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Muscle mass gain observed in patients with short bowel syndrome subjected to resistance training

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Abstract

Few studies are available about the evaluation of resistance training in patients with protein-energy malnutrition. To assess the effects of resistance training on the recovery of nutritional status of patients with short bowel syndrome, with a small bowel remnant of less than 100 cm, 9 patients of both sexes with protein-energy malnutrition after extensive resection of the small bowel were submitted to resistance training of progressive intensity consisting of concentric and eccentric work exercises for the upper limbs, trunk, and lower limbs, with the individuality and limitations of each patients being respected. Food consumption was monitored by 24-hour food recall performed during the initial phase of the study, before and 7 and 14 weeks after physical training, and by a dietary record for a period of 3 days of oral feeding. The nutrients administered by the enteral and parenteral route were recorded. A significant increase in total arm area ($P \le .01$) and fat-free mass ($P \le .01$) was observed as determined by computed tomography. An increase in total energy ingestion and carbohydrate consumption ($P \le .01$) was also observed. In addition, the activity of the enzyme carnosinase was increased after resistance training ($P \le .01$). The present results show that resistance training in patients with short bowel syndrome and protein-energy malnutrition can be considered to be a part of the nonmedicamentous treatment of these patients, leading to better nutrient use and to a gain of lean mass.

Keywords: Human; Protein-energy malnutrition; Short bowel syndrome; Physical activity; Resistance training
Abbreviations: E.C., *Escherichia Coli*; KV, kilovolt; Mg/creat/24 h, milligram of creatinine in 24 hours; µmol/ml/h, micromole per milliliter per hour; USP, University of São Paulo.

1. Introduction

Short bowel syndrome occurs after extensive resection of the small bowel. Among the causes of mesenteric ischemia are emboli and infarction of the superior mesenteric artery [1]. Because of the loss of an extensive portion of the small bowel, the patients develop severe protein-energy malnutrition, requiring parenteral nutrition during the immediate and late postoperative period, a fundamental procedure for increased survival [2].

The nutritional status expresses the extent to which the physiologic nutrient requirements are being met to maintain adequate composition and function [3]. Malnutrition predisposes to a series of severe complications including a

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tendency to infection, deficient wound healing, respiratory failure, cardiac insufficiency, reduced protein synthesis at the hepatic level with production of abnormal metabolites, and reduced glomerular filtration and production of gastric juice [4]. Physical inactivity causes muscle weakening, drastically reducing the capacity to generate muscle work, affecting the ability to "live independently" [5,6]. Resistance or strength physical training has been pointed out as the cause of positive hypertrophic adaptation of skeletal muscle [7].

Training with resistance or strength exercises can help reverse the malnutrition commonly occurring among patients with renal failure. This type of training is characterized by weight lifting, which results in increased muscle mass, improving physical function and attenuating progressive muscle loss [8].

In a study in which a low-protein diet potentially inducing malnutrition was administered to male Wistar rats to determine the physiologic and metabolic changes because of malnutrition in a control and in an exercised group, Neiva et al [9] concluded that malnutrition associated with sedentarism causes important alterations in patterns considered to be normal, with physical exercise potentiating the results obtained and aiding nutritional recovery.

To our knowledge, few data are available about resisted physical exercise applied to patients who underwent enterectomy. Thus, there is an urgent need to transmit information about the importance of resistance training as part of treatment to the professionals involved in the recovery of patients with protein-energy malnutrition. On the basis of the information, we believe that resisted physical exercise is associated with improved nutritional status in patients who underwent enterectomy, aiding their nutritional recovery.

2. Methods and materials

2.1. Patients

A total of 9 patients with short bowel syndrome, 4 women and 5 men older than 30 years followed at the Metabolic Unit of the University Hospital, Faculty of Medicine of Ribeirão Preto, University of São Paulo (São Paulo, Brazil), participated in the study. The study was approved by the research ethics committee of the University Hospital, Faculty of Medicine of Ribeirão Preto, University of São Paulo, and all patients gave written informed consent to participate.

2.2. Experimental design

The patients were submitted to evaluation of nutritional status before and after 14 weeks of resistance physical training, with each individual acting as his own control. The evaluation consisted of anthropometry, evaluation of food intake by 2 types of dietary survey, 24-hour diet recall and 3-day food record, and measurement of energy expenditure by indirect calorimetry. Computed tomography was used as the imaging method. The patients were submitted to resistance training twice a week for a period of 14 weeks. The inclusion criterion was not to have participated in any type of regular physical exercise in the last 12 months. The evaluation of nutritional status was repeated after the period of physical training. All evaluations were performed before and after the resistance training. Each individual served as his own control. Each evaluation method and the respective references are described below.

2.3. Anthropometry

The anthropometric measurements performed were weight, height, skin folds, arm circumference, and calculation of arm muscle circumference [10], and the results were defined as mild, moderate, and severe malnutrition [11].

2.4. Laboratory data

Venous blood samples were collected and used to determine total proteins, albumin, and carnosinase (*Escherichia coli*: 3.4.13.20) [12]; 24-hour urine samples were also obtained. Urinary creatinine level was determined by reaction with a picrate solution in alkaline medium, forming a red complex that was measured photometrically. The determination was performed using a Labtest kit (Lagoa Santa, Minas Gerais, Brazil) and a Beckman DU640 spectrophotomer (Corona, CA) at 510 nm.

2.5. Evaluation of food intake

Food intake was determined by the sum and the mean of the results obtained with the 24-hour diet recall, with the 3-day diet record [13] and with enteral and parenteral nutrition. The data were analyzed before and after physical training. Food intake was calculated with the aid of a computer program (Programa de Apoio à Nutrição [Nutrition Support Program] version 2.5, licensed by Escola Paulista de Medicina—Nutritional therapy, São Paulo, Brazil).

2.6. Measurement of resting energy expenditure

Resting energy expenditure was determined before and after the end of physical training using a Sensor Medics calorimeter (Sensor Medics Corporation, Yorba Linda, Calif) [14].

2.7. Computed tomography

Images of the midpoint of the nondominant arm were obtained (Tomoscan LX-C, Matrix 512 and 320; Eastlake, OH) at a speed of 9.5 seconds at 30 kV. The axis was oriented at 90° using a 256 × 256 matrix. Readings of total area and of muscle and bone areas were obtained with a Mini-Moop digitizing board (Eching, Bavaria, Germany) plus an associated computation program using a digital pen to circle the figure exposed on photographic paper to measure the different areas (total area, muscle area, and bone area). To determine the muscle area, bone area was measured and subtracted from muscle area, and to determine the adipose area, the muscle and bone areas were summed and the value was subtracted from the total area [15,16].

Table 1
Anthropometric measurements, resting energy expenditure, body composition obtained by computed tomography, and serum carnosinase levels before and after physical training in subjects

	Before physical training	After physical training
Age	50.7 ± 4.5	-
Height	1.63 ± 0.08	-
Weight (kg)	50.7 ± 5.4	51.9 ± 5.4
Body mass index (kg/m^2)	19.1 ± 1.8	19.5 ± 1.8
Triceps skin fold (mm)	8.2 ± 3.6	7.4 ± 3.0
Arm fat index	0.76 ± 0.31	-
Arm muscle circumference (cm)	21.7 ± 1.8	22.5 ± 2.1 *
Urinary creatinine (mg per creatinine per 24 h) (n = 6)	0.86 ± 0.37	1.01 ± 0.32
Resting metabolic rate (kcal/d)	5622 ± 744	7106 ± 1187 **
Carnosinase (μmol/mL per hour) (n = 6)	1.53 ± 0.57	3.11 ± 1.97 **

* Significantly different values (means ± SD) after resisted training at $P \le .01$ as determined by Wilcoxon test.
** Significantly different values (means ± SD) after resisted training at $P \le .05$ as determined by Wilcoxon test.

2.8. Program of physical training with weights

The subjects were submitted to resistance training of progressive intensity, with exercises of concentric and eccentric work for upper limbs, trunk, and lower limbs, with the individualities and limitations of each patient being respected. All exercise sessions were monitored for patient compliance. The training program lasted 14 weeks, with 2 sessions per week lasting approximately 60 minutes. During the first 2 weeks, 4 exercise sessions were held to permit the individuals to familiarize themselves with the equipment (Athletics 2001 mechanotherapy station, Albarreja, Fuenlabrada, Madrid), and with the exercise techniques. Eight different types of exercise, pectoral, back, shoulders, biceps, triceps, thigh, calf, and abdomen, were used. The subjects first executed the exercises for large muscle groups and then the remaining ones. They also performed general warm-up exercises for 3 minutes. Three series of 8 repetitions were executed (maximum load for 8 repetitions), corresponding to an approximate intensity of 80% of the maximum load for the muscle groups in general, except for the calf and abdomen, with abdominal exercises being performed when possible. Three series of 10 to 12 repetitions were executed for the calf and abdominal exercises. When an individual increased his strength to the point of being able to perform the exercises with ease, a new load was added. A resting period of ±1 minute was allowed between exercise series [17].

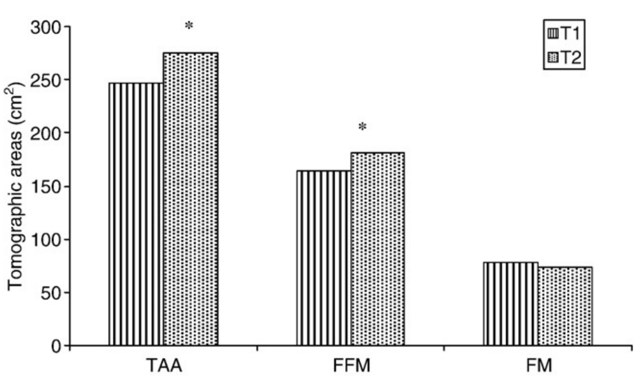

Fig. 1. Total arm area results in subjects at T1 and T2 during the study. TAA indicates total arm area at $P \le .01$; fat-free mass (FFM) at $*P \le .01$ as determined by the Wilcoxon test. FM indicates fat mass.

Table 2
Daily intake of total energy, protein, fat, and carbohydrates, before and after the resisted physical activity in subjects

	Before	After
Total calories (kJ/d)	7081 ± 1221	8439 ± 1852 *
Protein (kJ)	1467 ± 268	1584 ± 355
Fat (kJ)	1902 ± 815	2487 ± 1584
Carbohydrates (kJ)	3708 ± 915	4368 ± 798

* Significantly different values (means ± SD) after resisted training at $P \le .01$ as determined by the Wilcoxon test.

2.9. Statistical analysis

Data regarding total energy, carbohydrate, protein and lipid intake; anthropometric measurements; adipose area and muscle area obtained by computed tomography; and resting energy expenditure were analyzed statistically by nonparametric analysis of variance using the GraphPad software, version 3.00 for Windows 95, San Diego, Calif. The differences detected in the variable between the pre- and postexercise period were determined by the nonparametric Wilcoxon test [18]. The level of significance was set at $P \le .05$ in all analyses and values are presented as means ± SD.

3. Results and discussion

At the beginning of the study all patients presented some degree of malnutrition regarding the different variables studied. Analysis of the data presented in Table 1 shows that before resistance training, all patients presented a mild, moderate, or severe weight loss as indicated by the measurement of tricipital skin fold and arm fat index, in addition to loss of body muscle mass of a mild or moderate degree, as indicated by estimated arm muscle circumference.

After physical training, arm muscle circumference was the anthropometric measurement showing a statistically significant difference ($P < .05$). In addition, the resting metabolic rate measured (Table 1), the carnosinase enzyme (Table 1), and total arm area and fat-free mass (Fig. 1) demonstrated a statistically significant difference ($P \le .01$). No significant difference was observed regarding weight, body mass index, tricipital skin fold, bicipital skin fold, subscapular skin fold, or suprailiac skin fold (Table 1).

After the training period, there was a statistically significant increase in total caloric and carbohydrate intake (Table 2). Fig. 2 (A, B, and C) presents the data for lean body

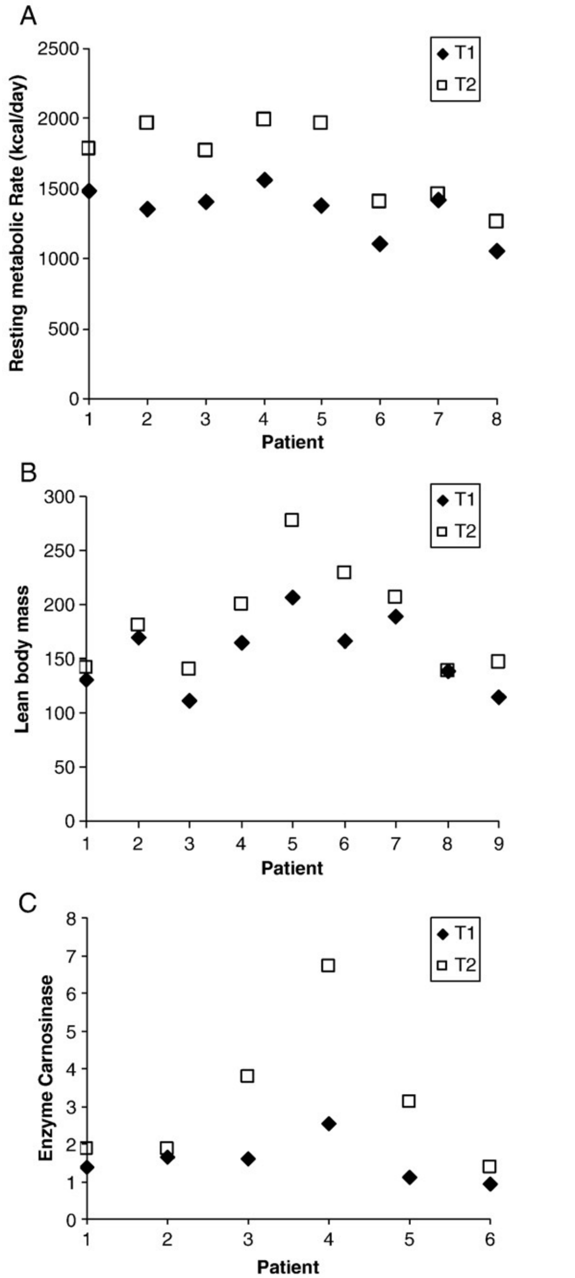

Fig. 2. Individual data points for resting metabolic rate (RMR), lean body mass (LBM), and carnosinase enzyme activity before (T1) and after (T2) resistance physical training for each patient. Resting metabolic rate, LBM, and carnosinase enzyme activity at $*P \leq .01$ as determined by the Wilcoxon test.

mass, resting metabolic rate, and carnosinase activity of each patient (variables related to increased muscle mass).

An increase in resting metabolic rate ($P < .01$) was observed in the present study before and after resistance training. This result suggests that the intensity and volume of physical exercise performed were sufficient to induce changes in energy expenditure. The significant increase in total energy intake (kcal/d) after resistance training and also the increased carbohydrate intake during the same period were probably because of the modification of energy expenditure that increased the energy requirements and the daily energy consumption because of resistance training. Carbohydrates are recognized as the main source of energy during physical training, thus sparing the consumption of proteins as an energy substrate [19].

Other authors [20] have also shown this increase in elderly patients, inducing an increase of approximately 15% in total energy intake. Pratley et al [21], in a study of the effect of resistance physical exercise on elderly men, also observed an increase in fat-free mass. However, they did not observe changes in food intake during resistance training.

In the present study, the patients were similar to elderly individuals, with evolution of the disease, surgeries, compromised absorption levels, large weight loss, sedentary life style, and consequent loss of fat-free mass, factors that contributed to a loss of quality of life. However, with resistance training, there was an increase in resting metabolic rate and in fat-free mass, with improved quality of life for the patients, who became able to perform the exercises independently without direct assistance.

During periods of inanition, the organism remains in a catabolic state, with depletion of lean mass because of a reduction of body reserves [5]. However, in the present study, there was a significant increase in body muscle mass and in arm muscle circumference after physical training. It is possible that the stimulus was efficient in changing the direction of the process from catabolism to anabolism, a fact that was not observed by Nelson et al [22] in elderly women after progressive resistance training. Urinary creatinine excretion was not correlated with muscle mass among the patients studied. Urinary creatinine excretion depends on factors such as physical activity and metabolic status and is lower in malnourished individuals [23].

A significant increase in serum carnosinase activity was observed after resistance training. Serum carnosinase is an enzyme that hydrolyzes its substrate, carnosine, into its constituent amino acids alanine and histidine. Carnosine (β-alanyl-1-histidine) is a dipeptide abundantly distributed throughout the body in organs such as muscles and kidneys [24]. According to Dubin et al [25], histidine is one of the substrates necessary for protein synthesis. Reduced urinary excretion of 3-methyl-histidine (a histidine derivative) and low carnosinase activity are phenomena described for patients with reduced muscle mass formation such as uremic patients and patients with progressive muscular dystrophy [12]. Thus, we conclude that the increase in carnosinase activity was related to the increase in body muscle mass.

Tomography data revealed an increase in total arm area and fat-free mass after physical training. The present study involved 28 training sessions with 24 repetitions per session at 80% maximum load and muscle evaluation by tomography that showed that physical exercise performed under the conditions described promoted an increase in muscle area and in total arm area. Similar results were reported by other authors in a 52-week study conducted on elderly males [20].

In contrast to these results, Moritani et al [26] found no muscle changes after the measurement of skin folds and arm circumference. The study involved 24 training sessions with 20 repetitions per session at 66% maximum load per exercise. These divergent results may be probably explained by differences in the intensity and duration of training and in the techniques used for evaluation. Frontera et al [27] and Pyka et al [28], in a study of the increase in muscle fiber area measured by subcutaneous muscle biopsy specimens and tomography after resistance training in elderly subjects, observed a significant increase in type I and II fibers. These results suggest that the ability to increase muscle mass is preserved in debilitated individuals.

We conclude that the proposed resistance training led to metabolic modifications in the patients studied, indicating better nutrient assimilation, helping nutritional recovery, and indicating that this is an important part of the nonmedicamentous treatment of patients with short bowel syndrome.

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