Increasing Surfboard Volume Reduces Energy Expenditure and Alters Biomechanics During Paddling

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Abstract

BACKGROUND: Surfboard shapers manipulate board volume (BV) with the notion of altering the surfer's experience. However, there is no scientific evidence on the impact of BV on a surfer's ability to paddle, catch, and ride waves. **PURPOSE**: The purpose of this study was to investigate how BV affects energy expenditure and biomechanics during paddling. We hypothesized that energy expenditure decreases as surfboard volume increases. **METHODS**: Twenty amateur surfers (18 men, 2 women, ages 18-45) paddled against a constant current in a swim flume (Endless Pool Elite) on five surfboards in random order twice. All surfboards were 60 in (178 cm) long, 19.8 in (50.9 cm) wide and varied only in thickness and, therefore, ranged in BV from 28.4 to 37.4 L. Heart rate (HR) and oxygen consumption (VO_2) were measured at 5-s intervals with a heart rate monitor (Polar RCX5) and metabolic cart (Parvo Medics TrueOne 2400), respectively. A digital camera (GoPro Hero 4) was attached to the inside lining of the swim flume to collect 2-D underwater footage of the sagittal plane in order to measure pitch angle, roll angle and paddling cadence. **RESULTS**: VO_2 and HR decreased on thicker boards [VO2 = 32.2 - 0.263*BV ($p < 0.001$); HR = 167 - 0.822*BV ($p < 0.001$)]. Pitch and roll angles also decreased on thicker boards [Pitch = 13.1 - 0.125*BV ($p < 0.001$); Roll = 36.1 - 0.344*BV ($p = 0.044$)]. Cadence was independent of BV ($p = 0.227$). **CONCLUSIONS**: Results from this study suggest that thicker surfboards reduce the metabolic cost of paddling and lower pitch and roll angles, thus linking metabolic and biomechanical responses to paddling a surfboard with increased volume.

Background

- Since the birth of the sport, changes to the material, shape, and size of surfboards have been made to alter the surfing experience (Warshaw, 2010)
- Because surfers spend a majority of their time paddling, and because average heart rate during paddling is greater than sitting or wave riding (Meir et al., 1991), paddling appears to be the most energetically costly portion of a surfing bout.
- Altering buoyancy has shown to impact body position (Pendergast et al., 1977) and improve performance (Cordain, 1991) during swimming.

Purpose

The purpose of this study was to investigate how board volume affects energy expenditure and biomechanics during paddling through well-controlled bouts on five surfboards of different volumes.

Methods

Subjects:

- Twenty amateur surfers (18 men, 2 women, ages 18-45) participated in this study.
- Mean years of surfing experience for all subjects was 16.25 ± 10.3.
- Consent, health history questionnaire, and surfing history forms were filled out by subjects.

Protocol:

- All surfboards varied only in thickness and, therefore, ranged only in volume.
- Subjects completed an initial paddling proficiency test consisting of a 3 minute paddle on the lowest volume board.
- All subjects paddled against a constant current in a swim flume (Endless Pool Elite) on five surfboards in random order twice.
- HR (Polar RCX5) and VO_2 (ParvoMedics) were measured at 5-s intervals.
- 2-D underwater footage of the sagittal plane was analyzed in order to measure pitch angle, roll angle and paddling cadence.

Statistical Analysis:

- Statistical significance was set at $p < 0.05$. All data is presented as mean ± SE.

Board	A	B	C	D	E
Volume (L)	28.4	31.2	32.2	35.1	37.4
HR (bpm)	144 ± 5	142 ± 5	140± 5	139 ± 5	136 ± 5
VO_2 (ml/kg*min)	24.8 ± 0.8	23.8 ± 0.6	23.7 ± 0.8	23.2 ± 0.8	22.3 ± 0.8
Cadence (strokes/min)	54.1 ± 1.4	53.3 ± 1.4	55.5 ± 1.2	55.2 ± 1.4	55.3 ± 1.3
Pitch Angle (°)	9.55 ± 0.29	9.30 ± 0.27	9.12 ± 0.28	8.70 ± 0.23	8.48 ± 0.27
Roll Angle (°)	26.0 ± 2.1	24.6 ± 1.9	25.4 ± 2.0	24.4 ± 2.0	23.3 ± 1.8

Table 1. Summary of results expressed as mean ± SE.

Energetics

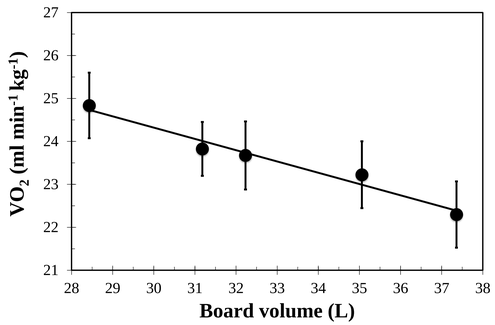

Figure 1. Mean VO_2 vs. board volume for all subjects. $VO_2 = 32.2 - 0.263*BV$; $p < 0.001$.

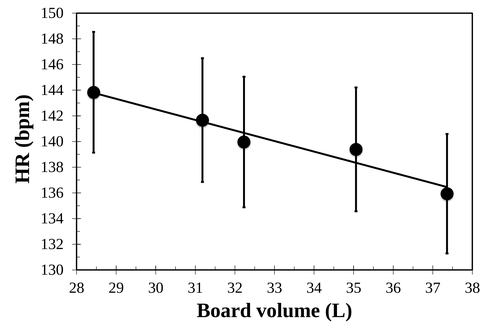

Figure 2. Mean HR vs. board volume for all subjects. HR = 167 - 0.822*BV; $p < 0.001$.

Biomechanics

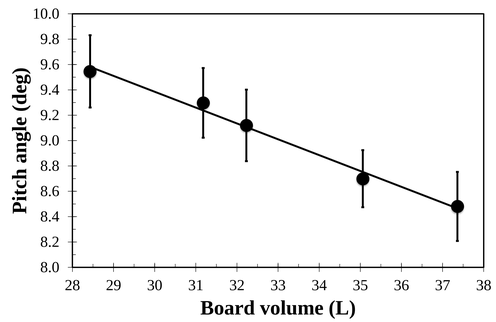

Figure 3. Mean surfboard pitch angle vs. surfboard volume for all subjects. Pitch = 13.1 - 0.125*BV: $p < 0.001$

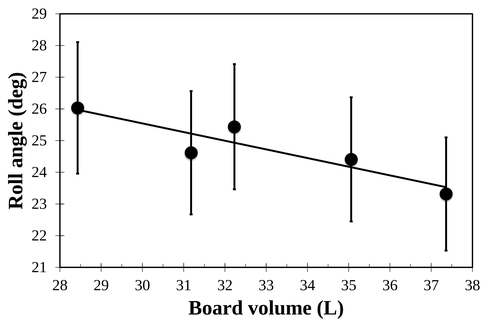

Figure 4. Mean surfboard roll range of motion vs. surfboard volume for all subjects. Roll = 36.1 - 0.344*BV; $p = 0.044$

Subject characteristics

	Women	Men	Total
Sex (# of subjects)	2	18	20
Age (years)	29.0 ± 5.7	30.6 ± 8.2	30.4 ± 7.9
Height (m)	1.71 ± 0.03	1.78 ± 0.06	1.77 ± 0.06
Weight (kg)	58.5 ± 0.6	77.4 ± 7.5	75.5 ± 9.3
BMI (kg/m^2)	20.1 ± 0.4	24.5 ± 2.5	24.1 ± 2.8
Experience (years)	11.5 ± 12.0	16.8 ± 10.4	16.3 ± 10.3
Competency (out of 10)	5.50 ± 2.12	6.67 ± 1.37	6.50 ± 1.40

Table 2. Summary of subject characteristics expressed as mean ± SE.

Conclusions

- We observed a significant difference for VO_2 and HR across the five boards (Figs. 1&2).
- There were significant differences in pitch angle and roll angle range of motion across the five boards (Figs. 3&4).
- No differences were observed in cadence across the five boards ($p = 0.227$).
- These findings suggest that paddling is less metabolically costly on more voluminous boards.
- These findings also suggest that compensations on less voluminous boards may be made via increasing stroke length and depth, as opposed to rate.

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