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Article

Retraining and nutritional strategy of an elite master athlete following hip arthroplasty: a case study

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Abstract

Background: The purpose of this case study was to evaluate the benefits that evidence-based nutritional and training recommendations could have on the time course of reconditioning following hip arthroplasty in a competitive master triathlete. Methods: During 38 weeks (from 6 weeks prior to surgery through to the return to competition), the athlete was provided with detailed training and nutritional recommendations based on the latest research evidence. Dietary intake (via the remote food photographic method), body composition (via DXA), peak oxygen uptake (VO_{2peak}), peak power output (PPO) and cycling efficiency (GE) were assessed 6 weeks pre- and 8, 12, 18, 21 and 25-weeks post-surgery. Training load was quantified (TRIMP score) daily during the retraining. Results: Total body mass increased by 8.2 kg (attributable to a 3.5 and 4.6 kg increase in fat mass and lean mass, respectively) between week -6 and week 8 despite a reduction in carbohydrate (CHO) intake post-surgery (<3.0g/kg/day). This was accompanied with a decrease in VO_{2peak}, PPO, and GE due to a drop in training load. From week 7, the athlete resumed training and was advised to gradually increase CHO intake according to the demands of training. Conclusions: Eventually the athlete was able to return to competition in week 32 with a higher PPO, improved VO_{2peak} and GE. Throughout retraining, energy availability was maintained around 30 kcal/kg LBM/day, protein intake was high while CHO intake was periodised. Such dietary conditions allowed the athlete to maintain and even increase lean mass, which represents a major challenge with ageing.

Keywords: body composition; triathlon; ageing; energy availability; macronutrients; performance

1. Introduction

Master athletes are defined as athletes >40 years old who maintain a high level of physical fitness despite the physiological effects of aging, allowing them to compete in sporting competitions [1]. Participation of master athletes is steadily increasing, especially in endurance events such as marathons [2], and triathlons [3], with male master triathletes accounting for 48% of male finishers in Ironman triathlons during 2007-2010 [4].

Although the continuation of training and exercise can mitigate the effects of aging, adverse health implications can arise including osteoarthritis (OA). OA is defined as the breakdown of joint cartilage and subsequently underlying bone as a result of joint inflammation [5]. Intense training programs, increased biomechanical load [6], and repetitive high impact activities such as long-distance running [5] are among the main factors responsible for OA. Endurance athletes have a 1.73 increased chance of being admitted into hospital with OA, generally affecting lower limb joints [7] at an average age of 59.7 years [8].

The standard course of treatment for severe OA of the hip is a total arthroplasty which replaces the entire joint [9] or resurfacing arthroplasty which replaces the surfaces of the hip joint affected by OA [10]. Resurfacing arthroplasty has become the preferred treatment for athletes because it preserves more bone. Whatever the technique used, the surgery is often preceded and followed by a period of reduced activity and even immobilization of lower limbs due to pain sensations about the joint. In general, the treated lower extremity is immobilized after a hip arthroscopy for six to eight weeks [11,12]. Such situation inevitably leads to a decrease in muscle mass, a possible reduction in bone mass, an increase in fat tissue, accompanied with metabolic and functional alterations such as a loss in muscle strength [13,14]. The time period of ceased training also elicits reversibility of training adaptions that take considerably longer to re-establish than the time period of detraining [13]. Furthermore, with the additional effect of aging, this may potentially result in the requirement of a longer reconditioning time period than that of younger athletes [15]. Little is known on the time-course of reconditioning and return to competition of young endurance athletes following surgery, and even less is known about deconditioning and reconditioning of master athletes.

With this in mind, we present the retraining and nutritional strategy that allowed an elite master triathlete to return to competition 32 weeks following a hip arthroplasty. Training load, energy intake, body composition and aerobic capacity were recorded at regular intervals during the period. Specifically we were interested in the changes in lean mass and bone mineral density which endured the combined effects of reduced physical activity and aging.

2. Materials and Methods

2.1. Experimental approach to the problem

As a result of increased pain after competing in the 70.3 Ironman World Championship in South Africa in September 2018 and diagnosis of osteoarthritis, the athlete underwent a resurfacing arthroplasty of the leg hip in November 2018. Surgery was performed 12 weeks after the last competition when pain was no longer bearable. In light of the previous research, this case study was therefore designed to observe the benefits that informed-based nutritional and training recommendations could have on the time course of reconditioning following hip arthroplasty. The pre-surgery assessment of the athlete was carried out 6 weeks following the last competition corresponding to 6 weeks prior to the surgery. Due to excessive pain, at the time of the first assessment (week -6), the athlete's daily activity was already dramatically reduced with only 2737 ± 1234 steps/day, 55min of strength and conditioning, 65min of swimming and 135min of cycling recorded during the week (figure 1). In the last 4 weeks prior to the surgery, a worsening of pain even obliged the athlete to use a wheelchair on certain days. The athlete was not completely immobilized at any point following the surgery but stayed 7 days post operation nonweight bearing on his injured leg with the help of crutches. Nutritional and physical training recommendations were provided to the athlete from the first day following the surgery (week 1) until the end of the intervention (week 32). The athlete's physiotherapist also contributed to the design and implementation of the training program. Nutritional recommendations were adapted to the energetic demands of the athlete's physical activity on a weekly basis, while the training load was adapted to the sensations of the athlete. Physical testing sessions were organized regularly during the intervention (6 weeks prior to and 8, 12, 18, 21 and 25 weeks post-surgery) to evaluate the progress made by the athlete and to readjust the nutritional and physical training recommendations. The main investigator met the athlete on a monthly basis for testing sessions and spoke to the athlete on the phone on a weekly basis during the whole duration of the study to ensure compliance with the protocol and answer potential questions. The rationale for nutritional and training recommendations was systematically discussed.

2.2. The subject

The athlete is a 52 year old elite master triathlete who competes in 5-6 triathlons (from Olympic to Ironman distance) per year. He regularly competes in the Ironman and 70.3 Ironman age group World Championship. At the time of the surgery, the athlete's physical characteristics were: age 51 years old, body mass 83.4 kg and height 195 cm. The athlete had a training history of at least 3 training sessions per week in swimming, cycling and running for the last 15 years. The study, methodology and the possible health risks and benefits that could result from participation were explained to the athlete. The athlete voluntarily agreed to participate in this study and signed an informed consent for the publication of the data reported in this case study. The protocol was in conformity with the declaration of Helsinki (last modified in 2013).

2.3. Procedures

Six weeks prior to and 8, 12, 18, 21 and 25 weeks post-surgery, the athlete underwent the same series of tests. Caffeine and alcohol consumption were abstained in the 24h preceding each testing session. After an overnight fast, the athlete reported to the laboratory for a whole-body fan beam dual-energy X-ray absorptiometry (DXA) measurement scan (Hologic Discovery A, WA, USA) according to the methods described by Nana et al. [16,17]. Values of lean body mass (LBM), fat mass and bone mineral content (BMC) for the whole body and the treated leg were retained for analysis. Subsequently, the athlete performed a submaximal intensity cycling test, immediately followed by a step test until volitional exhaustion [18]. Oxygen uptake was continuously measured using indirect calorimetry via an automated open circuit system (Medgraphics, Ultima CariO$_2$, MGC Diagnostics, Minnesota, USA). Heart rate (HR) was monitored via a Polar V800 heart rate monitor (Polar, Finland) and blood lactate (La) was recorded at the end of each cycling stage using a portable lactate analyzer (Lactate Pro2, Arkray, Japan). Gross efficiency (GE) and substrate (CHO and FAT) oxidation were determined from the submaximal intensity test [19] while peak aerobic capacity (VO_{2peak}) and peak power output (PPO) were obtained from the step test [20].

The athlete completed a detailed training diary (including duration, distance, session RPE and HR) for strength & conditioning (S&C), swimming (Swim), cycling (Cycl), running (Run) and walking activities (Walk) at week -6, and then daily from post-surgery until competition in week 32. From week 1 (surgery week) to week 6, the athlete engaged in S&C (mainly isometric strength training), Walk and Swim sessions only, accompanied with physiotherapy sessions 3 times a week (including stretching, massage and proprioception). Structured training (including S&C, Swim and Cycl) resumed in week 7 and gradually increased until week 32 (figure 1).

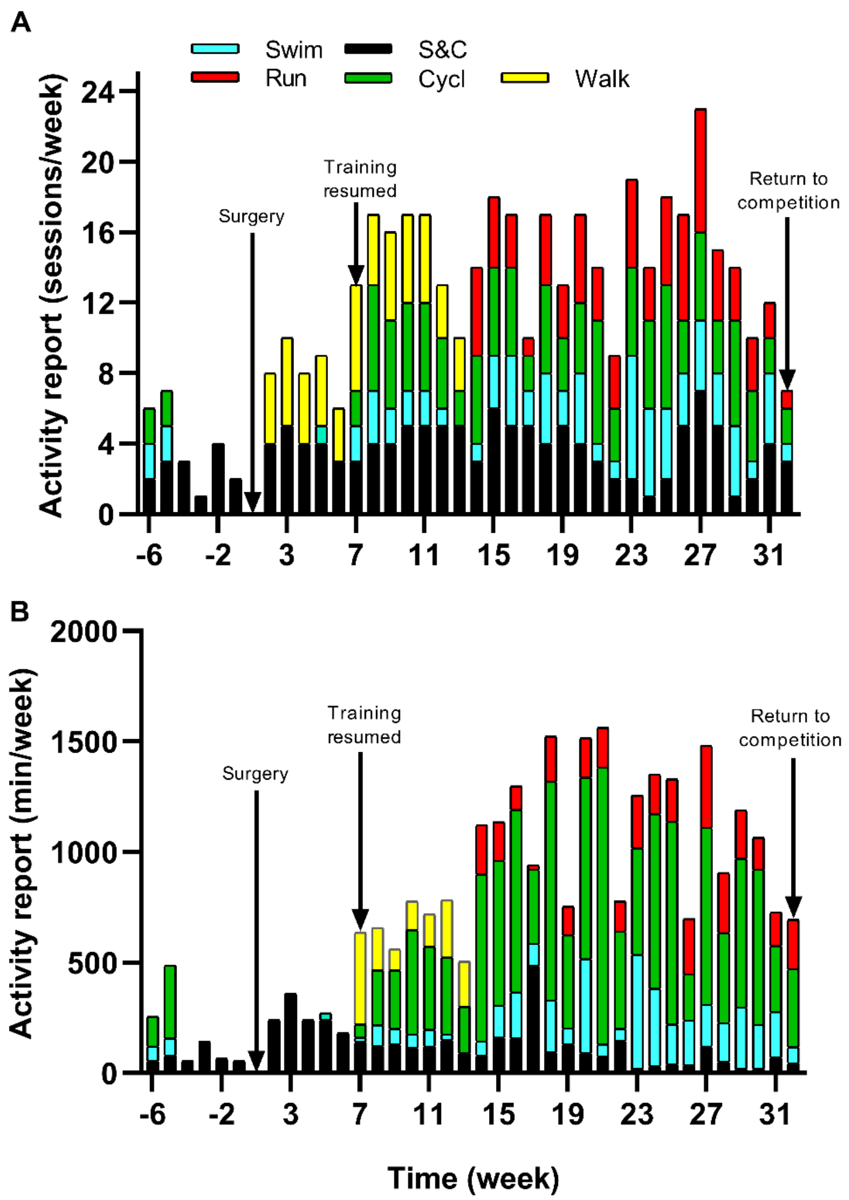

Figure 1. Timeline of physical activity and training undertaken with (A) Frequency and (B) Duration of strength and conditioning (S&C), walking (walk), swimming (swim), cycling (cycl) and running (run) sessions from week -6 to 32.

Run sessions resumed in week 14 and gradually increased thereafter. During this period of structured training, training load was calculated as training impulse (TRIMP) by using session rate of perceived exertion (RPE, 1-10) and session duration (min) according to the method of Foster et al. [21]. Using RPE, three training intensity zones could be identified: Zone 1 = RPE 0-4 (*very easy to somewhat hard*); Zone 2 = RPE 5-7 (*hard*); and Zone 3 = RPE >7 (*very hard to maximal*) [22] (figure 2).

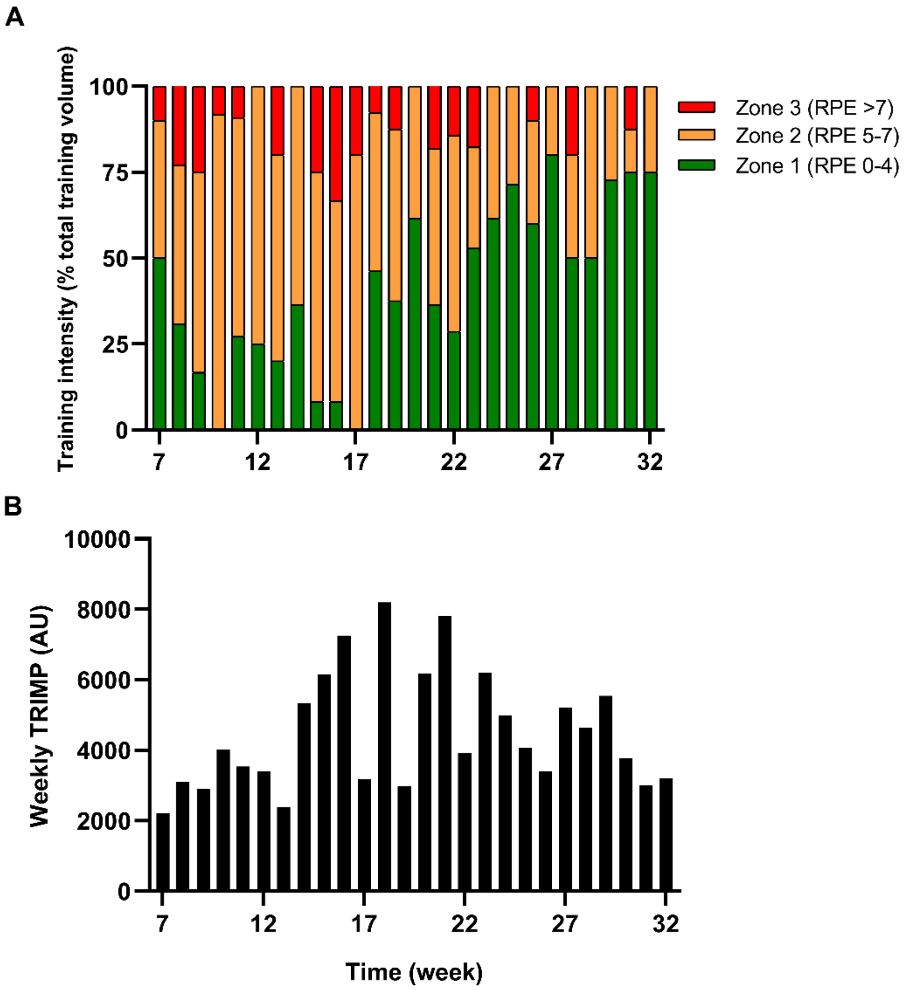

Figure 2. Training (A) intensity (according to RPE) and (B) load (expressed as TRIMP) during the period of retraining from week 7 to 32.

By monitoring HR and using the equation described by Crouter et al. [23] we could quantify energy expenditure during training sessions (ExEE, kcal). Daily energy availability (EA, kcal/kg LBM) could therefore be estimated for the testing weeks during which dietary intake was also monitored [24]. In week -6, 1, 4, 8, 12, 18, 21 and 25, the athlete reported all food and fluid ingested for 7 consecutive days by using the remote photographic technique, so that energy intake (EI) and the distribution in macronutrients (CHO, FAT and PRO) could be determined. In order to achieve energy balance during reduced ExEE (weeks 1 to 7), the athlete was advised to adopt a daily low CHO-high PRO diet (CHO < 3.0g/kg BM; PRO > 2 g/kg BM; FAT; 1-1.5 g/kg BM). From week 7, the athlete was advised to increase his daily CHO intake (up to 8g/kg BM in days including high intensity or long duration training sessions) according to the training load, while PRO and FAT intake were maintained. In order to maximize anabolic processes, the athlete was recommended to ingest 30-40g of protein at each meal and snacks (i.e. every 3-4h) [25]. Dietary protein sources were the preferred choice while protein based supplements were consumed as snacks on certain occasions. The athlete was also recommended to ingest a casein protein based supplement before sleep [26]. Daily nutritional plans were provided to the athlete (table 1). A breakdown of actual energy and macronutrient intake is presented in table 2.

Table 1. Examples of dietary meal plans provide to the athlete during the immobilization and rehabilitation/return to training period. Nutritional information calculated with a nutrition analysis software (Nutritics, Research Edition, Dublin, Ireland).

Meal (Time)	Immobilization phase	Rehabilitation/training phase
Breakfast (7am)	3 fried eggs + 1 avocado + 1 slice brown bread + 1 fresh orange	1 medium banana + 200ml orange juice + porridge (with 100g oat flakes, 28g honey, 250ml semi-skimmed milk, 40g mixed nuts and raisins)
Morning snack (10am)	200g yogurt + 15 blueberries	40g Whey protein powder with 250ml water + 1 pear
Lunch (1pm)	200g mixed salad with olive oil + 1 medium chicken breast without skin (120g) + 80g boiled courgettes + 160g boiled basmati rice + 250ml semi-skimmed milk	200g boiled pasta + 1 tablespoon olive oil + 1 medium chicken breast without skin (120g) + 80g boiled courgettes + 140g fruit salad
Afternoon snack (4pm)	40g Whey protein powder + 250ml semi-skimmed milk	1 medium banana + 150ml apple juice + 40g Whey protein with 250ml water
Dinner (7pm)	200g mixed salad with olive oil + 1 tomato + 1 average salmon darn + 160g protein rich yogurt	200g mixed salad with olive oil + 200g boiled basmati rice + 1 average salmon darn + 115g baguette bread + 150ml apple juice + 1 Greek style fruit yogurt (125g)
Evening snack (10pm, approx. 30-60min before sleep)	40g Casein protein powder + 250ml semi-skimmed milk	40g Casein protein powder + 250ml semi-skimmed milk
Approximate daily macronutrient intake	2305kcal: 151g CHO, 207g PRO, 97g FAT	3352kcal: 440g CHO, 200g PRO, 88g FAT
Approximate daily macronutrient intake (relative to body weight)	27.1kcal/kg: 1.8g/kg CHO, 2.4g/kg PRO, 1.2g/kg FAT	39.4kcal/kg: 5.2g/kg CHO, 2.3g/kg PRO, 1g/kg FAT

Table 2. Daily Exercise Energy Expenditure, Energy Intake, Energy Availability, Carbohydrate, Lipid and Protein intake during each testing week.

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	Week -6	Week 1	Week 4	Week 8	Week 12	Week 18	Week 21	Week 25
ExEE (kcal/kg LBM)	7.9 ± 7.7	3.7 ± 2.0	12.2 ± 3.4	13.5 ± 6.0	32.3 ± 12.9	28.5 ± 9.2	28.0 ± 9.1	30.6 ± 15.0
EI (kcal/kg LBM)	54.4 ± 13.6	40.3 ± 6.3	44.3 ± 6.8	45.6 ± 8.1	57.2 ± 15.0	55.1 ± 5.4	54.6 ± 6.7	60.5 ± 16.8
EA (kcal/kg LBM)	46.5 ± 17.8	36.6 ± 4.9	32.1 ± 9.1	32.1 ± 8.2	24.9 ± 21.6	26.6 ± 10.7	26.6 ± 12.6	29.9 ± 21.3
CHO (g/kg BM)	4.5 ± 0.8	2.7 ± 0.3	3.0 ± 0.2	3.5 ± 0.7	4.8 ± 1.2	5.0 ± 1.0	5.0 ± 0.8	6.1 ± 2.2
CHO (as % of EI)	43.1 ± 7.0	35.3 ± 3.8	36.9 ± 7.3	39.0 ± 4.0	43.8 ± 7.4	44.3 ± 6.6	45.2 ± 3.8	48.8 ± 8.2
FAT (g/kg BM)	2.0 ± 0.8	1.3 ± 0.3	1.7 ± 0.5	1.5 ± 0.3	1.7 ± 0.8	1.6 ± 0.3	1.6 ± 0.3	1.8 ± 0.6
FAT (as % of EI)	39.6 ± 9.3	38.7 ± 5.1	44.1 ± 12.7	37.7 ± 5.7	33.3 ± 7.3	31.4 ± 5.1	33.1 ± 4.9	33.4 ± 8.4
PRO (g/kg BM)	1.7 ± 0.5	2.0 ± 0.4	1.8 ± 0.3	2.2 ± 0.7	2.4 ± 0.6	2.6 ± 0.3	2.4 ± 0.3	2.2 ± 0.6
PRO (as % of EI)	15.7 ± 2.9	26.0 ± 3.4	21.8 ± 2.3	23.4 ± 4.1	21.9 ± 3.2	23.7 ± 3.2	21.3 ± 2.0	17.8 ± 1.3

LBM, Lean Body Mass; BM, Total Body Mass

3. Results

Changes in body composition are presented in figure 3. Between week -6 and 8 which corresponded to the period of low ExEE, total body mass increased by 8.2 kg. It was attributable to a 3.5 and 4.6 kg increase in fat mass and lean mass, respectively. Lean mass and fat mass of the injured leg presented a similar evolution to total body over the period. Interestingly no decrease in lean mass was recorded in week 8 despite low EA (close to 30 kcal/kg LBM/day) post operation (table 2). In the successive 17 weeks, body mass gradually decreased along with fat mass, while lean mass remained higher than pre-surgery. A high PRO intake associated with periodized CHO and EI according to the demands of training likely contributed to this positive outcome. In addition, thanks to a gradual increase in training load between week 7 and 32 (figure 2), EA was gradually reduced likely contributing to the decrease in fat mass (table 2). Total bone mineral density (BMC) was not negatively altered during the period and even increased (+3.4%) from week -6 to 25 (figure 3).

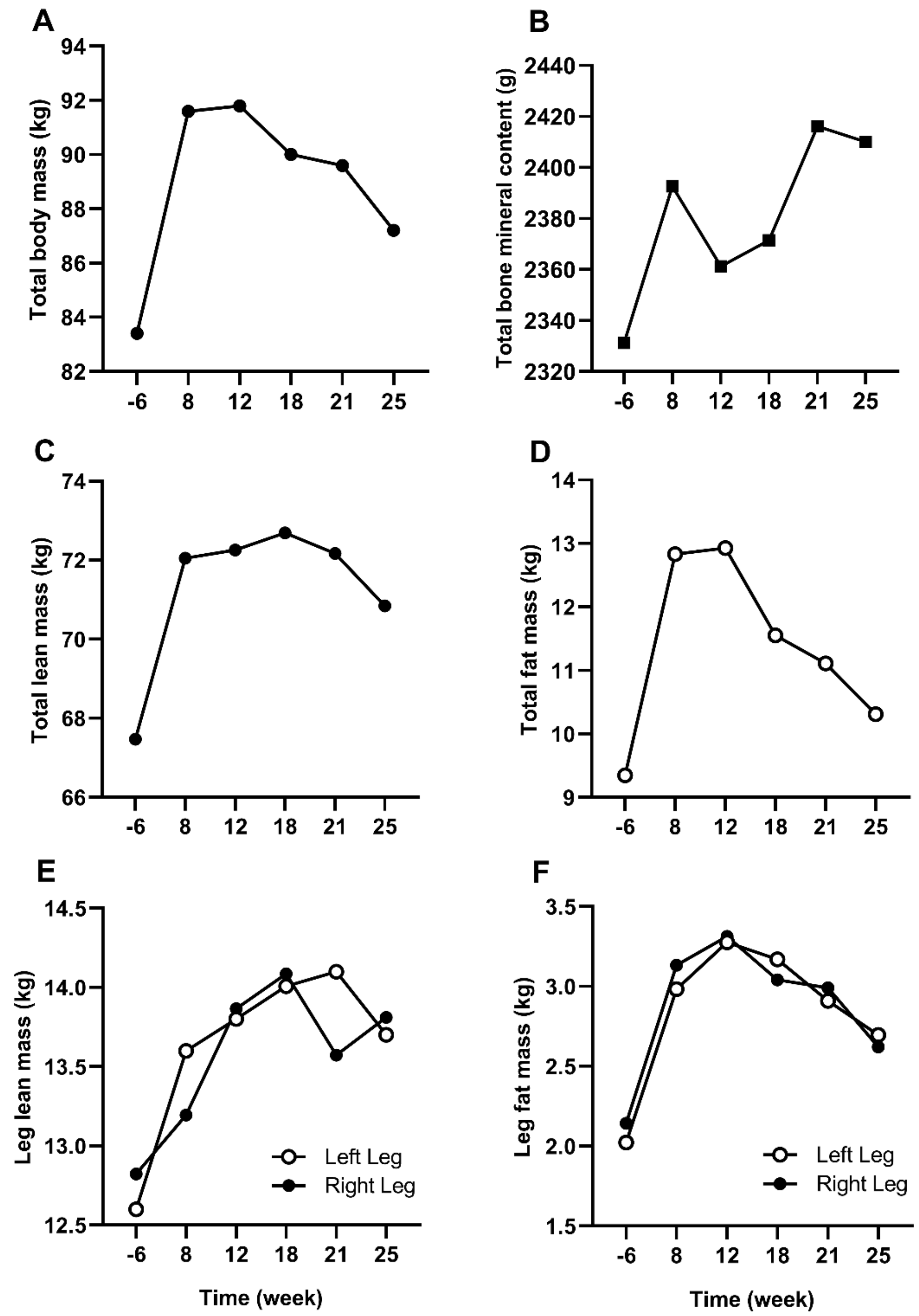

Figure 3. Changes in total (A) body mass, (B) bone mineral content, (C) lean mass and (D) fat mass from week -6 to 25. Changes in (E) lean mass and (F) fat mass for the injured (left) and non-injured (right) leg from week -6 to 25.

The cycling test results of VO_{2peak}, PPO, HR, [La], substrate oxidation and GE are presented in table 3. Compared to week -6, VO_{2peak} (in ml/min/kg) was reduced by 31.4, 14.3, 9.5, 7.7 and 13.5 % in week 8, 12, 18, 21 and 25, respectively. However, the decrease in VO_{2peak} was lower when excluding body mass from the calculation (in L/min) with a decrease of 21.2, 6.4, 2.1, 6.4 and 10.6% in week 8, 12, 18, 21 and 25, respectively, showing that aerobic capacity was almost recovered. PPO was recovered from week 18 (405W) and even improved by 8.6% (440W) and 17.3% (475W) in week 21 and 25.

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Table 3. Physiological data recorded during the cycling tests during each testing week

	Week -6			Week 8			Week 12			Week 18			Week 21			Week 25		
Intensity (W)	**135**	**240**	**405**	**135**	**240**	**275**	**135**	**240**	**345**	**135**	**240**	**405**	**135**	**240**	**440**	**135**	**240**	**475**
VO_2 (L/min)	1.7	3.1	4.7	2.1	3.4	3.7	2.1	3.3	4.4	1.9	3.0	4.6	1.8	2.5	4.4	1.8	3.0	4.2
VO_2 (ml/min/kg)	20.8	37.3	56.1	23.4	37.4	38.5	22.9	36.5	48.1	20.9	32.9	50.8	21.1	32.9	51.8	20.8	34.3	48.5
VO_2 (% VO_{2peak})	37	66	100	58	93	100	48	76	100	41	65	100	41	57	100	43	71	100
HR (beats/min)	102	136	163.0	100	131	136	99	133	154	99	127	154	93	119	156	88	117	156
[La] (mmol/L)	1.3	1,7	4.7	1.2	2.2	2.5	1.3	1.9	3.2	2.3	2.4	4.7	1.9	1.3	4.3	2.3	1.5	4.2
CHO oxidation (g/min)	1.31	2.35		1.69	3.85		1.11	2.01		1.09	1.45		1.39	2.33		1.47	2.10	
FAT oxidation (g/min)	0.31	0.62		0.38	0.15		0.60	0.88		0.49	0.89		0.33	0.44		0.31	0.64	
Gross efficiency (%)	22.7	22.5		18.4	20.0		19.0	23.8		21.2	26.2		22.0	26.2		21.6	23.5	

VO_2, oxygen uptake; HR, heart rate; [La], blood lactate concentration; CHO, carbohydrates; FAT, lipids. CHO and FAT oxidation rates were determined by using the equation developed by Jeukendrup and Wallis (2005). VO_2 values for submaximal intensities (135 and 240W) correspond to the mean of the last minute of each 5 minute stage. VO_2 values for maximal sustained intensity corresponding to peak power output (PPO) correspond to the 30 second interval containing the two highest 15 second O_2 consumption value. The highest intensity (W) corresponds to PPO which is the highest power output sustained for 1 minute.

4. Discussion

Overall, the rehabilitation and retraining intervention was a success as the athlete was able to return to competition 32 weeks after surgery. At the end of the intervention, lean mass and BMC were improved, though fat mass was still higher than pre-surgery. The athlete had recovered his entire capacity in cycling with a higher PPO, though VO_{2peak} was not recovered. Running was possible as the athlete completed an average of 189 ± 73 min per week between week 14 and 32, though the athlete required more time to increase the training volume and be entirely competitive in the discipline.

The main challenge faced by the athlete was to maintain his body composition which endured the cumulated effects of low physical activity for several weeks and the catabolic effects of ageing [27]. Bed rest studies, albeit an extreme form of immobilization, have reported an average decrease of ~0.5% of total muscle mass per day of immobilization and the effect was even accentuated for lower limbs compared to upper limbs [28,29]. In our study, as expected, fat mass increased between week -6 and 8 due to high EI compared to ExEE (EA = 46.5 ± 17.8 kcal/kg LBM/day in week -6) pre surgery. During this time, FAT intake was also high (corresponding to 39.6, 38.7 and 44.1% of total EI in week -6, 1 and 4, respectively) which could contribute to the increase in fat mass. However, lean mass concomitantly increased thanks to the combination of increased daily PRO intake and regular S&C training as soon as in week 2 [30]. Such conditions, likely provided an increased anabolic stimulus for muscle protein synthesis despite the comparatively low EA (25-27 kcal/kg LBM/day) between weeks 1 and 25 [31]. Furthermore, PRO consumption every 3-4h was recommended during the entire period to maximize the stimulation of muscle protein synthesis throughout the day [32]. However, dietary analyses revealed that only 59%, 85%, and 69% of morning, afternoon, and bedtime PRO snacks were consumed, respectively, suggesting that daily PRO intake >2.0g/kg BM may be of greater importance than consuming PRO every 3-4h in maintaining lean mass in master athletes. Another positive outcome of this study was that BMD increased from pre to post-surgery likely explained by the early return to full weight bearing activities and the maintenance of a balanced diet [33].

The regular monitoring of cycling aerobic capacities showed that VO_{2peak} (in ml/min/kg) dropped by 31.4% in week 8 which corresponded to only 21.2% when expressed in absolute value (in L/min). Hence, it appears that the increase in body mass and more specifically non-contractile tissue (fat mass) greatly impacted maximal aerobic capacity. This rapid decrease in VO_{2peak} following training cessation is also generally explained by cardiac mechanisms (i.e. decrease in stroke volume), while peripheral mechanisms (i.e. decrease in mitochondrial enzyme activity) appear more slowly in athletes with numerous years of endurance training [34,35]. The overall pattern of retraining from week 8 to 25 showed a steady improvement in VO_{2peak} and PPO concomitant with an improvement in GE. Surprisingly in week 25 the athlete reached 117% of pre-surgery PPO likely explained by an increased muscle mass with >2kg located in the legs. Substrate oxidation also gradually returned to baseline with the contribution of fat and carbohydrates to total energy production increasing and decreasing, respectively, from week 8 to 25. Unfortunately, the absence of data from other master athletes prevent the comparison with other studies.

Return to sport after hip arthroplasty is becoming common expectation for patients, though return to competition-level sport can be challenging. In a 4.7 years' prospective study, Girard et al. [36] recently reported that 94% of patients returned to sport by 4 months post-arthroplasty, but only

58% of them returned to competition-level sport (i.e. long distance triathlon in this study). This was mainly explained by the fear of early wear despite 100% implant survival rate. In the present study, the athlete returned to competition in week 32 at the IronMan 70.3 of Finland. He placed 1st in his age group in swimming and 3rd in cycling, but could not maintain the pace in the running part of the triathlon (123th in running and 82th/155 overall). In week 45, the athlete took part in another competition (IronMan 70.3 of Portugal) and placed 1st in swimming, 4th in cycling, and 45th in running, finishing in 9th place/155 overall. This confirms the retraining data showing that master triathletes can return to competition 7 to 10 months after hip resurfacing arthroplasty but more time is required to retrieve their full potential in running.

Overall this case study provides a positive outcome which must be considered in light of its limitations. As in all case study, the first limitation is that only one master athlete was studied, hence additional studies are necessary to verify whether this pattern of retraining would be consistent in other master athletes. Due to logistical constraints, no body composition and physiological measurements were possible closer to the cessation of training, surgery time and return to competition. Nevertheless, we hope the data will provide guidance to practitioners and athletes who must deal with periods of forced reduced physical activity due to surgery or injury.

5. Conclusions

This case study was conducted as a real-world applied example for master athletes and practitioners seeking to optimize rehabilitation/retraining programs through to the return to competition following hip arthroplasty. More specifically these data inform about the timeline of deconditioning and reconditioning following surgery and how it can be optimized through adapted nutrition and physical training. Our main findings suggest that endurance master athletes can counteract the combined deleterious effects of prolonged periods of muscle disuse and ageing on body composition and physical capacity. This requires the avoidance of total immobilization, an early return to physical activity in the form of S&C sessions and the maintenance of daily energy availability around 30 kcal/kg LBM.

Author Contributions: The study was designed by JL and TB; data were collected by JL, TB, AL and BB; data were analysed by JL, AL, TB, JA and ET; data interpretation and manuscript preparation were undertaken by JL, AL, ET, BB, JA, TB. All authors approved the final version of the article.

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Conflicts of Interest: The authors declare no conflict of interest.

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