Preparation of Former Heavyweight Oarsmen to Compete As Lightweight Rowers Over 16 Weeks: Three Case Studies

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To strengthen the depth of lightweight rowing talent, we sought to identify experienced heavyweight rowers who possessed physique traits that predisposed them to excellence as a lightweight. Identified athletes \( n = 3 \) were monitored over 16 wk. Variables measured included performance, anthropometric indices, and selected biochemical and metabolic parameters. All athletes decreased their body mass (range 2.0 to 8.0 kg), with muscle mass accounting for a large proportion of this (31.7 to 84.6%). Two athletes were able to maintain their performance despite reductions in body mass. However, performance was compromised for the athlete who experienced the greatest weight loss. In summary, smaller heavyweight rowers can successfully make the transition into the lightweight category, being nationally competitive in their first season as a lightweight.

**Key Words:** weight loss, body composition, athlete, ergometer

Aside from the requirement to achieve a pre-determined body mass, successful lightweight and heavyweight rowers share similar physiological traits. Both groups are characterized by high aerobic capacities and a high proportion of slow twitch skeletal muscle fibers (30). While anthropometric data suggest lightweight rowers are shorter and leaner, less mesomorphic and more ectomorphic than their heavyweight counterparts (26), some heavyweight rowers possess similar anthropometric traits to lightweight oarsmen. Furthermore, data consistently show that larger and more muscular lightweight oarsmen are more likely to succeed in international competition (26). Thus, recruitment of heavyweight rowers with the potential of...
achieving the lightweight rowing weight specification would reasonably place these athletes at a competitive advantage over smaller and lighter opponents.

It has been suggested that success at an elite athletic level demands upwards of 10 y experience (5). This is likely to be particularly so in rowing due to the high skill and technical demands of the sport. This considered, the identification of potential lightweight rowers from within the existing heavyweight rowing community ensures the performance potential of an athlete could be somewhat fast tracked, as the oarsman would already possess many of the skills required for competitive success. That is, the talent could be transferred (10) so long as the athlete is able to manipulate their weight and achieve specified body mass limits. This rapid interdisciplinary or within discipline transfer of talent from within one comparable sport to another has been successfully undertaken previously; most notably between rugby union and rugby league in the football codes.

The primary aim of the present investigation was to support and monitor a group of relatively small but experienced heavyweight rowers as they decreased their body mass to qualify as lightweight rowers for the first time.

**Methods**

Three male heavyweight oarsmen competing in the Australian Rowing Championships were invited to participate in the present study. Prior to acceptance into the 16 wk program, volunteers had their physique traits assessed and completed a questionnaire that sought responses relating to issues such as body mass/composition history (including typical variation in mass over a competitive season). In addition, current dietary and training practices were recorded. None of the volunteers had previously raced in the lightweight division but all were experienced oarsmen and naturally “light” heavyweights. Given the maximum weight limit of 72.5 kg for the male lightweight category, individuals with a body mass in excess of 82 kg were not considered for inclusion in the investigation as the rate of weight loss necessary to qualify as lightweight rowers was likely to approach or exceed current recommendations (14). Volunteers were fully informed of the nature and possible risks of the investigation before giving their written informed consent. The investigation was approved by the Human Research Ethics Committee of the Australian Institute of Sport (AIS).

Volunteers attended the AIS on three separate occasions (each separated by 8 wk) over a 16 wk period. During this time, each athlete worked closely with support staff, including a physiologist, dietitian, and psychologist. Dietary and training recommendations proposed by support staff were in accordance with current guidelines (24). Prescription of rowing training during this time remained the responsibility of each athlete’s coach, all of whom were fully informed of the goals of the investigation. In addition to the support and advice offered to assist athletes in achieving the specified body mass limit imposed by the International Federation of Rowing Association (FISA), volunteers also undertook a number of routine tests that provided information relating to maximal rowing performance, peak oxygen uptake, resting metabolic rate (RMR), and body composition. In addition, blood was sampled for the analysis of various biochemical markers.
Progressive Maximal Ergometer Test
On their first visit to the laboratory, athletes performed a progressive maximal test on a rowing ergometer (Concept 2, Morrisville, VT). The test protocol was modified from that previously described (12) and consisted of three submaximal workloads and one maximal workload, each of 4 min duration and separated by 1 min recovery intervals. Throughout the testing period, mixed expired air passed through a fully automated, first principles, indirect calorimetry system (Australian Institute of Sport, Belconnen, ACT, Australia). The operation of this system has been described elsewhere (28). $\text{VO}_2^{\text{peak}}$ was defined as the highest $\text{O}_2$ uptake athletes attained during two consecutive 30 s sampling periods. In our laboratory this technique has a typical error of 1.8%.

Resting Metabolic Rate
Following a familiarization session the day before, volunteers presented to the laboratory soon after waking, in a fasted state. To minimize variation in resting metabolic rate, volunteers were requested to perform no exercise in the previous 12 h and to standardize other exercise undertaken in the previous 36 h. They were also requested to standardize dietary intake in the previous 24 h and ingest no caffeine during this time.

RMR was measured while volunteers rested in a supine position with their head and shoulders slightly elevated, in a darkened room maintained at 22 °C. After 20 min of bed rest, the breathing apparatus (comprising a mouthpiece, respiratory valve, and 120 L Douglas bag) and noseclip were attached. Following a further 10 min of bed rest, expired gas was collected for 10 min, ensuring the collection period was initiated at the end of a respiratory cycle. A 350 L tissot tank was used to quantify gas volumes; the gas mixture was first passed through CO$_2$ and O$_2$ analyzers (Amatek, Pittsburgh, PA), both of which were calibrated daily using three alpha gases spanning the physiological range. Following the initial analysis, a second sample was collected over another 10 min period and analyzed using the same procedures. The equation of Elia and Livesey (4) was used to calculate RMR values (kJ/24 h) for the two collection measurements, which were subsequently averaged. In our laboratory this technique has a typical error of 2.3%.

Biochemistry
Immediately following measurement of RMR, 8 mL of venous blood was sampled via venipuncture from a superficial forearm vein into a serum separation tube using standard phlebotomy procedures and centrifuged at 4500 rpm for 5 min. The resultant serum was stored at –20 °C and later analyzed for pre-albumin (pre-ALB), insulin like growth factor-1 (IGF-1), $\beta$-hydroxy butyrate ($\beta$-HB), cortisol, and total triiodothyronine (T$_3$) using techniques previously described (31). Upon waking, urine samples were collected each day while in attendance at the AIS. Hydration status was monitored via the measurement of urinary osmolality (OSM) using the freezing point depression method on an Osmomat 030-D cryogenic osmometer (Gonotec, Berlin, Germany).
Body Composition

Full anthropometric profiles, including body mass, skinfolds at eight sites, eleven girths, twelve lengths and six breadths were measured by an International Society for the Advancement of Kinanthropometry (ISAK) accredited level III anthropometrist with technical errors of measurement of 1.7% for skinfolds and ≤ 1% for all other measures, using techniques previously described (23). All measurements were made on the right side of the body. The full anthropometric profile was undertaken in duplicate. If the difference between duplicate measures exceeded 5% for skinfolds or 1% for any other parameter, a third measurement was taken but only after the full profile had been completed in duplicate. The mean of duplicate or median of triplicate measurements were used for all subsequent analyses. Anthropometric variables were used to create a four-way fractionation of body mass, partitioning total body mass into fat mass, muscle mass, bone and residual mass using the phantom model (3).

Other Variables

Rowing performance was assessed using a 2000 m ergometer time trial on the final day of each attendance, as described previously, inclusive of a standardized warm-up (33). In our laboratory this test has a typical error of 1.6%. Training was standardized for the week prior to, and during each attendance at the AIS. Volunteers were required to maintain training diaries throughout the investigation. Completion of periodic food diaries was also required, which were later analyzed by a qualified dietitian using the Foodworks dietary analysis program (version 3.02, Xyris Software, Brisbane, Australia). Dietary intake was standardized for the 24 h prior to and throughout assessment periods at the AIS.

Results

Descriptive data of the three athletes at the start of the investigation are presented in Table 1. Data of both lightweight and heavyweight oarsmen who competed at the Sydney 2000 Olympic Games are also included for comparison (1). Changes in selected physique traits throughout the 16 wk investigation are presented in Figure 1. Excluding somatotype, athletes in the present investigation more closely resembled Olympic lightweight oarsmen than heavyweight rowers. Body mass loss during the investigation ranged between 2.0 and 8.0 kg; muscle mass accounted for a large proportion of this absolute loss (Case 1: 84.6%, Case 2: 59.1%, Case 3: 31.7%). Athletes with the lowest initial body fat stores incurred the greatest proportional loss of muscle mass.

Changes in performance, VO\textsubscript{2peak} and RMR over the same time period are presented in Figures 2 and 3 respectively. When expressed relative to body mass (Case 1: 0.0; Case 2: 4.0; Case 3: 3.5 mL · kg\textsuperscript{-1} · min\textsuperscript{-1}) or muscle mass (Case 1: 7.0; Case 2: -1.9; Case 3: 2.1 mL · kg\textsuperscript{-1} · min\textsuperscript{-1}), aerobic capacity tended to increase with training. Case 2 experienced the largest reduction in muscle mass and greatest performance decrement during the investigation. This association between loss of muscle mass and performance was also in evidence for the other two athletes. A similar trend was observed for RMR. Training load and nutrient intake data are
Table 1  Descriptive Characteristics, Including Anthropometric Traits, of Volunteers At the Start of the 16 Week Investigation. Anthropometric Characteristics of Lightweight and Heavyweight Oarsmen Who Competed in the Sydney 2000 Olympic Games Are Included for Comparison (1)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Case</th>
<th>Olympic oarsmen (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Age (y)</td>
<td>20.1</td>
<td>22.6</td>
</tr>
<tr>
<td>VO$_2$ peak (L/min)</td>
<td>4.7</td>
<td>4.6</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>181.4</td>
<td>180.7</td>
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<tr>
<td>Sitting height (cm)</td>
<td>95.7</td>
<td>91.2</td>
</tr>
<tr>
<td>Arm span (cm)</td>
<td>182.9</td>
<td>195.0</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>77.3</td>
<td>77.3</td>
</tr>
<tr>
<td>Sum 8 skinfolds (mm)</td>
<td>39.7</td>
<td>66.7</td>
</tr>
<tr>
<td>Endomorphy</td>
<td>1.4</td>
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</tr>
<tr>
<td>Mesomorphy</td>
<td>5.1</td>
<td>5.7</td>
</tr>
<tr>
<td>Ectomorphy</td>
<td>2.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Flexed arm girth (cm)</td>
<td>34.9</td>
<td>33.6</td>
</tr>
<tr>
<td>Chest girth (cm)</td>
<td>105.7</td>
<td>100.5</td>
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<td>Waist girth (cm)</td>
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<td>Hip girth (cm)</td>
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<td>Thigh girth (cm)</td>
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<td>Forearm length (cm)</td>
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<td>28.2</td>
</tr>
<tr>
<td>Thigh length (cm)</td>
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<td>49.6</td>
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<tr>
<td>Lower leg length (cm)</td>
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<td>48.3</td>
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<td>A-P chest depth (cm)</td>
<td>18.8</td>
<td>18.6</td>
</tr>
<tr>
<td>Shoulder breadth (cm)</td>
<td>41.1</td>
<td>42.0</td>
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<tr>
<td>Elbow breadth (cm)</td>
<td>7.2</td>
<td>7.6</td>
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<tr>
<td>Knee breadth (cm)</td>
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</tr>
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</table>
presented in Figures 4 and 5 for each individual. Average daily training load was similar for Cases 1 (118.4 min) and 3 (120.0 min) but greater than Case 2 (96.5 min) throughout the investigation. Energy intake averaged 201 (range 193 to 219), 127 (116 to 145) and 108 kJ/kg (88 to 124) for Cases 1 to 3 respectively, while protein intake averaged 2.6 (2.6 to 2.6), 1.4 (1.2 to 1.8) and 1.6 g/kg (1.4 to 1.8) during the periods of assessment. Biochemical parameters remained relatively stable throughout the investigation (Figure 6).

Only Case 2 achieved the maximum specified body mass limit of 72.5 kg required to race as a lightweight rower during the 16 wk investigation. While the other two athletes did race as lightweights over subsequent months, it is not known how their remaining body mass losses were achieved or the performance implications of this. Upon completion of the investigation, all three athletes secured scholarships with their respective state academy/institute of sport. Case 3 was

![Figure 1](image_url)  
**Figure 1**—Changes in (a) body mass, (b) muscle mass and (c) fat mass throughout the 16 wk investigation. Muscle and fat masses were calculated using the equations of Drinkwater and Ross (3).
selected in the national team to compete in the subsequent World Championships in his first year as a lightweight.

**Discussion**

The primary finding of this investigation is that smaller, experienced heavyweight rowers can successfully make the transition towards the lightweight maximum weight limit, with only a small impact on overall performance. We have also shown that any loss of body mass among already lean individuals results in a decrease in both fat and muscle mass. The proportion of total body mass loss derived from muscle is likely related to the rate of body mass loss or degree of energy deficit induced through training/dietary intervention and initial body fat stores; athletes with lower body fat levels losing proportionally more muscle mass. These
Figure 4—Average weekly training volume undertaken by volunteers during the 16 wk period of observation. “Other” primarily involved running, cycling, and other cross-training activities.

Figure 5—Average weekly nutrient intake as estimated via 7-d food diaries.
Figure 6—Changes in (a) triiodothyronine ($T_3$), (b) cortisol, (c) insulin like growth factor-1 (IGF-1), (d) $\beta$-hydroxy butyrate ($\beta$-HB), and (e) pre-albumin (pre-ALB) concentrations throughout the 16 wk period of planned weight loss.
reductions in muscle mass may have been associated with compromises in both RMR and 2000 m rowing ergometer time trial performance observed in the present investigation.

The proportionally high loss of muscle mass experienced by volunteers in the present investigation is similar to that observed by our group among 17 nationally competitive lightweight rowers over a three month period as they prepared for the Australian Rowing Championships (unpublished observations). Using the same method of monitoring physique changes, muscle mass accounted for three-quarters of the total body mass loss. Among this larger population of lightweight oarsmen, a negative correlation was found between initial body fat stores and proportional muscle mass loss \( r = -0.54, P = 0.04 \) i.e., those with the lowest estimates of body fat had the greatest loss of muscle mass. Similar proportional losses of fat free mass have been observed among elite lightweight oarswomen (20), independent of whether the weight loss was achieved over two or four months (16). This suggests that loss of fat free mass may be inevitable among athletes with already very low body fat levels. Reductions in fat free mass have also been observed among wrestlers and physically active individuals adhering to energy restricted meal plans over as short a time as 2 to 3 wk (22, 37) and up to 16 wk (27). While reductions in muscle mass associated with body mass loss over a competitive season are not always reported among lightweight rowers (21), the present data are consistent with the observations of Forbes (7), who suggests that a change in one physique component (i.e., lean or fat) is typically associated with a change in the other, and generally in the same direction.

When attempting to minimize the loss of muscle mass associated with reductions in body mass, the degree of energy deficit and time frame available for body mass loss are critical (7). Assuming energy expenditure associated with normal daily activities and rowing training to be \( \sim 6000 \text{ kJ/d} \) above resting requirements, a comparison of energy intake and expenditure confirmed Case 2 and Case 3 were in moderate negative energy balance. However, Case 1 was only periodically in negative energy balance, explaining the slower rate of body mass loss observed. A sustained, moderate energy restriction is less detrimental to loss of lean body mass than repeated dieting for periods of three to four days or the creation of substantial energy deficits (35). Among very lean individuals, slower rates of body mass loss should be encouraged (e.g. < 0.5 kg/wk); this equates to a conservative energy deficit within the range of 2000 kJ/d (13, 35).

The source of any energy deficit (i.e., increased energy expenditure and/or decreased energy intake) does not appear to influence nitrogen balance and thus body composition adaptations (9). However, dietary protein intake should remain within the range of 1.5 to 2.0 g/kg body mass for athletes during weight loss (24). It is unknown if the moderate dietary protein intake found for Case 2 (1.2 to 1.8 g/kg) contributed to the loss of muscle mass observed although pre-albumin concentrations suggest dietary protein intake did not compromise protein nutritional status. While protein intake was well above that recommended for the general population (19), it was on average below recommendations for weight loss among an athletic population.

The present body composition data suggest one volunteer (Case 2) experienced a large imbalance between energy intake and expenditure in the last 8 wk of the investigation. The IGF-1 response, a reliable indicator of energy restriction (8), supports this. The energy deficit resulted in an average weight loss of 0.84 kg/wk,
a rate at the upper limit of current weight loss guidelines (14), and a substantial reduction in muscle mass. During the first 8 wk of the intervention, Case 2 decreased his mass by 1.3 kg (~0.2 kg/wk) and muscle mass was retained, suggesting the rate of loss during the second half of the investigation was too rapid, and was likely the primary contributor to the proportionally large loss of muscle mass observed. However, a progressive reduction in body fat stores may also have contributed to the response, i.e., as body fat stores decrease, there is less potential for further loss of fat mass and thus a larger proportion of total body mass loss will be derived from muscle mass. The physique changes observed throughout the investigation for Case 1 and Case 3 support this. Case 1 experienced the greatest proportional loss of muscle mass after presenting with the lowest body fat levels. Conversely, proportional loss of muscle mass was lowest for Case 3 after initially possessing the largest body fat stores.

It has been suggested that resistance training may limit the loss of muscle mass associated with planned weight loss. However, even high volume resistance training in preparation for a bodybuilding competition does not protect an athlete from loss of muscle mass (13). Despite variance in the volume and frequency of resistance training undertaken by volunteers, the present data tend to support this. Reasons postulated for the concomitant loss of lean body mass while attempting to decrease fat mass include the use of body protein as a gluconeogenic precursor, diminished production of anabolic hormones (6), and different sensitivities to metabolic hormones between individuals in accordance with their level of adiposity (34).

While we have previously confirmed the impact of acute weight loss (i.e., 4 to 5% of body mass over 24 h) on performance is small (33), it may nonetheless influence competitive outcomes. The present data suggests chronic body mass manipulation may not be without performance implications either. Thus optimal weight loss strategies for an individual may depend on several factors, including the amount of weight loss required, presenting body composition, frequency of weigh-ins, and personal experience. For example, Case 1 presented with body fat levels lower than normative data of lightweight oarsmen competing at the Sydney Olympic Games. With limited potential for further loss of body fat, reliance on at least some degree of acute weight loss may have been required if the athlete was to achieve the specified body mass limit without sacrificing substantial amounts of muscle mass. Current guidelines encourage acute weight loss to not exceed 2% of body mass (36).

The modalities and duration of training in the present investigation were not dissimilar to those reported among internationally competitive oarsmen (15). However, training adaptation appeared to be suppressed compared to that previously reported. For example, while aerobic capacity has been reported to increase by 20% or more throughout a competitive season among elite oarsmen (11), VO_{2peak} (absolute) remained stable or decreased throughout the pre-season training block in the present investigation. While factors such as training intensity may have influenced aerobic adaptations (18), the present response may merely reflect the loss of skeletal muscle mass experienced among the athletes (25). Indeed, when expressed relative to body mass, maximal aerobic capacity remained stable or increased throughout the training block for all athletes. The same outcome was evident when aerobic capacity was expressed relative to muscle mass, except for Case 2. This is consistent with the observed performance outcome of the investigation. While Case 2 was the only athlete to experience a compromise in performance
over the 16 wk of support, training adaptations were limited for the other athletes considering they had undertaken 16 wk of pre-season work.

Performance of all three athletes deteriorated during the final 8 wk of the investigation, outside the range associated with normal random variation in performance (29). Given the association between muscle mass and competitive success among lightweight rowers (32), this may not be surprising. Indeed, the large reduction in muscle mass observed for Case 2 during the last 8 wk of the study could well be responsible, at least in part, for the compromise in performance and VO$_{2\text{peak}}$ evident over the same time frame. While data from Case 1 and Case 3 support this hypothesis, cause and effect cannot be determined; an array of other factors may have influenced the performance response observed over the 16 wk investigation, including differences in nutrient intake, training quality, load and modality plus individual idiosyncrasies.

In agreement with the present investigation, compromises in physiological parameters such as VO$_{2\text{peak}}$ and peak power have been observed among lightweight oarswomen following a 2-month period of body mass reduction (6%) during the pre-season (16). However, when a similar degree of weight loss (7.4%) was induced over 4 months during pre-season training the following year, absolute VO$_{2\text{peak}}$ and peak power actually increased. Fat free mass accounted for ~ 50% of the total body mass loss independent of the period allocated to weight loss, suggesting that favorable physiological adaptations can occur during periods of weight (and muscle) loss among lightweight rowers if the rate of weight loss is low, as has been observed elsewhere (2). This strengthens support for the recommendation to initiate body mass management strategies well in advance of competition.

Any loss of fat free mass is likely to decrease resting metabolic rate (20), as was evident in the present investigation. While a decrease in metabolic rate appears to be an acute response to loss of muscle mass that is negated by post-season weight and muscle regain (20), a reduction in RMR may be inevitable during periods of energy restriction (17). However, minimizing decrements in RMR would likely be advantageous, allowing a greater total energy intake that may result in enhanced recovery, higher quality training, and ultimately more favorable performance adaptations despite continued body mass loss.

In summary, the present investigation has confirmed that the targeted recruitment of potential lightweight rowers from within the heavyweight rowing community is an effective method of strengthening the depth of lightweight rowing talent. However, the chronic weight loss strategies undertaken by these rowers may not be without consequence. Energy restriction results in a decrease in muscle mass, especially when large energy deficits are created among athletes with very low body fat levels. Consequently, RMR decreases, potentially making continued body mass loss more difficult to achieve. Reductions in muscle mass may also be associated with a compromise in performance. Thus, strategies that can assist in minimizing the loss of muscle mass while “dieting” among lean, athletic populations warrant further investigation.

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