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Resistance *versus* endurance training in patients with COPD and peripheral muscle weakness

M.A. Spruit*,#,¶, R. Gosselink*,#,¶, T. Troosters*,#,¶, K. De Paepe*,#, M. Decramer*,#,¶

Resistance versus *endurance training in patients with COPD and peripheral muscle weakness. M.A. Spruit, R. Gosselink, T. Troosters, K. De Paepe, M. Decramer. ©ERS Journals Ltd 2002.*
ABSTRACT: The effects of endurance training on exercise capacity and health-related quality of life (HRQL) in chronic obstructive pulmonary disease (COPD) patients have been studied thoroughly, while resistance training has been rarely evaluated. This study investigated the effects of resistance training in comparison with endurance training in patients with moderate to severe COPD and peripheral muscle weakness (isometric knee extension peak torque <75% predicted).

Forty-eight patients (age 64±8 yrs, forced expiratory volume in one second 38±17% pred) were randomly assigned to resistance training (RT, n=24) or endurance training (ET, n=24). The former consisted of dynamic strengthening exercises. The latter consisted of walking, cycling and arm cranking. Respiratory and peripheral muscle force, exercise capacity, and HRQL were re-evaluated in all patients who completed the 12-week rehabilitation (RT n=14, ET n=16).

Statistically significant increases in knee extension peak torque (RT 20±21%, ET 42±21%), maximal knee flexion force (RT 31±39%, ET 28±37%), elbow flexion force (RT 24±19%, ET 33±25%), 6-min walking distance (6MWD) (RT 79±74 m, ET 95±57 m), maximum workload (RT 15±16 Watt, ET 14±13 Watt) and HRQL (RT 16±25 points, ET 16±15 points) were observed. No significant differences in changes in HRQL and 6MWD were seen between the two treatments.

Resistance training and endurance training have similar effects on peripheral muscle force, exercise capacity and health-related quality of life in chronic obstructive pulmonary disease patients with peripheral muscle weakness.
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*Respiratory Rehabilitation and Respiratory Division, University Hospital Gasthuisberg, #Respiratory Muscle Research Unit, laboratory of Pneumology, ¶Dept of Rehabilitation Sciences, Faculty of Physical Education and Physiotherapy, Katholieke Universiteit Leuven, Belgium.

Correspondence: R. Gosselink, Division of Respiratory Rehabilitation, University Hospital Gasthuisberg, Herestraat 49, 3000 Leuven, Belgium.
Fax: 32 16346866
E-mail: rik.gosselink@uz.kuleuven.ac.be

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Despite optimal medical treatment, patients with moderate-to-severe chronic obstructive pulmonary disease (COPD) often experience a functional deficit, which is associated with dyspnoea, deconditioning, and especially muscle weakness [1]. Exercise training has been shown to be an effective means of reversing this functional impairment and improving health-related quality of life (HRQL). Whole body endurance training at a high intensity resulted in significant improvements in HRQL, exercise capacity and peripheral muscle force in these patients [2–4]. In practice, however, patients are not always able to execute high intensity endurance exercises because of overt symptoms of leg fatigue and dyspnoea [5]. The rationale for applying resistance training in COPD patients is two-fold. First, COPD patients suffer from peripheral muscle weakness which may contribute to impaired exercise performance [6–10]. Therefore, selective resistance training of peripheral muscle groups is well indicated in these patients. Secondly, training smaller muscle groups can keep the level of dyspnoea modest [11].

Resistance training is an exercise modality in which small muscle groups are trained by repetitively lifting heavy weights. This training modality has been successfully used in the rehabilitation of elderly subjects and in patients with chronic heart failure to improve peripheral muscle force, exercise capacity and ambulation [12–14]. Resistance training enhanced peripheral muscle force, muscle endurance and whole body endurance in COPD patients, in comparison with a control group (no intervention) [7, 15]. To the best of the authors' knowledge, a comparison between resistance training and endurance training has not been studied in COPD. Hence, it remains unclear whether effects of resistance training are similar to those of endurance training. Therefore, the present study compared the effects of resistance training with the effects of endurance training in COPD patients with peripheral muscle weakness.

Materials and methods

Study subjects

Forty-eight COPD patients (age 64±8 yrs, forced expiratory volume in one second (FEV1) 38±17% predicted) who attended the outpatient clinic with dyspnoea, poor exercise tolerance and peripheral muscle weakness (isometric knee extension peak torque <75% pred) were enrolled. Patients gave verbal informed consent to take part in this study, which was approved by the Medical Ethical Board of the University Hospitals Leuven. Patients did not suffer from cardiovascular or neurological disorders. Table 1 shows the baseline characteristics of the patients who completed the training program (no hospitalization during the training period and >18 training sessions). On average, these patients showed moderate-to-severe airflow obstruction, a normal body mass index, a moderately reduced oxygen tension in arterial blood, impaired respiratory and peripheral muscle forces, and a decreased exercise performance. Exercise was limited by the ventilatory system in combination with high symptom scores for fatigue and dyspnoea (table 2).

Study design

The study was a prospective randomized controlled trial. Concealed envelopes were used to randomly allocate the patients to either resistance training (RT n=24), or endurance training (ET n=24). No control group was added to this design, since the present authors have shown previously that after three months of no intervention (except for standard medical treatment) COPD patients showed no improvement, using the same methodology used in this study [16].

Pulmonary function [17], respiratory muscle forces [18], isometric knee extension peak torque [8], handgrip force [19], maximal exercise capacity [20], and the 6-min walking distance (6MWD) [21] were assessed before and after completing a 12-week training program, as described previously by the present authors' group [16, 22]. HRQL was measured with the Chronic Respiratory Disease Questionnaire (CRDQ) [23]. In addition, maximal isometric knee extension force, knee flexion force, shoulder abduction force and elbow flexion force were determined with a handheld dynamometer (MicroFET; Biometrics, Almere, the Netherlands) using a "break" test as described by BOHANNON and ANDREWS [24]. The highest values were related to the normal values proposed by ANDREWS *et al.* [25]. Patients also underwent a cycling endurance test at 70% of the initial maximum workload (W$_{\mathrm{peak}}$) to determine the exercise endurance capacity. Technicians performing pulmonary function and exercise tests were blinded for the randomization and all the tests were part of the routine screening of patients undergoing respiratory rehabilitation in the centre.

Table 1. – Baseline characteristics

	Resistance training	Endurance training
Sex M:F	12:2	14:2
Age yrs	64±7	63±8
FEV1 % pred	40±18	41±20
FVC % pred	75±20	73±17
$T_{\mathrm{L,CO}}$ % pred	33±13	56±13*
BMI kg·m^{-2}	24±5	26±5
$P_{\mathrm{a,O_2}}$ mmHg	63±14	70±20
$P_{\mathrm{a,CO_2}}$ mmHg	42±9	43±8

Data are presented as mean±SD. M: male; F: female; FEV1: forced expiratory volume in one second; FVC: forced vital capacity; $T_{\mathrm{L,CO}}$: diffusion capacity for carbon monoxide; BMI: body mass index; $P_{\mathrm{a,O_2}}$: oxygen tension in arterial blood; $P_{\mathrm{a,CO_2}}$: carbon dioxide tension in arterial blood. *: p<0.05 between groups.

Table 2. – Baseline muscle forces, exercise capacity, and health related quality of life

	Resistance training	Endurance training
$P_{\mathrm{I,max}}$ % pred	65±11	62±22
$P_{\mathrm{E,max}}$ % pred	76±14	74±26
KEPT % pred	61±15	54±14
HGF % pred	83±20	81±27
VO$_{\mathrm{2peak}}$ % pred	47±18	54±12
W$_{\mathrm{peak}}$ % pred	38±14	46±15
HR$_{\mathrm{peak}}$ % HR$_{\mathrm{max}}$ pred	84±8	91±11
V'_{E}/MVV %	101±10	104±12
Borg score dyspnoea points	8±2	8±2
Borg score fatigue points	7±3	8±1
6MWD % pred	45±14	48±18
CRDQ points	72±17	75±21

Data are presented as mean±SD. $P_{\mathrm{I,max}}$: maximal inspiratory pressure; $P_{\mathrm{E,max}}$: maximal expiratory pressure; KEPT: knee extension peak torque; HGF: handgrip force; VO$_{\mathrm{2peak}}$: peak oxygen uptake; W$_{\mathrm{peak}}$: peak workload; 6MWD: 6-min walking distance. Peak heart rate (HR$_{\mathrm{peak}}$) expressed as % of maximal heart rate (HR$_{\mathrm{max}}$) predicted. Ventilation (V'_{E}) expressed as a % of maximal voluntary ventilation (MVV). Borg scores for dyspnoea and fatigue were taken at W$_{\mathrm{peak}}$. Total score Chronic Respiratory Disease Questionnaire (CRDQ) expressed in points.

Methods

Patients attended the outpatient clinic three times per week (90-min sessions) for 12 weeks. Resistance training consisted of dynamic strengthening exercises. Quadriceps muscles, pectoral muscles and triceps brachia muscles were trained on a multigym (AT 1000B-Atech, Fysiomed NV-SA, Edegem, Belgium). Deltoid muscles, biceps brachia muscles and hamstrings were trained on a pully (Steens Industriers AS, Oslo, Norway). Patients started at 70% of the initial one-repetition maximum (1RM: the maximum load which can be moved only once over the full range of motion without compensatory movements) in the first week (3×8 repetitions). Every week the load was increased by 5% of the 1RM. In healthy elderly subjects, this is a suitable resistance training program [26]. Endurance training consisted of ergometry cycling, treadmill walking, and arm cranking. According to the findings of MALTAIS *et al.* [5], the initial intensity for cycling was set at 30%W_{peak} for 10 mins. Increases in workload were based upon symptom scores, trying to achieve a workload of 75% W_{peak} for 25 mins in week 12. Treadmill walking speed was set at 60% of the average speed obtained from the 6MWD ($6MWD_{peak}$) for 10 mins in the first week and was increased to 25 mins in week 12. Arm cranking started at 4 mins increasing to 9 mins in week 12. A Borg score of 5–6 for dyspnoea or fatigue was set as a target.

Since none of the patients included had cycled in the previous 5 yrs, 2-min lasting cycling and treadmill walking at a low intensity (40%W_{peak} or $6MWD_{peak}$) were added to resistance training to minimize the influence of a better technique on the outcome of the exercise tests. Stair climbing, as an activity of daily living, was incorporated in both training protocols. Stair climbing was performed on a two-step stair (step height 21 cm) for 3 mins in week 1, increasing to 6 mins in week 12.

Statistical analyses

All data were tested for normality with the Kolmogorov-Smirnov test. Baseline results and differences after 3 months training are presented as mean±SD. Differences at baseline and after 3 months of rehabilitation between the two groups were analysed with a two-tailed unpaired t-test. Changes within the two groups were analysed with a two-tailed paired t-test [27]. *A priori*, a two-sided level of significance was set at 0.05. Data were analysed per protocol.

Results

Practicability of the two training modalities

At baseline, anthropometrical characteristics, pulmonary function, exercise capacity and muscle forces were equal for both groups. Only the diffusion capacity for carbon monoxide was significantly lower in the resistance training group. The scores on the CRDQ showed a poor HRQL in both groups. During the training period some patients dropped out due to lack of motivation (RT n=3, ET n=3) or because of hospitalization for an exacerbation (RT n=7, ET n=5). Three of the hospitalized patients passed away as a consequence of respiratory insufficiency (RT n=2, ET n=1). Patients who completed the training showed higher baseline peripheral muscle forces in comparison with patients who dropped out. Knee extension peak torque (57±14 *versus* 42±18% pred, $p<0.002$), maximal isometric knee extension force (63±17 *versus* 49±22% pred, $p<0.04$) and handgrip force (82±24 *versus* 69±17% pred, $p<0.05$, respectively) were significantly different.

On average, loads of the strengthening exercises were increased every week by 5±2% of the 1RM (week 1–6), and 3±2% of the 1RM (week 7–12), as expected (fig. 1). In general, resistance training was well accepted. Patients only complained about the exercise to strengthen the pectoral muscles. Decreased shoulder mobility prevented some patients moving the load over the full range of motion in rearward direction. If necessary, supervising physiotherapists adjusted the exercise by decreasing the range of motion. Analyses of the endurance training schedules showed training loads that were close to predetermined target loads. The training intensity (%W_{peak} and %$6MWD_{peak}$) and/or duration (min) increased every week for arm cranking, cycling, and walking (fig. 2). No significant difference in compliance was seen between the two groups (RT 28±6 *versus* ET 29±6 training sessions).

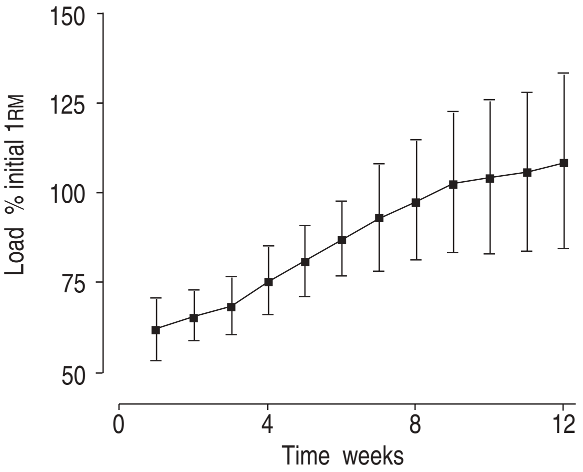

Fig. 1. – Increments in training loads during shoulder abduction exercise expressed as a percentage of the initial one-repetition maximum (%1RM) *versus* time (weeks). Data are presented as mean±SD.

Effects of resistance training and endurance training

After the 12-week training period, both groups showed significant changes in peripheral muscle force of the trained muscle groups (fig. 3). Maximal inspiratory pressure did not improve signficantly (RT 10±23, $p=0.14$; ET 27±52, $p=0.23$). Maximal expiratory pressure (RT 8±14%, $p=0.06$; ET 27±52%, $p=0.06$) and handgrip force (RT 8±15%, $p=0.09$; ET 30±62%, $p=0.07$) tended to increase in comparison with baseline values. 6MWD increased significantly in both groups (RT 38±50%, $p<0.01$; ET 41±43%, $p<0.002$). The maximal incremental cycling exercise test showed significant improvements in W_{peak} (RT 15±16 Watt, $p<0.01$; ET 14±13 Watt, $p<0.001$). Peak oxygen uptake, however, increased only significantly after endurance training (ET 89±166 $mL \cdot min^{-1}$, $p<0.05$; RT 106±253 $mL \cdot min^{-1}$, $p=0.21$). In addition, to the improved maximal exercise capacity a significant reduction in ventilation at 80% of the initial peak oxygen uptake was found (RT -3±4 $L \cdot min^{-1}$, $p=0.04$; ET -1.5±3 $L \cdot min^{-1}$, $p=0.08$). The time cycled during the 70%W_{peak} test increased significantly only after endurance training (ET 352±276 s, $p<0.003$; RT

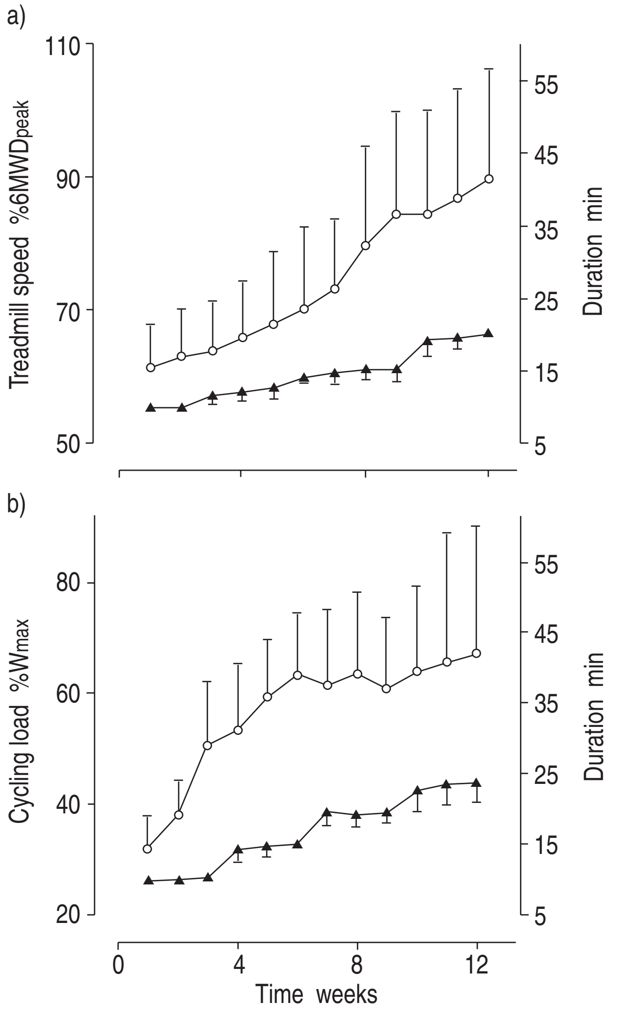

Fig. 2. – Increments in a) treadmill speed and b) cycling load. Treadmill speed (○) is expressed as a percentage of the average speed obtained from the initial 6-min walking distance (%6MWDpeak) and treadmill duration (▲) is expressed in minutes (min) *versus* time (weeks). Cycling load (○) is expressed as a percentage of the initial maximum workload (%W$_{\text{peak}}$) and cycling duration (▲) expressed in minutes (min) *versus* time (weeks). Data are presented as mean±SD.

149±254 s, $p=0.14$). HRQL improved significantly in the two groups (RT 16±25 points, $p<0.05$; ET 16±15 points, $p<0.001$) compared to baseline. No significant changes were observed in static and dynamic lung volumes. After 3 months of training, no significant differences were found in changes between the two groups, except for the mean change in isometric knee extension peak torque ($p<0.01$, in favour of ET).

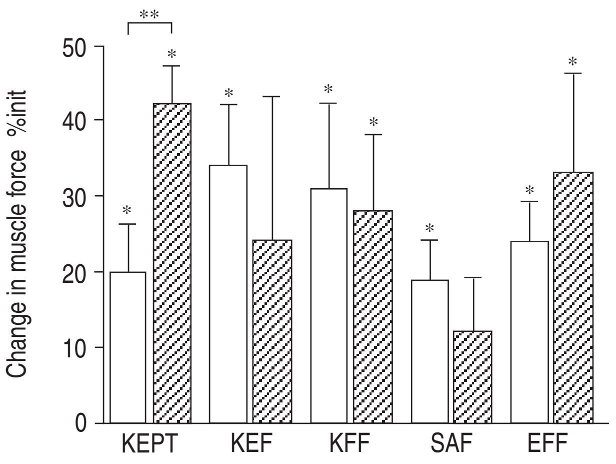

Fig. 3. – Change in isometric knee extension peak torque (KEPT), maximal isometric knee extension force (KEF), knee flexion force (KFF), shoulder abduction force (SAF), and elbow flexion force (EFF), all expressed as a percentage of the initial value (%init) after strength training (□) or endurance training (▨). Data are presented as mean±SEM. *: $p<0.05$ within group; **: $p<0.01$ between groups.

Discussion

The aim of this study was to compare the effects of resistance training with those of endurance training in patients with moderate-to-severe COPD and peripheral muscle weakness. After a 12-week training period, equivalent improvements were observed in important outcome parameters, such as HRQL and 6MWD. Peripheral muscle force and exercise performance increased significantly after resistance or endurance training. Furthermore, results showed important crossover training effects. Resistance training resulted in significant improvements in peak workload and 6MWD, while endurance training caused significant improvement in peripheral muscle force.

Effects on heath-related quality of life and exercise capacity

The results of the present study corroborate the improvements of HRQL after resistance training or endurance training in COPD patients [3, 15]. Simpson *et al.* [15] showed previously a positive trend towards a treatment effect of resistance training on 6MWD (391±23–427±27 m, $p<0.1$) in COPD patients. There was a significant improvement in 6MWD after resistance training which was comparable to the results of 3-months resistance training in healthy, community-dwelling elderly subjects [28] and to the effects of combined aerobic and resistance training in COPD patients [2, 16]. The mean change in 6MWD of the two study groups was clearly above the minimal clinically important difference of 54 m [3]. No significant changes in 6MWD were found between the two training modalities. This has previously been reported in elderly women [29].

After resistance training in COPD patients, improvements in peak work capacity were seen, which have not been reported previously. The observed improvements in exercise capacity after strengthening exercises in the present study differ from the results of other studies in COPD patients [7, 15]. The strengthening exercises and the training intensity were comparable, but the number of training sessions and the inclusion criteria were different. In previous studies patients had a maximum of 24 training sessions [7, 15], while the patients in this study were given the opportunity to attend 36 sessions. The higher number of training sessions probably resulted in greater improvements in the peak workload and functional exercise capacity. Secondly, CLARK *et al.* [7] included relatively young patients (age 51±10 yrs) with mild obstruction (FEV1 76±23% pred) in comparison with the resistance training group in this study (age 64±7 yrs, FEV1 40±18% pred). More importantly, severity of peripheral muscle weakness was not explicitly described at baseline in previous studies [7, 15], whereas peripheral muscle weakness was a clear inclusion criterion in the present study.

Besides methodological differences, the improvements in peak work capacity could be explained by the fact that the baseline maximal exercise test performed by the patients in the present study was submaximal, therefore underestimating the peak exercise capacity. The physiological data at maximal workload (table 2), however, showed clear ventilatory exercise limitations accompanied with high Borg scores, indicating that the initial cycle ergometry test was a true peak exercise test. Improvements in peak oxygen uptake after resistance training were not statistically significant, but there was a significant decrease in ventilation at equivalent levels of oxygen uptake after resistance training, without significant changes in the breathing pattern. These findings might indicate potential adaptations in peripheral muscle metabolism. This is in contrast with the common belief that resistance training improves only peripheral muscle force without significant changes in exercise capacity [30]. Recent studies in elderly subjects showed that resistance training can induce muscular adaptations that are in line with improvements seen after endurance training. In several independent studies involving healthy elderly subjects, resistance training enhanced components of the oxygen transport system (*i.e.* number of capillaries per fibre and activity of oxidative enzymes), leading to improved peak oxygen uptake [26, 31, 32]. In addition, a rise in mitochondrial volume density and a significantly faster phosphocreatine recovery rate were seen [33], indicating significant increases in the oxidative properties of the muscles after resistance training. Similar results were found in chronic heart failure patients suffering from peripheral muscle weakness where a 10-week resistance training led to significant increases in type I fibre area and enhanced oxidative enzyme activity in skeletal muscles [14]. It appears that weak peripheral muscles respond to resistance training. Whether this is to be expected in COPD patients without peripheral muscle weakness remains speculative.

Effects on peripheral muscle forces

Since previous studies have shown a significant correlation of peripheral muscle force with both exercise capacity [9, 10] and utilization of healthcare resources [34], improving peripheral muscle force may be clinically very relevant for COPD patients. In the present study, resistance training caused significant increases in peripheral muscle force of the trained muscle groups, which are similar to the findings of previous studies, which compared resistance training in COPD patients with a control group (no intervention) [7, 15]. The significant improvements in peripheral muscle force after endurance training have been reported before in COPD patients with peripheral muscle weakness [2, 4]. Like resistance training, endurance training seems to be an adequate training stimulus to enhance muscle force in COPD patients with peripheral muscle weakness. Initially, it seems surprising that after endurance training only knee extension peak torque (assessed in 60° knee flexion) was enhanced significantly, while after resistance training maximal isometric knee extension force (assessed in 90° knee flexion) was also significantly increased. However, MULLER [35] and THEPAUT-MATHIEU *et al.* [36], found that resistance gains from training were significantly better at the angle at which resistance training was undertaken than at other angles. In the present study, knee extension in the resistance-training program was performed over a range of 0–90° flexion, while cycling in the endurance training was performed with a 10–60° knee flexion. Hence, differences in resistance gain between the study groups might be due to angle specificity.

Clinical implications

COPD patients often encounter peripheral muscle weakness, which affects exercise performance. In addition, these patients have difficulties with, or are not able to complete, high intensity endurance training. The present study shows that resistance training might be a worthwhile alternative to achieve a high intensity training load. In addition, COPD patients have shown different degrees of muscle weakness between different peripheral muscle groups [37]. Resistance can be used for selective muscle training, adapted to the individual needs of the patient.

In conclusion, in patients with chronic obstructive pulmonary disease and peripheral muscle weakness: 1) 12-week resistance training or endurance training resulted in significant improvements in peripheral muscle force, exercise performance and health-related quality of life; 2) despite two completely different training programs, no significant differences were observed in the effects on 6-min walking distance or health-related quality of life; 3) the capacity for improving muscle force with an adequate training regime, which could involve resistance or endurance training, is retained. At present, resistance training appears to be a good alternative to endurance training for patients who suffer from peripheral muscle weakness.

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