MEASURING THE WAVE DISSIPATION PRODUCED BY A SWIMMING-LINE SEPARATION ROPE

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INTRODUCTION: Hydrodynamic drag (D) seems to be one of the major determinants of swimming performance. D is usually divided into pressure, friction and wave drag (D_w). Meanwhile, D_w can be due to two distinct phenomena: (i) wave production ($D_w$wp) and (ii) transfer of negative wave momentum ($D_w$tm). $D_w$wp refers to the energy dissipated from the kinetic energy of the swimmer and used to generate waves, and $D_w$tm refers to the drag effect (reduction of forward kinetic energy of the swimmer) attributed to the impact of waves produced by others, or produced by the swimmer itself and rebounded at a swimming pool wall. In order to define the competition lane of each swimmer, the competition swimming pools dispose of swimming-line separation ropes (S-LSR). In the meantime, the manufacturers of this S-LSR claim that they have the ability to absorb waving energy, and thus to dissipate waves avoiding $D_w$tm, and other perturbing wave effects. The purpose of this research was to characterize the swimmer's wave production, and to measure the effect upon the wave energy dissipation of a common S-LSR (Fig.1).

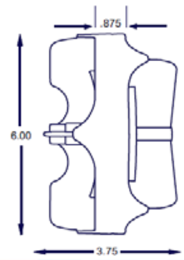

Figure 1. Profile of the S-LSR studied.

METHOD: Two experienced and trained competitive swimmers (25 / 17 years, 1.83 / 1.78 m, 83.8 / 72.1 kg, 56.02 / 59.61s 100 medley) performed 5 x 12 m in each competitive swimming technique (N = 10) with and without S-LSR, at maximal velocity, and at the mean maximal velocity obtained for breaststroke (1.3 m/s). During each 12 m swim, a 6 m section (between 4 and 10 m) was timed using a stopwatch and an experienced operator. The interval between repetitions was casuistic and decided based on the inexistence of dynamometric evidences of water disturbance. At a distance of 2 m from the swimming lane an extensiometric force-plate of 0.5x0.5 m (Pereira et al., 2006) was fixed on the wall of the swimming pool (Fig. 2).
The S-LSR was fixed at 1.15 m from the force-plate. The force-plate was operating at 1000 Hz, and data was exported to a PC using a 16 bit A/D Biopac converter and the Acqknowledge 3.2.5 software. Dynamometric data were acquired during 24 s in each trial, from where the most prominent wave was selected to extract variables corresponding to this wave-train. These include wave amplitude (difference, in N, from the lower to the higher value registered in one wave) and intensity (the highest positive value, in N, registered in each wave train, after removal of the offset). In each side of the S-LSR a vertical ruler was mounted, allowing to measure the height of the waves using the high-speed video mode (300 Hz) of one Casio-Exilim F1 camera. SPSS and ANOVA were used after checking for normality (Shapiro-Wilk).


Figure. 2. Picture of the experimental setup. The force-plate and the rulers are shown.

RESULTS: The main results of the study are presented in Table 1.

Table 1. Mean ± standard deviation of the dynamometric and wave height values

		Without Swimming-line separation rope				With Swimming-line separation rope			
		Velocity (m/s)	Wave intensity (N)	Wave amplitude (N)	Wave height (m)	Velocity (m/s)	Wave intensity (N)	Wave amplitude (N)	Wave height (m)
Maximal velocity	Crawl	1.7±0.8	40.4±7.8	66.8±15.9	0.079±0.025	1.7±0.5	28.3±8.0[a]	54.0±11.8[c]	0.047±0.022[a,c]
	Back	1.5±0.8	36.3±5.8	53.0±12.8[e]	0.050±0.010[e]	1.5±0.6	27.3±5.8[a,c]	50.5±10.6[c]	0.033±0.010[a,c]
	Butterfly	1.6±0.7	34.3±7.0	58.0±14.0	0.040±0.014[e]	1.6±0.9	26.2±5.2[a]	48.1±12.7	0.032±0.01[a]
	Breast	1.3±0.4	33.1±4.1	65.6±4.5	0.048±0.017	1.3±0.9	20.5±7.0[a]	36.5±13.9[a]	0.023±0.009[a]
Breaststroke mean velocity	Crawl	1.3±0.9	27.1±9.2[b]	46.9±19.2[b]	0.064±0.030[b]	1.3±0.6	15.9±3.9[a,b]	27.1±7.4[a,b]	0.026±0.006[a,b]
	Back	1.3±0.7	25.9±5.0[b,c,d]	43.4±6.2[c,d]	0.061±0.023[b]	1.3±0.5	22.6±3.4[e,d]	42.3±6.6[e,d]	0.038±0.007[a,c,e]
	Butterfly	1.3±0.9	38.4±13.1	69.2±14.3[e]	0.060±0.011[b]	1.3±0.8	34.2±3.2[b,c,e]	56.2±8.9[a,c,e]	0.045±0.015[a,b,c,e]

[a] Significantly different from “without” S-LSR; [b] Significantly different from the correspondent maximal velocity; [c] Significantly different from breaststroke ($p<0.05$); [d] Significantly different from butterfly ($p<0.05$); [e] Significantly different from crawl ($p<0.05$)

DISCUSSION: The measured wave heights were partially coherent with previously available results (Ohmichi et al., 1983). Absolute values are of the same magnitude, but the relative butterfly values were higher than expected. Moreover the wave height values only grew with velocity for the front crawl. Both for backstroke and butterfly lower values were found at maximal compared to sub-maximal velocities, suggesting that these ones might be too low to allow proper hydrodynamics. Considering dynamometrical data, butterfly also showed a tendency to produce more intense waves at lower velocities, probably for the same reason. Out of these exceptions, data obtained at lower velocity normally present also lower values. Results also suggest that, at the same velocities, front crawl technique seems to produce less intense waves than the other techniques, including backstroke. Moreover, the generality of the measured wave variables were reduced when the S-LSR was included, showing that these devices are able to significantly attenuate water surface waves during swimming events.

CONCLUSION: This study showed that swimming-line separation ropes are able to significantly attenuate water surface waves during swimming events. Moreover it emphasises that front crawl seems to be the lower wave producer technique among the four swimming competitive strokes at comparable velocities, and that at least butterfly needs to be swam at velocities higher than a critical value to ensure proper hydrodynamics of the swimmer.

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