Wearing A Wetsuit Alters Arm Motion During Simulated Surfboard Paddling

CSUSM Kinesiology Department

California State University SAN MARCOS

Jeff A. Nessler, Madison N. Silvas, and Sean C. Newcomer

Dept. of Kinesiology, California State University, San Marcos, CA 92096

CSUSM Surf Research

INTRODUCTION

- **Surfing is increasing in popularity.** There are approximately 10-20 million people participating in surfing worldwide more more than 2.1 million surfers in the United States alone (International Surfing Association).
- **Wetsuits are an important piece of surfing equipment.** Primarily used for their thermoregulatory properties[1], wetsuits also provide increased buoyancy and help to reduce drag in the water[2]. Beyond these factors, relatively little is known regarding their effects on human performance.
- **Neoprene sleeves have been shown to enhance proprioceptive acuity.** This effect has been noted in both the shoulder[3] and the knee[4] joints, but these data are for passive, joint position sensing only. Wetsuits provide a similar compressive effect. Therefore, it is possible that this same phenomenon may occur in the surfing athlete.
- **Little is known regarding the effects of a neoprene sleeve on active, multi-joint movements**. A change in proprioceptive acuity might alter the control of upper limb movement in the paddling surfer. This type of change may therefore lead to observable differences in the paddling motion.
- **Approximate Entropy (ApEn) and maximal Lyapunov exponents (LyE) are often calculated in studies that focus on the variability structure of human movement[5-6].** Changes in the complexity and variability of movement patterns may be indicative of differences in nervous system control. If proprioceptive acuity is enhanced by wearing a wetsuit, it is possible that this may alter these aspects of the paddling motion.

The purpose of this study was to determine the effects of wearing a wetsuit on the complexity and variability of the surfboard paddling motion in experienced, recreational surfers.

METHODS

Subjects

Table 1 Characteristics for 12 male, recreational surfers recruited from the local population.

	Age [years]	Height [m]	Mass [kg]	Experience [years]
Mean	33.1±8.6	1.82±0.07	79.9±9.4	21.8±12.4
Range	19-43	1.73-1.96	64.8-91.5	2-38

Equipment

- Commercially available swim bench ergometer (VASA Inc., Fig 1).
- 2mm front zip neoprene jacket.
- Vicon 8 camera motion capture system.

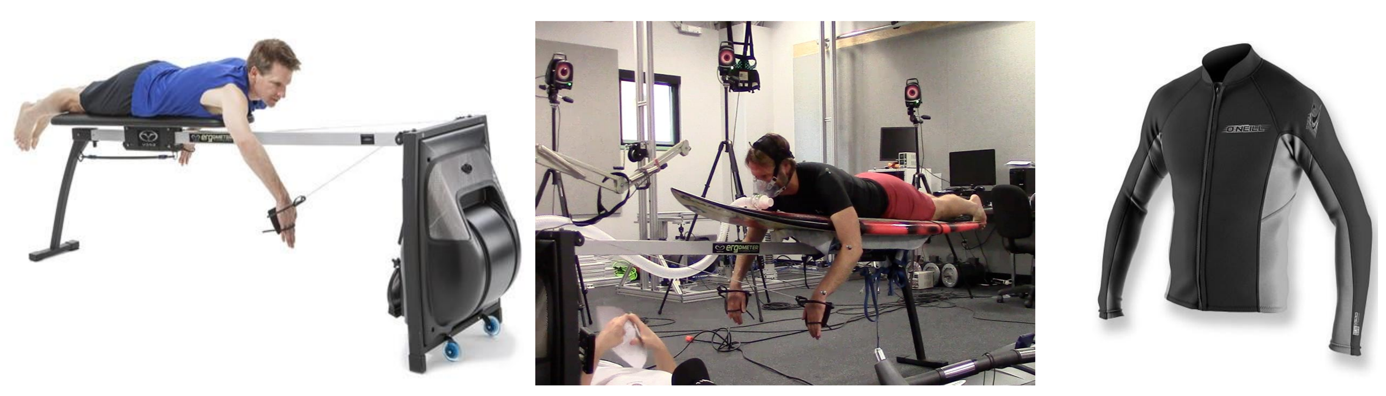


Figure 1 *Vasa Inc.* swim bench ergometer (left), experimental setup (center), 2mm front zip neoprene jacket (right).

Procedures

- Following a brief warm-up, subjects paddled at a submaximal level for 2 minutes with and without a wetsuit (randomized order).
- Resistance to paddling was provided by a small flywheel incorporated within the ergometer (Figure 1).
- Subjects were closely monitored to ensure they maintained a consistent cadence (25 strokes/min each arm) and power output (20 watts).
- Subjects were instructed to paddle in a manner that was similar to their normal motion while in water.
- 3D wrist trajectory was captured for the entire 2 minute trial.
- Average stroke height, length, and width were calculated for each trial. Approximate Entropy[6] (ApEn) and maximal Lyapunov exponents[5] (λ_{long} over 10 strokes and λ_{short} over 0-1 stroke) were then calculated for motion in the antero-posterior (stroke height), cranial caudal (stroke length), and medio-lateral (stroke width) directions.
- Paired t-tests were utilized to determine if differences between paddling conditions were statistically significant.

RESULTS

Table 2 Physiological Measurements

	Cadence [spm]	Workload [watts]	Mean HR [bpm]	Mean Skin Temp [°C]
Wetsuit	25.2±2.7	20.2±1.9	113.8±11.7	34.4±0.9
No Wetsuit	26.1±3.4	20.6±1.6	114.2±18.4	33.1±1.3*

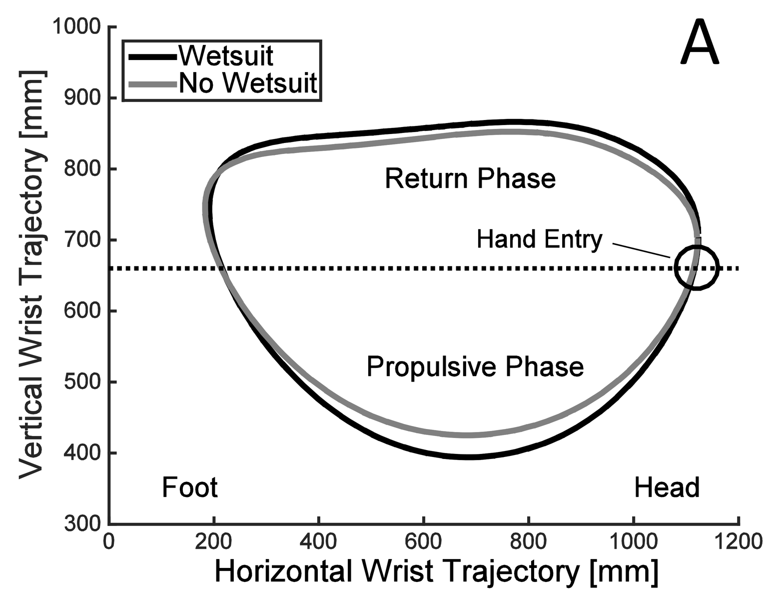
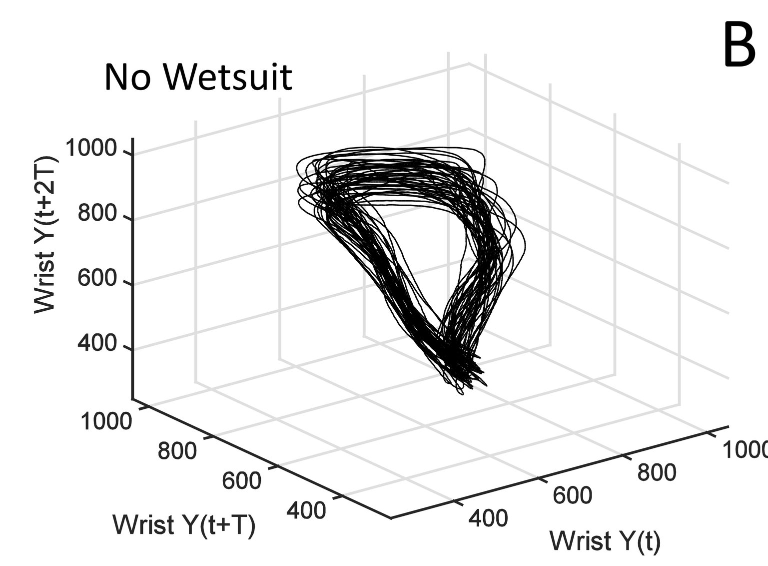


Figure 2 Wrist trajectories. **A:** comparison of the average (n=12) sagittal plane motion between conditions. **Below:** 3D state space plots for a representative subject for wrist trajectory in the vertical direction (using an embedding delay of 20). **B:** No Wetsuit, **C:** Wetsuit.



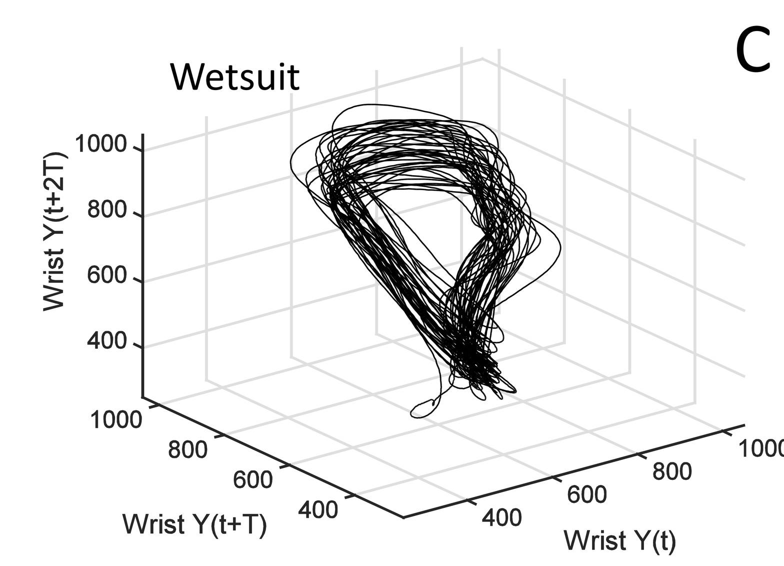


Table 3 Kinematic Results

	Antero-posterior [Stroke Height]		Cranial-caudal [Stroke Length]		Medio-lateral [Stroke Width]	
Condition	**Wetsuit**	**NW**	**Wetsuit**	**NW**	**Wetsuit**	**NW**
Mean Excursion [mm]	481.5±86.1*	438.5±75.8	970.0±64.2	971.6±76.9	169.9±66.8	171.8±59.4
λ_{short} (0-1 stroke)	1.49±0.26*	1.38±0.28	1.93±0.25	1.91±0.19	1.04±0.30	1.03±0.18
λ_{long} (10 strokes)	0.035±0.036	0.027±0.029	0.047±0.044	0.041±0.030	0.022±0.024	0.021±0.023
ApEn	0.45±0.05*	0.39±0.09	0.46±0.13	0.43±0.11	0.50±0.11	0.48±0.09

DISCUSSION

1. Wearing a wetsuit resulted in a significant increase in stroke height complexity (ApEn), variability in the vertical direction (λ_{short}), and mean stroke height.
2. These results suggest that wearing a wetsuit alters control of the upper extremity and may therefore have a beneficial effect on performance of the paddling motion in surfers.
3. These results might be considered in the design of wetsuits or garments for surfers that might be worn in warmer conditions that provide proprioceptive stimulus without thermoregulatory influence.
4. These findings may also have implications for other aspects of movement in the upper extremity, including those performed by overhead athletes and individuals recovering from neurological injury.

These results support the hypothesis that wearing a wetsuit leads to changes in nervous system control of the paddling motion, possibly through enhanced proprioceptive acuity.

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For more information:
Jeff Nessler, Ph.D.
Sean Newcomer, Ph.D.
California State University, San Marcos
760-750-7352
jnessler@csusm.edu
snewcomer@csusm.edu
www.csusm.edu/kinesiology