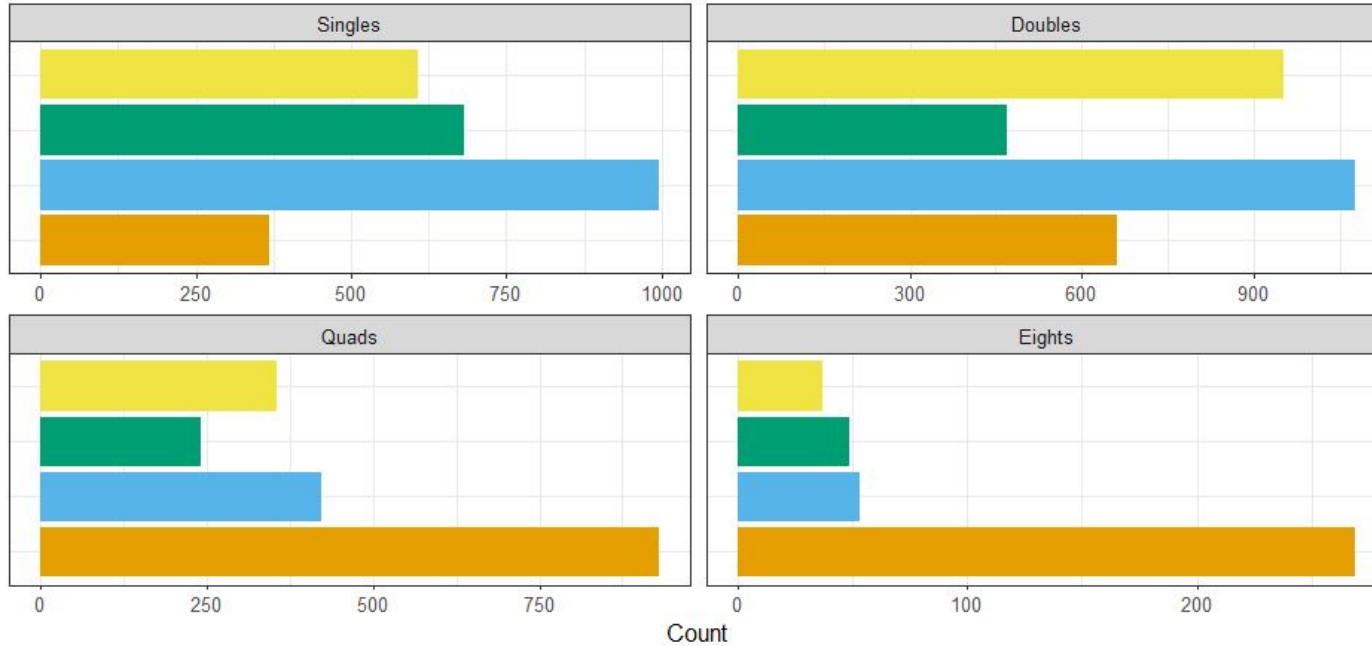
Cluster Centroids



Pacing Profiles



Boat Sizes



Pacing Profile: ■ Even ■ Positive ■ Reverse J-Shaped ■ U-Shaped

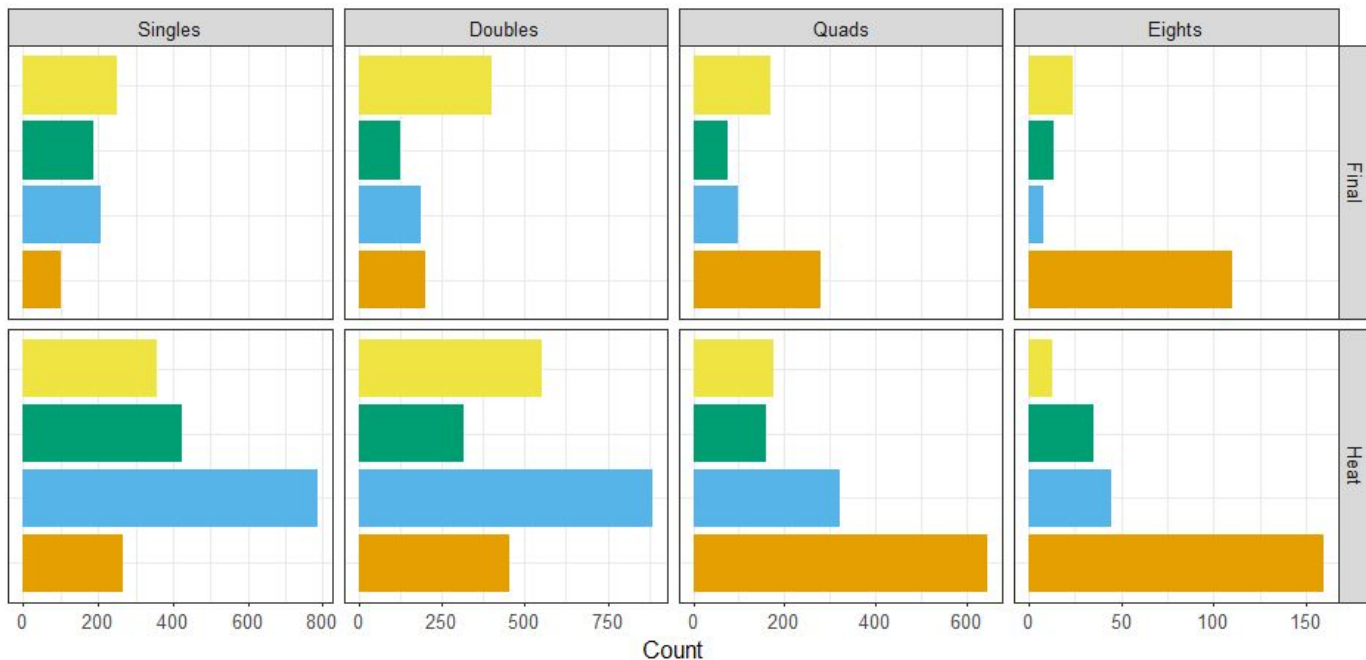
Modelling Pacing Profiles

- ▶ Response variable is the identified pacing profile
- ▶ Modelled as a function of race factors
- ▶ Using multinomial logistic regression
 - Even profile is the baseline
 - Report the relative risk ratio for a one-unit increase in the variable

Model Results

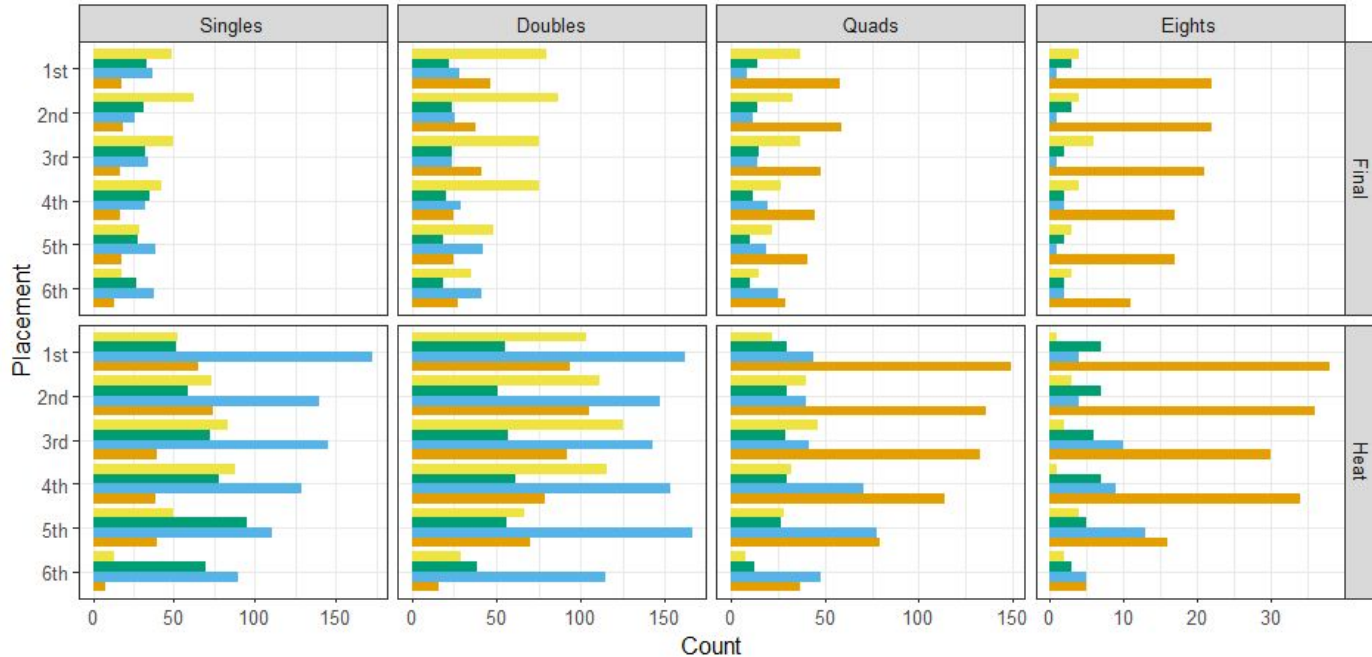
	Positive	Reverse J-Shaped	U-Shaped
Intercept	0.90	0.77	1.41
Size: Doubles	0.48	0.38	0.68
Size: Quads	0.13	0.14	0.16
Size: Eights	0.04	0.08	0.04
Heat or Final: Heat	1.81	1.04	0.54
Race Placement: 2nd Place	0.86	1.02	1.21
Race Placement: 3rd Place	1.08	1.33	1.50
Race Placement: 4th Place	1.36	1.60	1.60
Race Placement: 5th Place	1.76	1.93	1.24
Race Placement: 6th Place	3.16	3.16	1.21
Discipline: Sweep	1.81	1.20	1.97
Gender: Women	1.88	1.68	1.66
Weight Class: Open	1.43	1.52	1.28

Boat Sizes and Heat/Final



Pacing Profile: ■ Even ■ Positive ■ Reverse J-Shaped ■ U-Shaped

Boat Sizes, Heat/Final and Placement



Pacing Profile: ■ Even ■ Positive ■ Reverse J-Shaped ■ U-Shaped

Limitations

- ▶ Observational Data
- ▶ Interaction terms are not fit in the model
- ▶ Cannot choose a “optimal” profile to help coaches and athletes
- ▶ Only uses World Championship Races

Conclusions

- ▶ Can identify pacing profiles with k-Shape Clustering
- ▶ Interesting preliminary results for which race factors affect pacing profiles
- ▶ Available data:
github.com/danichusfu/rowing_pacing_profiles
- ▶ I'd love your feedback and thoughts!

THANKS!

Any Questions?

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References

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