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ORIGINAL ARTICLE

The influence of stroke mechanics into energy cost of elite swimmers

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Abstract The purpose of this study was to analyze the relationships between energy cost (*C*), swimming velocity (*v*), stroke frequency (SF) and stroke length (SL) in top-level swimmers. Eighteen elite swimmers (four freestylers, five backstrokers, five breaststrokers and four butterflyers) performed an intermittent set of $n \times 200$ m swims ($n \leq 8$) with increasing velocity. The oxygen consumption was measured breath-by-breath by a portable metabolic cart (K4 b2, Cosmed, Rome, Italy). A respiratory snorkel and valve system with low hydrodynamic resistance was used to measure pulmonary ventilation and collect expiratory gases. Blood samples were taken from the ear lobe before and after each swim to analyze the blood lactate concentration (YSI 1500L, Yellow Springs, OH, USA). At Backstroke, Breaststroke and Butterfly strokes, increases of SF were associated to increases of *C*, even when controlling the *v*. The increases in SL only promoted significant decreases in the *C* in Breaststroke. There was a significant and polynomial relationship between *v* and SF for all competitive swimming techniques. The polynomial relationship between *v* and SL was significant only in Freestyle and Butterfly stroke. Partial correlations between *v* and SF controlling the effect of SL and between *v* and SL controlling the effect of SF, were positive and significant for all techniques. It is concluded that manipulation of stroke mechanics variables (SF and SL) may be one of the factors through which *C* in competitive swimming can be altered for a given *v*.

Keywords Swimming · Energy cost · Velocity · Stroke frequency · Stroke length

Introduction

Energy cost (*C*) has been described as a bioenergetical predictor of performance in human locomotion, in both terrestrial and aquatic environments (di Prampero 1986; Zamparo et al. 1992, 2005a, b; Alexander 2005). Traditionally, *C* is defined as the total energy expenditure required for displacing the body over a given unit of distance (Schmidt-Nielsen 1972; di Prampero 1986; Pendergast et al. 2003; Barbosa et al. 2005). *C* is related to mechanical efficiency and mechanical work, as expressed in the Eq. (1):

$$C = \frac{w_{tot}}{\eta_o} \quad (1)$$

C represents energy cost, w_{tot} total mechanical work per unit of distance and η_o overall efficiency. Another related important topic is propulsive efficiency (e.g., Toussaint 1992; Zamparo 2006). Only a fraction of the metabolic power can be utilized to displace the swimmer's center of mass. A fraction of the total mechanical work has to be used to accelerate and decelerate the limbs with respect to the center of mass and another fraction is wasted to accelerate water backwards (not useful for propulsion).

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