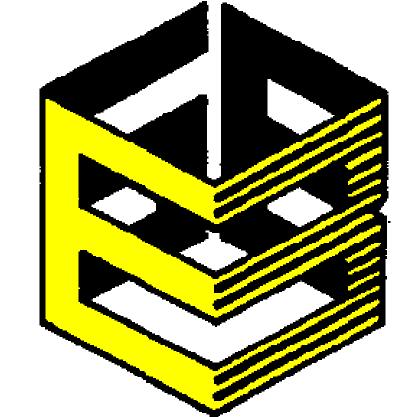
Relationships between energy cost, swimming velocity and speed fluctuation in elite butterfliers







T Barbosa¹, F Lima², A Portela², D Novais², A Lima², P Colaço², P Gonçalves², R Fernandes², KL Keskinen^{3,4}, JP Vilas-Boas²

Department of Sport Sciences, Polytechnic Institute of Bragança, Bragança, Portugal
 Faculty of Sport, University of Porto, Porto, Portugal

³ Finnish Society for Research in Sports and Physical Education, Helsinky, Finland

⁴ Department of Biology of Physical Activity, University of Jyväskylä, Jyväskylä, Finland

1. INTRODUCTION

understand the role of bioenergetical profile to performance. Most of those studies focused exclusively on the contribution of aerobic system to produce energy for movement, even though all competitive swimming events also require significant contribution from anaerobic energetic system to cover total energy expenditure.

of swimming techniques. There are some evidences of positive relationships between high dv and increased energy cost in Butterfly stroke (Barbosa et al. (2005). In this perspective, it is important to obtain a better understanding of this relationship.

Some investigators suggested that high dv is related with lower swimming velocities (e.g., Barbosa et al., 2005). It was

observed a significant and negative relationship between mean horizontal velocity and dv in Butterfly stroke (Togashi and Nomura, 1992). Nevertheless, there are no sufficient studies in the literature about the relationship between swimming velocity and dv, in this particular swimming technique.

The purpose of this study was to analyse the relationships between total energy expenditure (E-tot), energy cost (EC), intracyclic variation of horizontal velocity (dv) and mean swimming velocity (v) in elite butterfliers.

2. METHODS

Subjects. 4 elite butterfliers, including 3 males and 1 female were studied (19.5 \pm 3.3 years old; 66.5 \pm 10.7kg of body mass; 175.7 \pm 8.3-cm of height; 9.3 \pm 3.8% fat mass; 123.53 \pm 16.78 for 200-m butterfly best time in 25-m swimming pool).

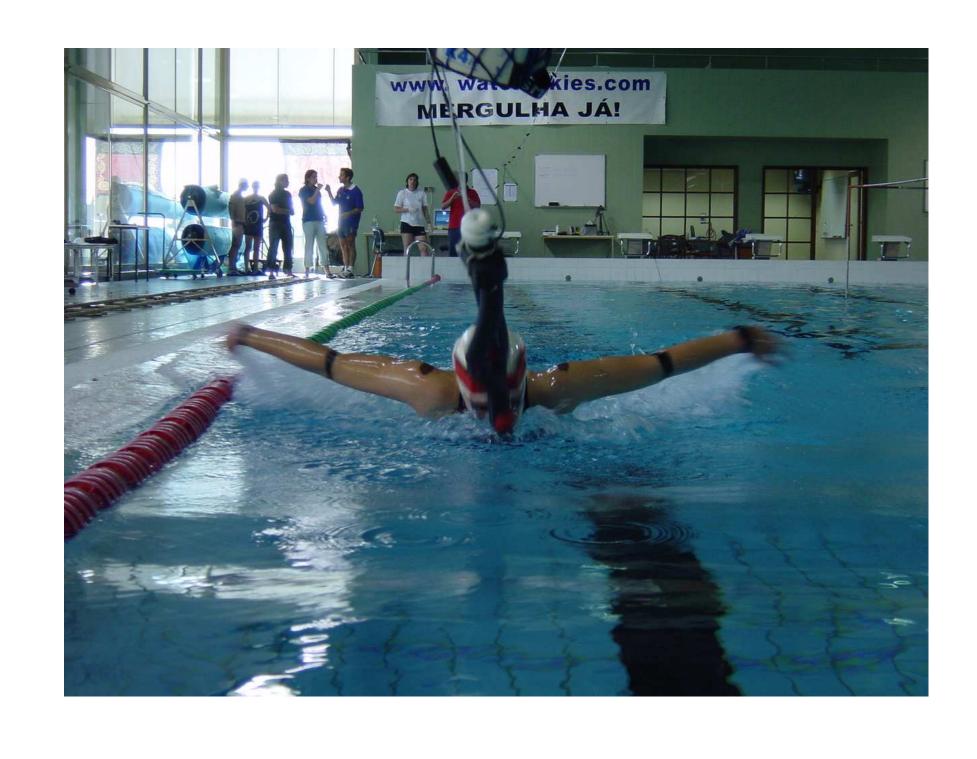
Design. The subjects were submitted to an incremental set of nx200-m swims. The velocities and increments were chosen in agreement with swimmers. The starting velocity was set at a speed, wich represented a low training pace, approximately 0.3 m.s⁻¹ less than a swimmer's best performance. The last trial should represent the swimmers all out pace. After each 200-m swim, the velocity was increased by 0.05 m.s⁻¹ until exhaustion and/or until the swimmer could not swim at the predetermined pace. The resting period between swims was 30-s to collect blood samples.

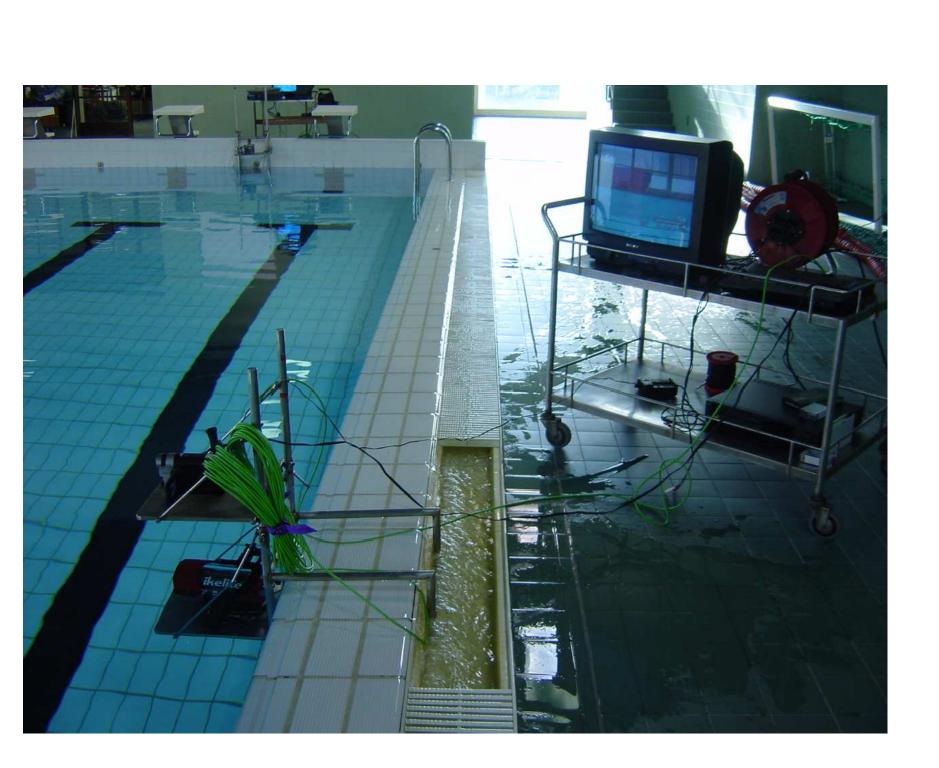
Under-water pace-maker lights (GBK-Pacer, GBK Electronics, Aveiro, Portugal) on the bottom of the 25-m pool, were used to control the swimming velocity and to help swimmers to keep an even pace along each step. In addition, elapsed time for each swim was measured with a chronometer to control the swimmer's velocity.

Data collection. The swimmers breathed through a respiratory snorkel and valve system (Toussaint et al., 1987; Keskinen et al., 2003), connected to a telemetric portable gas analyzer (K4 b², Cosmed, Rome, Italy). The oxygen consumption (VO₂) was measured for each swim breath-by-breath. Blood samples (25 µl) from the hyperemisized ear lobe were collected to analyze blood lactate concentration (YSI 1500 L, Yellow Springs, Ohio, USA) before and after each swim, as well as, 1, 3, 5 and 7 minutes after the last swim. Total energy expenditure (E-tot) was calculated using the VO₂ net and the blood lactate net (difference between the highest value measured in the end of the stage and the rest value), transformed into VO₂ equivalents using a 2.7 mlO₂.kg⁻¹.l⁻¹ constant (di Prampero et al., 1978). The energy cost (EC) was calculated dividing the E-tot by the swimming velocity (v).

The swims were videotaped (50 Hz) in sagital plane with a pair of cameras (JVC GR-SX1 SVHS and JVC GR-SXM 25 SVHS, Yokoama, Japan), providing a dual-media images from both underwater and above the water perspectives as described elsewhere (Barbosa et al., 2005). The images of the two cameras were real time synchronized and edited on a mixing table (Panasonic Digital Mixer WJ-AVE55 VHS, Japan) to create one single image. Ariel Performance Analysis System (Ariel Dynamics Inc, California, USA) and a VCR (Panasonic AG 7355, Japan) at a frequency of 50 Hz were used to perform a kinematical analysis of the stroke cycles, including the dv of the centre of mass. Zatsiorsky's model with an adaptation by de Leva (1996) was used with the division of the trunk in 3 articulated parts. A filter with a cut-off frequency of 5Hz was used for the analysis of the horizontal velocity curve of the centre of mass (Winter, 1990).

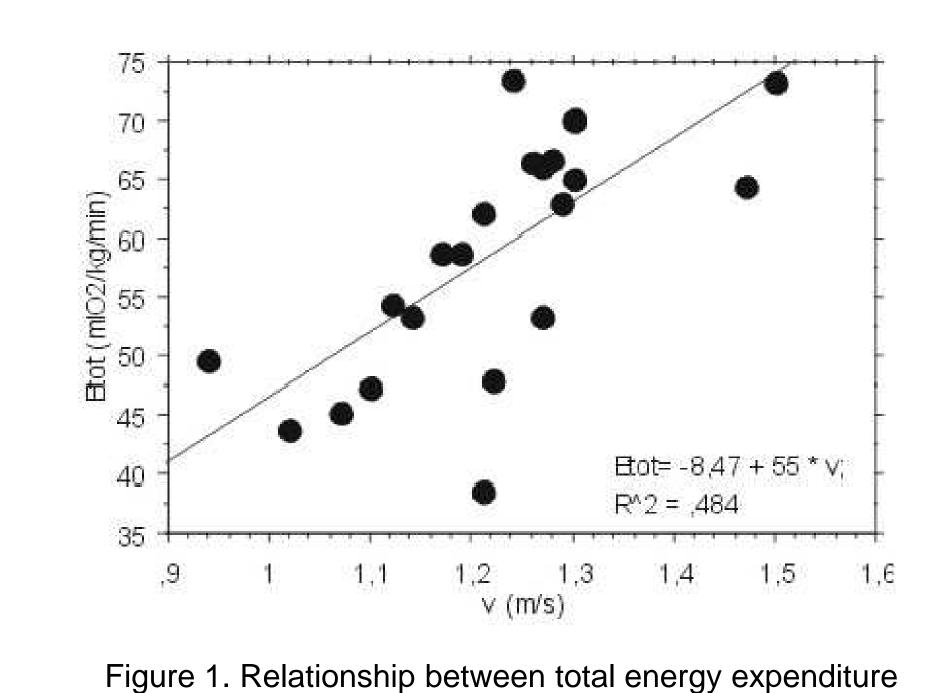
Statistical procedures. Means and standard deviations of all variables were calculated. Coefficients of variation for the horizontal velocity of the centre of mass along with the stroke cycle were calculated. Linear regressions between the E-tot and v, between EC and dv and polynomial regressions of 2nd order between dv and v were computed. Partial correlations between EC and dv controlling v and between EC and v controlling dv were also calculated. The level of statistical significance was set at P<0.05.





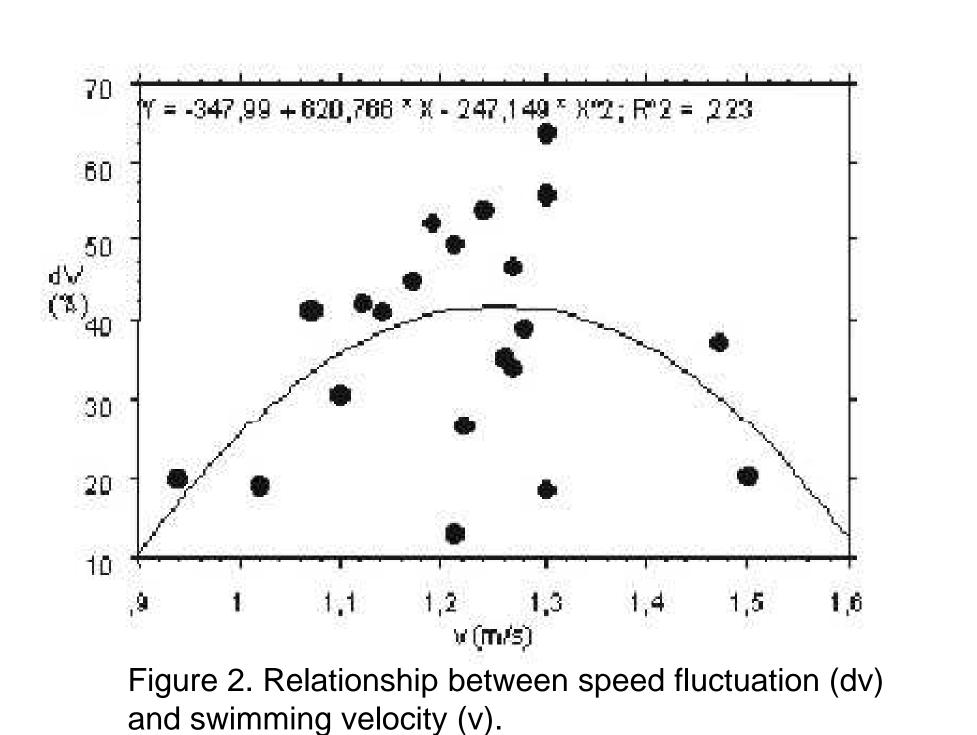
3. RESULTS

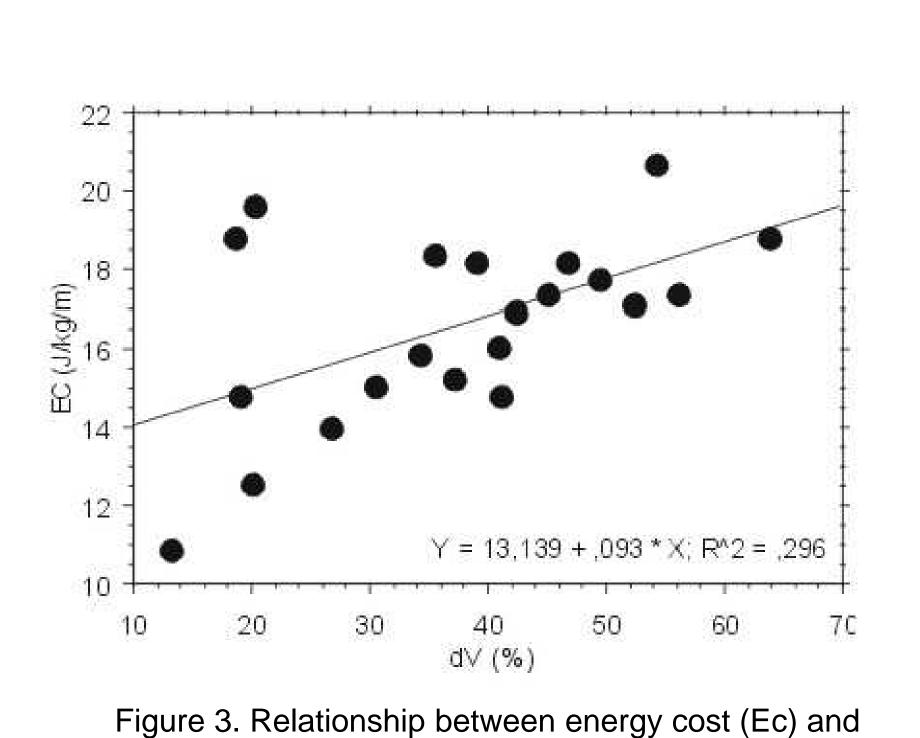
The individual correlations between E-tot and v ranged from R=0.95 (p=0.05) to R=0.90 (p<0.01). For pooled data the relationship was R=0.70 (p<0.01). The individual correlations between EC and dv controlling the effect of v ranged from R=0.99 (p=0.06) to R=-0.81 (p=0.09). For pooled data, the relationship between EC and dv was R=0.55 (p=0.01). The individual correlations between EC and v controlling the effect of dv ranged from R=0.92 (p=0.02) to R=-0.84 (p=0.36). When pooled data was plotted, it was observed a association of R=0.51 (p=0.02). The individual correlations between dv and v ranged from R=0.99 (p=0.04) to R=-0.83 (p=0.16). For pooled data, the relationship between dv and v was R=0.47 (p=0.05). Therefore, when analysed on individual bases, it is possible to observe different profiles between EC and dv, as well as, between EC and v. However, for pooled sample, it seems that increases of EC were related to increases of dv and v.



(E-tot) and swimming velocity (v).

speed fluctution (dv).





4. DISCUSSION AND CONCLUSIONS

relationship between dv and v was R=0.47 (p=0.05).

The purpose of this study was to analyse the relationships between E-tot, EC, dv and v in elite butterfliers. The main conclusion was that there are significant relationships between bioenergetical and biomechanical variables in butterfly stroke.

The individual correlations between E-tot and v ranged from R=0.95 (p=0.05) to R=0.90 (p<0.01). For pooled data the relationship was R=0.70 (p<0.01). E-tot was significantly related to increases in swimming velocity. The increase of E-tot is due to the necessity to overcome drag force, which is related to v (D = k.v2).

The individual correlations between EC and dv, controlling the effect of v, ranged from R=0.99 (p=0.06) to R=-0.81 (p=0.09). For pooled data, the relationship between EC and dv was R=0.55 (p=0.01).

The individual correlations between EC and v controlling the effect of dv ranged from R=0.92 (p=0.02) to R=-0.84 (p=0.36). When pooled data was plotted it was observed a relationship of R=0.51 (p=0.02).

Increases of the dv promoted significant increases of the EC. Speed fluctuation while swimming, as compared to swimming with constant velocity, leads to an increase in the amount of total energy expenditure done by the swimmer (Barbosa et al., 2005). Therefore, when analysed on individual bases, it is possible to observe different profiles between EC and dv, as well as, between EC and v. However, for overall sample, it seems that increases of EC was related to increases of dv and v.

The individual correlations between dv and v ranged from R=0.99 (p=0.04) to R = -0.83 (p= 0.16). For pooled data, the

Polynomial relationship between dv and v presented a better adjustment than the linear one. This phenomenon is described on regular bases for terrestrial locomotion (Minetti, 2000). The parabolic function is explained by the curve between force and velocity for neuromuscular activity (Enoka, 1988; Minetti, 2000). So, data suggests that the neuromuscular activation of several muscles in a multi-segment and multi-joint movement follows the force-velocity relationship pattern for a single joint system

5. REFERENCES

2.De Leva P (1996) Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. J Biomechanics 29: 1223-1230
3.Di Prampero P, Pendergast D, Wilson D, Rennie D (1978). Blood lactic acid concentrations in high velocity swimming. In: Eriksson B and Furberg B (eds). Swimming Medicine IV. Baltimore: University Park Press, 249-261.
4. Enoka R (1988). Neuromechanical Basis of Kinesiology. Illinois: Human Kinetics.
5. Keskinen KL, Rodríguez FA, Keskinen OP (2003). Respiratory snorkel and valve system for breath-by-breath gas analysis in swimming. Scand J Med Sci Sports, 13: 322-329.
6.Minetti A (2000). The three modes of terrestrial locomotion. In: Nigg B, MacIntosh B, Mester J (eds.). Biomechanics and Biology of Movement. Illinois: Human Kinetics, 67-78
7.Togashi T, Nomura T (1992). A biomechanical analysis of the novice swimmer using the butterfly stroke. In: MacLaren D, Reilly T, Lees A (eds). Biomechanics and Medicine in Swimming VI. London: E & FN Spon, 87-90.
8.Toussaint H, Meulemans A, de Groot G, Hollander AP, Schreurs A,Vervoon K (1987) Respiratory valve for oxygen uptake measurement during swimming. Eur J Appl Physiol 56: 363-366
9.Winter D (1990) Biomechanics and Motor Control of Human Movement. Chicheste: John Wiley and sons.

I. Barbosa TM, Keskinen KL, Fernandes R, Colaço P, Lima AB, Vilas-Boas JP. (2005). Energy cost and intracyclic variation of the velocity of the centre of