

# DIFFERENCES AMONG 500-METER INTERVALS IN LOWER LIMB KINEMATICS AND PERFORMANCES DURING 2000-METER ON-WATER ROWING

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## Summary

This study investigated key biomechanical factors in rowing, emphasizing the relationship between leg extension strength and technique. The Xsens MVN Awinda was used to analyze lower limb kinematics and synchronized with Speedcoach GPS to analyze performances during a 2000-meter on-water rowing test. A repeated-measures ANOVA was used to assess differences among four 500-meter intervals. Significant differences in lower limb kinematics were found in the first 500-meter interval compared to the later intervals. Performances showed notable improvements in stroke rate and speed in the last 500-meter interval. The findings indicated that lower limb kinematics varied early in the on-water rowing but become more stable and efficient over time.

## Introduction

While ergometers offer insights into rowing power [1,2], they do not fully capture lower limb push-off strategies in on-water rowing. The purpose of this study was to analyze 2000-meter on-water rowing kinematics and performances in each 500-meter interval for contributing to the scientific understanding of rowing biomechanics.

## Methods

This study recruited 27 male rowers (age:  $17.37 \pm 2.04$  years; height:  $1.75 \pm 0.05$  m; weight:  $69.81 \pm 8.30$  kg), all with at least four years of experience and training five days per week. Participants were healthy, with no history of lower limb injuries or surgeries, and provided written informed consent. The study was approved by the Institutional Review Board (IRB).

Lower limb kinematics were assessed using the Xsens MVN Awinda system (100 Hz), while a SpeedCoach GPS sensor was used to record performances of distance, stroke rate, velocity, and heart rate during a 2000-meter rowing test. The data were divided into four intervals of 500 meters each.

Statistical analyses were performed in SPSS 14.0, with a repeated-measures one-way ANOVA evaluating differences

among four 500-meter intervals. Mauchly's test assessed sphericity, and a Greenhouse-Geisser correction was applied when necessary ( $\alpha = .05$ ).

## Results and Discussion

Table 1 presents the parameters for each 500-meter interval of the 2000-meter rowing distance. Significant differences were found between each 500-meter interval for lower limb kinematics and performances. The 0m~500m showed greater hip flexion at rowing finish and knee flexion at rowing catch and finish (all  $p < 0.001$ ), and smaller ankle dorsiflexion at rowing catch and plantarflexion at rowing finish than the rest intervals. In performers, the stroke rate and speed were significantly greater in the 1500m~2000m (all  $p < 0.001$ ) than in the previous intervals.

## Conclusions

The significant difference was found in the initial interval of rowing compared to the later intervals, likely due to the need to accelerate the boat at the race start. As the race progressed, movement patterns became more stable and consistent, with reduced kinematical variation. In the final 500 meters, stroke rate and boat velocity significantly increased compared to the preceding segment, indicating a gradual transition into a sprint phase to optimize race performance.

## Acknowledgments

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## References

- [1] Mäestu, J., Jürimäe, J., & Jürimäe, T. (2005). Monitoring of performance and training in rowing. *Sports medicine*, 35, 597-617.
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**Table 1:** Kinematics of lower limbs and performers for each 500-meter interval. Data are mean  $\pm$  standard deviation.

		0m~500m	500m~1000m	1000m~1500m	1500m~2000m
Hip	Flexion (°) at rowing catch	104.32 $\pm$ 13.98 <sup>b,c,d</sup>	106.79 $\pm$ 14.65 <sup>a</sup>	107.33 $\pm$ 14.05 <sup>a</sup>	107.32 $\pm$ 13.56 <sup>a</sup>
	Flexion (°) at rowing finish	45.65 $\pm$ 8.61 <sup>b,c,d</sup>	33.96 $\pm$ 7.22 <sup>a</sup>	33.56 $\pm$ 7.44 <sup>a</sup>	34.83 $\pm$ 7.33 <sup>a</sup>
Knee	Flexion (°) at rowing catch	59.56 $\pm$ 9.45 <sup>b,c,d</sup>	56.44 $\pm$ 10.46 <sup>a</sup>	54.99 $\pm$ 10.86 <sup>a</sup>	55.79 $\pm$ 10.27 <sup>a</sup>
	Flexion (°) at rowing finish	21.26 $\pm$ 8.38 <sup>b,c,d</sup>	14.74 $\pm$ 10.23 <sup>a</sup>	13.12 $\pm$ 5.21 <sup>a</sup>	13.55 $\pm$ 5.27 <sup>a</sup>
Ankle	Dorsiflexion (°) at rowing catch	-8.19 $\pm$ 11.72 <sup>b,c,d</sup>	-12.33 $\pm$ 17.81 <sup>a</sup>	12.85 $\pm$ 18.01 <sup>a</sup>	-12.67 $\pm$ 17.99 <sup>a</sup>
	Plantarflexion (°) at rowing finish	25.75 $\pm$ 13.95 <sup>b,c,d</sup>	31.38 $\pm$ 20.72 <sup>a</sup>	31.49 $\pm$ 21.76 <sup>a</sup>	-31.33 $\pm$ 21.27 <sup>a</sup>
Boat	Speed (m/s)	3.82 $\pm$ 0.29	3.84 $\pm$ 0.22	3.80 $\pm$ 0.26 <sup>d</sup>	3.86 $\pm$ 0.29 <sup>c</sup>
	Stroke rate (SPM)	28.40 $\pm$ 3.02 <sup>d</sup>	28.13 $\pm$ 3.03 <sup>d</sup>	28.10 $\pm$ 2.87 <sup>d</sup>	31.35 $\pm$ 4.23 <sup>a,b,c</sup>
Athletes	Heart rate (BPM)	137.42 $\pm$ 20.27 <sup>b,c,d</sup>	164.62 $\pm$ 23.75 <sup>a,c,d</sup>	175.25 $\pm$ 18.97 <sup>a,b,d</sup>	179.31 $\pm$ 18.01 <sup>a,b,c</sup>

<sup>a</sup> indicates significant difference from the 0m~500m; <sup>b</sup> indicates significant difference from the 500m~1000m; <sup>c</sup> indicates significant difference from the 1000m~1500m; <sup>d</sup> indicates significant difference from the 1500m~2000m.  $p < 0.05$ .