Calculation of Running Economy with a Biomechanical Model versus Indirect Calorimetry

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1 OBJECTIVES

The interest in running economy (RE) analysis, based on metabolic and biomechanical measurements, has increased during the last decades. In this study a new "body marker-free" (BMF) method (MotionMetrix Inc., Stockholm, Sweden), based on two depth sensitive cameras was used to capture the runners motion during treadmill running. A 3D segment model was generated and after kinematic and kinetic analysis a number of running parameters were derived. Running economy is originally defined as the metabolic cost from measurement of oxygen uptake (VO_2) in $mL \cdot kg^{-1} \cdot min^{-1}$ at submaximal and steady state velocities (Costill et al., 1970) and is here compared to energy expenditure (EE) in $J \cdot kg^{-1} \cdot min^{-1}$, derived from the new biomechanical model (BM).

2 METHODS

Seven well trained middle- and long distance runners, with an average mass and height of 68.7 ± 3.9 kg and 187.7 ± 5.2 cm, respectively and a VO_2 max of 67.8 ± 5.1 $mL \cdot kg^{-1} \cdot min^{-1}$, volunteered in the study according to the Helsinki Declaration. Four submaximal (12, 14, 16 and 18 $km \cdot h^{-1}$) speeds were performed on a high precision treadmill. VO_2 was measured with a validated metabolic chart (OxyconPro, CareFusion GmbH, Germany) in the mixing chamber mode. Simultaneously the motions were captured with the new BMF method. The new biomechanical model used body segments movements which were calculated to represent one whole centre of mass movement (Willems et al., 1994, Cavagna and Kaneko, 1977).

3 RESULTS

The correlation coefficient calculated between VO_2 related to body mass ($mL \cdot kg^{-1} \cdot min^{-1}$ and $mL \cdot kg^{-0.75} \cdot min^{-1}$) and BM EE were 0.854 and 0.856, respectively and were significant (Figure 1). When the biomechanical rate of energy expenditure was related to VO_2 expressed in $L \cdot min^{-1}$ the correlation coefficient was still high with a significant p-value of 0.834. Furthermore, using the OxyconPro software to get EE ($kcal \cdot day^{-1}$) from VO_2 and calculated to $J \cdot kg^{-1} \cdot min^{-1}$, based on the de Weir formula (de Weir, 1949), resulted in a similar correlation. Even though a strong correlation was found, the EE values derived from the 2 methods differed 20-40 % (Coefficient of Variation 7.8%) and were related to both individual athletes as well as running speeds (Figure 2).

4 DISCUSSION

To calculate RE by means of biomechanical variables with the BMF method is of great interest. This method allows evaluation of RE without manual attaching of body markers and using expensive respiratory equipment. Thus the participants are not connected to any measurement device that may be related to restrictions in running. In addition, interesting data for evaluating RE such as stride rate, stride length, foot contact time and vertical displacement can be obtained. These are possible biomechanical factors influencing the RE. Unexpectedly, specifically the centre of mass (CoM) vertical displacement (V_{disp}) data in this investigation showed a low, not significant correlation to VO_2 - derived RE. CoM V_{disp} is in the literature regarded as one of the more important sub factors influencing the running economy (Williams and Cavanagh, 1987). Nevertheless, the BM EE and VO_2 values showed a strong correlation.

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When translating EE from VO_2 data and comparing to the BM calculated EE, although strongly correlated, we found significant differences ranging from 20-40%. There may be several biomechanical reasons for this discrepancy. For example, it is unknown if the model accounts for stored elastic energy in stretch-shortening cycle components, which would add to the BM EE and reduce the difference.

However promising, we intend to further validate the actual method against a more sophisticated optoelectronic set up with multi joint reflectors, which may be regarded as a biomechanical gold standard.

4.1 Figures

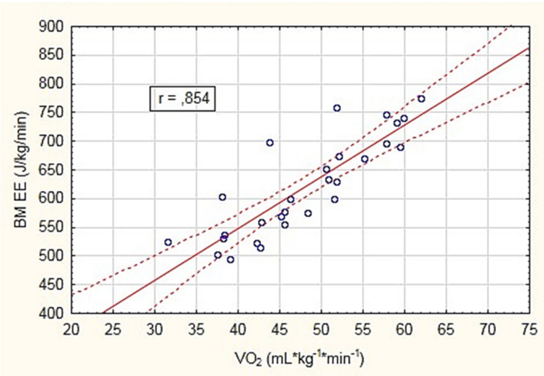

Figure 1: BM calculated EE compared to VO_2 during running at 12, 14, 16 and 18 km·h^{-1}.

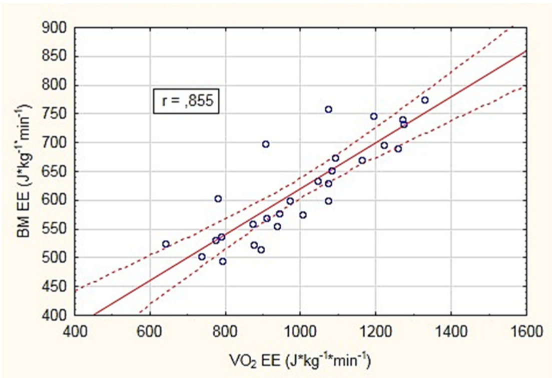

Figure 2: BM calculated EE compared to VO_2 based EE during running at 12, 14, 16 and 18 km·h^{-1}.

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