Eur J Appl Physiol (2005) 93: 519–523
DOI 10.1007/s00421-004-1251-x

ORIGINAL ARTICLE

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Energy cost and intracyclic variation of the velocity of the centre of mass in butterfly stroke

Accepted: 2 October 2004 / Published online: 17 December 2004

Abstract The purpose of this study was to examine the relationship between the intra-cycle variation of the horizontal velocity of displacement (dV) and the energy cost (EC) in butterfly stroke. Five Portuguese national level swimmers performed one maximal and two submaximal 200-m butterfly swims. The oxygen consumption was measured breath-by-breath by portable metabolic cart. A respiratory snorkel and valve system with low hydrodynamic resistance was used to measure pulmonary ventilation and to collect breathing air samples. Blood samples from the ear lobe were collected before and after each swim to analyse blood lactate concentration. Total energy expenditure (E_{tot}) and EC were calculated for each swim. The swims were videotaped in the sagittal plane with a set of two cameras providing dual projection from both underwater and above the water surface. The APAS system was used to analyse dV for the centre of mass. The E_{tot} increased linearly with the increasing V, presenting a significant correlation coefficient between these parameters ($r = 0.827$, $P < 0.001$). The increase in EC was significantly associated with the increase in the dV ($r = 0.807$, $P < 0.001$). All data were presented as the mean value and the standard deviation. It is concluded that high intra-cycle variation of the velocity of the centre of mass was related to less efficient swimming and vice versa for the butterfly stroke.

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Keywords Butterfly · Centre of mass · Energy cost · Velocity fluctuation

Introduction

Swimming at a fluctuating velocity leads to an increase in the amount of work done by the swimmer as compared to swimming at a constant velocity (Nigg 1983). This increase is related to the need for overcoming inertia, as well as hydrodynamic drag. However, the swimmer does not move at a constant velocity. Variations in the action of the arms, the legs and the trunk lead to variations in the swimming velocity in each stroke cycle. Whereas these movements are necessary to move the swimmer forward, they include elements which add to the necessary work done by the swimmer (Nigg 1983; D'Acquisto et al. 1998). However, less energy may be consumed with lower intra-cyclic variations in velocity. Thus, fluctuations in velocity within a stroke cycle should give an indication of the swimming efficiency (Barthels and Adrian 1975; Kornecki and Bober 1978).

Although numerous papers addressing the biomechanical (kinematical) and bioenergetic (energy cost) characteristics of different swimming techniques have been published, only a few approaches combine these two domains. Alves et al. (1996) analysed an attempt to explore the links between the intra-cycle variation of the horizontal velocity of displacement (dV) and the energy cost (EC) of swimming front crawl and backstroke. In backstroke, the correlation between the dV of the hip and the EC presented significant values at low velocities ($r = 0.78$ at 1.1 m.s^{-1} and $r = 0.66$ at 1.2 m.s^{-1}). In front crawl this relationship was non-existent at all velocities studied (Alves et al. 1996).

Vilas-Boas (1996) made a similar study of breaststroke. The overall correlation coefficient between the EC and an index of the dV from the hip was evaluated for all the swimmers and was not statistically significant.