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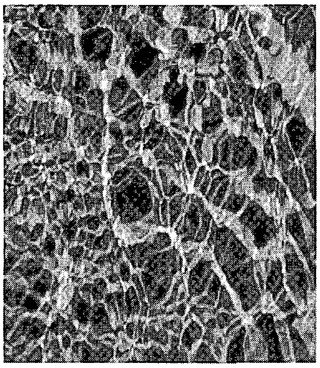

Anthropometric and Physiological Responses to Prolonged Open Water Rowing: A Case Study

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The objective of the study was to examine the anthropometric and physiological responses to a prolonged period of open water rowing 4950 km. A single male (novice) rower underwent assessment of anthropometric variables, pre- and post-race, for the assessment of mass (kg), girths of selected regions, skinfold thickness and regional muscularity. The results showed that following ~61 days of continual rowing there was a decrease in the participant's mass by 11.7%, sum of skinfolds decreased by 19.5 cm and regional muscularity decreased by 11.1%. The data would suggest that the participant exhibited symptoms of muscle atrophy and energy deficit. It was concluded that poor dietary intake and the ability of the participant as a rower produced the significant changes in body composition. These data have profound implications when devising both training programs and dietary programs for athletes competing in such extreme events.

In a previous study (Gordon, 2003) the metabolic cost to prolonged open water rowing was demonstrated. The results highlighted that the energy cost per day was in the region of 43249 ± 15391 kJ^{-1}. Furthermore the results indicated using linear regression analysis that there was an energy deficit per day of 18133 $kJ.d^{-1}$. For ultra endurance athletes there are two major concerns; maintaining an adequate calorie intake and also avoiding dehydration. As Benson, Gillien, Bourdet, and Loosli (1985) highlight the detrimental effects of inadequate nutrition are: ketonuria; hypoglyeamia; decreased urinary output; weakness; fainting; loss of electrolytes, minerals and lean tissue; glycogen depletion and an increased risk of injury. All of these physiological responses would result in a decreased level of exercise performance. Hill and Davies (2001) determined the metabolic cost of running 14,500 km in 195 days and showed a loss in body mass of 1.5 kg. Furthermore McMurray, Proctor, and Wilson (1991) showed that when energy intake was restricted to less than 135 $kJ.Kg.d^{-1}$ there was a resultant loss in body mass of between 0.5 and 1 kg/week.

For ultra endurance athletes there are two major concerns; maintaining an adequate calorie intake and also avoiding dehydration.

To date there has been little research conducted to examine the physiological and anthropometric responses to extreme prolonged open water rowing. Therefore the purpose of this study was to examine the effects of a prolonged period of open water rowing on selected anthropometric variables, in relation to energy balance.

Method

Participant

One male athlete (age 29, body mass 109 kg, height 175 cm) participated in the current study. Written informed consent was given prior to commencement of testing, in accordance with the institutional human subjects guidelines (Anglia Polytechnic University).

Assessment of Anthropometric Variables

Skinfold thickness, body mass and selected girths were determined 24 hr prior to the commencement of the race, and within 1 hr of completion of the race. Skinfold thickness was assessed using a set of pre-calibrated skinfold callipers (Harpenden, British Indicators, UK) a pair of pre-calibrated portable scales (Seca UK) were used to determine body mass.

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For the determination of skinfold thickness the four-site method of Durnin and Wormesley (1974) was used measuring skinfold thickness of the biceps, triceps, subscapular and suprailiac. In addition to these four measurements, skinfold thickness was calculated at the thigh and medial calf. All measurements were conducted three times at each landmark on the right hand side of the participant, with a minimum of two min between each measurement (Eston & Reilly 2001).

The assessment of body girths were conducted using a flexible steel tape according to the methods of Gore (2000) at six sites; upper arm (flexed); forearm; chest; waist; thigh and medical calf, with the greatest value recorded taken as representing the girth.

Assessment of Muscle Mass and Regional Muscularity

Using the method of Martin, Spenst, Drinkwater, and Clarys (1990), muscle mass of the participant was calculated both pre- and post-race, as presented in equation 1.

Equation 1

$M(kg) = [ht \times (0.0553CTG^2 + 0.0987FG^2 + 0.0331CCG^2) - 2445] \times 0.001$

where:

ht = stature in cm; CTG = corrected thigh girth (equation 2); FG = maximum forearm girth; CCG = corrected calf girth (equation 3)

Equation 2

CTG = thigh girth – _ (front thigh SF/10) where SF = skinfold thickness cm

Equation 3

CCG = calf girth – _ (calf girth SF/10) where SF = skinfold thickness cm

Assessment and Calculation of Energy Expenditure

Two weeks prior to the commencement of the race maximal oxygen uptake (VO_2max) and the submaximal oxygen cost of rowing were determined using open circuit spirometry. Also measured were heart rate (HR) and lactate turn-point (LTP). Throughout the duration of the race the participant recorded exercise and resting heart rates bpm^{-1} (Sports tester, Polar Electro, Kempele, Finland). Using linear regression interpolation the metabolic cost of the race was estimated. Energy expenditure (kJ^{-1}) was determined using the formula of Weir (1948). For a more detailed explanation of the methods employed, refer to Gordon (2003).

Results

The total distance rowed was 4950 km and was completed in 61 days, 2 hr, 43 min. Mean distance covered per day was 78.5 ± 8.9 km. The participant's sum of skinfolds decreased by 24.9% from a pre-race value of 56.5 cm. to a post-race value of 37.2 cm. Table 1 shows the skinfold thickness for the four sites, pre and post race.

Table 1

	BI	TR	SS	SI
Pre	5.7	6.2	21.0	23.6
Post	4.8	11.2	11.0	10.2

BI = biceps; TR = triceps; SS = Subscapular; SI = suprailiac; all vales in mm

The mass of the participant showed substantial change decreasing from a pre-race value of 107 kg to a post-race value of 95.5 kg. The values obtained from the selected body girths are presented in Table 2.

Table 2

	UA	FA	C	W	T	MC
Pre	37.5	31.0	110.5	102.0	69.0	44.5
Post	33.0	30.2	110.5	98.3	64.0	40.0

UA = upper arm; FA = forearm; C = chest; W = waist; T = thigh; MC = medical calf; all in cm

Using the equations of Martin et al. (1990), regional muscle mass and muscularity were determined pre- and post-race. Pre-race muscle mass was 67.8 kg and decreased to a value of 60.3 kg post-race, with fat mass also decreasing from 21.6 to 14.5 kg, a decrease of 33%. Mean energy expenditure and metabolic data obtained from the race are presented in Table 3.

Table 3

	HR	VO_2	KJ	RER	PO
Exercise	109.2	2.3	46.8	0.87	164.5
SD +/-	14.7	0.6	14.2	0.03	48.2
Rest	73.1	0.87	13.0	0.78	
SD +/-	7.6	0.03	7.07	0.02	

All values represent mean data; HR bpm^{-1}; VO_2 $l \cdot min^{-1}$; $KJ \cdot min^{-1}$; PO = Power output (W)

SD = one standard deviation

The mean $kJ.day^{-1}$ energy expenditure was 43249 ± 15391, with the participant consuming ~25116 $kJ{\cdot}d^{-1}$. This resulted in an energy deficit of 18133 $kJ.d^{-1}$.

Discussion

This study showed that following rowing for ~61 days there was a decrease in lean body mass (LBM) of 5.2%. Further the data suggested that a large factor in the reduction in LBM was muscle atrophy as highlighted by the 11.1% decrease in muscle mass and regional muscularity. According to Horswill, Park, and Roemmich (1990), a reduced carbohydrate and or protein intake can induce losses of body proteins and muscle glycogen. Furthermore Van Dale, Schrijver, and Saris (1990) highlighted that reductions in dietary macro-nutrients can cause disturbances in micro-nutrient content. The outcome of this would be a potential loss of specific vitamins (thiamin; riboflavin; vitamin B6; magnesium; iron and zinc), the principle vitamin and mineral elements needed as enzyme activators in muscle metabolism (Fogelholm, Koskinen, Laakso, Rankinen, & Ruokinen, 1993). The resultant effect on performance would be an increased integrated Electromyographic (IEMG) level associated with greater motor unit recruitment (Gibala et al 1995), and an increased oxygen cost of exercise (Astrand & Rohdal, 2003).

It is well established that resistance-based exercise promotes muscle hypertrophy and fibre-type proliferation (Gibala et al., 1995). The outcome of such exercise is an increase in isotonic and isometric strength (Astrand & Rohdal, 2003). Beyond an initial 6 weeks of resistance training increases in cross sectional area (CSA) and girth size have been reported (Sale, 1988). In the present study, however, it was demonstrated that the participant experienced a decrease in skinfold thickness (24.9%); muscle mass (11.1%) and mass (10.8%). This would appear to be consistent with previous findings by Mayer, Marshall, Vitale, Christensen, Mashayekhi, and Stare (1954) which showed that in both rats and humans who were exposed to regular exercise in excess of 6 hr/day, there was a decrease in energy intake compared to resting values. As a result there was a subsequent reduction in body mass and exercise performance. As the participant was exposed to 12 hr/day^{-1} of resistance based exercise (rowing), it would be expected that there would have been selected hypertrophy of the engaged muscles. According to Shephard (1998), the involved muscle groups in rowing are the quadriceps; hamstrings; biceps; triceps and pectorals. The data though would suggest that rather than developing selected hypertrophy of the engaged muscles there was a degree of atrophy. The girth data shows an overall decrease in girth diameter of 4.7%. A probable explanation for the decrease in active muscle mass could be that the participant experienced a significant energy deficit 18133 $kJ.d^{-1}$.

To date there has been very little research conducted to examine the long-term effects of dietary restriction on body composition and exercise capacity. During a meta-analysis, Ballor and Poehlman (1995) demonstrated that a restriction in dietary intake resulted in a $0.59kJ.min^{-1}$ reduction in resting metabolic rate (RMR). When this was normalised for body weight this equated to a 2% reduction in RMR. Furthermore Ballor, Tommerup, Smith, and Thomas (1990) showed that in 48 Sprague-Dawley rats the level of dietary restriction had an effect on the ability of exercise training to elicit conservation of both LBM and the mass of the individual muscles. They demonstrated exercise training resulted in a conservation of lean mass at a moderate level of dietary restriction, but not at a severe level. This would appear consistent with the present case study where a combination of exercise and diet restriction, as evidenced by the energy deficit, resulted in a reduction in LBM, fat mass and regional muscularity.

The energy cost of rowing can largely be attributed to drag and wind resistance that together oppose the forward motion of the boat (Secher, 1993). Furthermore, Shephard (1998) suggests that smaller resistance and gravitational costs can be attributed to the back and forth movement of the body on the seat. The energy cost of rowing is though further dependent on the skill of the rower, indeed Affeld, Schict, and Ziemann (1993) have suggested that depending on the skill of the rower between one quarter and one third of the energy applied to an oar is lost in the flow of the water around the blade. The participant involved in this study was a physically active, non-competitive rower who would therefore potentially exhibit ~10% less mechanical efficiency than a more experienced rower (Nelson & Widule, 1983). Therefore it could be argued that in comparison to a more experienced rower, the participant would have an increased oxygen cost per stroke. Indeed Daireaux (1983) demonstrated that novice rowers sustain Electromyographic (EMG) activity for longer than experienced rowers.

The data would suggest that as the duration of the race increased the efficiency of the participant decreased. In the initial stages any energy deficit that occurred would have had a negligible effect on either the metabolic or physiological responses. The energy deficit would however become greater as the intramuscular stores of glycogen, free fatty acids, and even protein are metabolised without sufficient replenishment. The resultant outcome on performance would be that to cover the same distance the participant would be exposed to a greater metabolic cost. As the duration of the race increased the availability of glycogen would appear to have decreased and so protein and Free Fatty Acids (FFA's) would have become significant contributors to energy supply. This is supported by the present data, which shows that from the Respiratory Exchange Ratio (RER) data (0.83) that the predominant metabolic substrate was in the form of fat. Throughout the race the participant's macro-nutrient consumption was ~65% fat; 35% carbohydrate and 10% protein. The data would therefore suggest that the macronutrient composition was correct, but there was clearly an underestimation in the total energy intake to be consumed, as evidenced by the large changes in anthropometric measures.

Recently concern has been raised as to the use of anthropometric body mass fractionation techniques (Cattrysse, Zinzen, Caboor, Duquet, Van Roy, & Clarys, 2002) such as those used in this study to assess regional muscularity. It has been suggested that the method of Martin et al. (1990) develops an overestimation in the mass of the participant, in the order of 22%, when compared against assessed body mass techniques. This point not withstanding, the method of Martin has been useful to show the percentage change in regional muscularity, and the overestimation suggested by Cattrysse et al. is relative and would be the same both pre- and post-race.

This study has presented data as to the anthropometric and physiological responses to ~61 days of open water rowing. Despite undertaking resistance based work (rowing) for the duration of the race the participant exhibited a profound reduction in mass, fat mass, and regional muscularity. From the data it would appear that the overriding reason for this was an energy deficit of 18133 $kJ.d^{-1}$. This in combination with the ability of the novice participant led to an increased oxygen cost per stroke and a greater metabolic demand. These results have implications for any form of activity where the participant is exposed to extremes of energy expenditure and suggest that in such situations care be taken in the preparation of provisions so as to reduce the onset of rapid weight loss and skeletal muscle atrophy.

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