

Effects of Anaerobic Training in Children With Cystic Fibrosis*

A Randomized Controlled Study

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Background: Children's physical activity patterns are characterized by short-term anaerobic activities. Anaerobic exercise performance in children with cystic fibrosis (CF) has received little attention compared to aerobic performance. This study investigated the effects of anaerobic training in children with CF.

Design and methods: Twenty patients were randomly assigned to the training group (TG) [11 patients; mean (\pm SD) age, 13.6 \pm 1.3 years; mean FEV₁, 75.2 \pm 20.7% predicted] or the control group (CG) [9 patients; mean age, 14.2 \pm 2.1 years; FEV₁, 82.1 \pm 19.1% predicted]. The TG trained 2 days per week for 12 weeks, with each session lasting 30 to 45 min. The training program consisted of anaerobic activities lasting 20 to 30 s. The control subjects were asked not to change their normal daily activities. Body composition, pulmonary function, peripheral muscle force, habitual physical activity, aerobic and anaerobic exercise performance, and quality of life were reevaluated at the end of the training program, and again after a 12-week follow-up period.

Results: Patients in the TG significantly improved their anaerobic performance, aerobic performance, and quality of life. No significant changes were seen in other parameters, and no improvements were found in CG. After the follow-up period, only anaerobic performance and quality of life in TG were significantly higher compared to pretraining values.

Conclusions: Anaerobic training has measurable effects on aerobic performance (although not sustained), anaerobic performance, and health-related quality of life in children with CF. Therefore, anaerobic training could be an important component of therapeutic programs for CF patients. (CHEST 2004; 125:1299-1305)

Key words: anaerobic training; cystic fibrosis; nutritional status; pulmonary function; quality of life

Abbreviations: BMI = body mass index; BW = body weight; CF = cystic fibrosis; CFQ = cystic fibrosis questionnaire; CG = control group; FFM = fat-free mass; HRQOL = health-related quality of life; MP = mean power; PP = peak power; TG = training group; $\dot{V}O_2$ = oxygen uptake; $\dot{V}O_{2peak}$ = peak $\dot{V}O_2$; WAnT = Wingate anaerobic test; Wmax = maximal workload

Regular aerobic exercise has positive effects on the aerobic capacity of patients with cystic fibrosis (CF).¹⁻³ In addition, higher aerobic fitness has been associated with prolonged survival and quality of life.^{4,5} Compared to the attention given to aerobic

studies, little has been given to anaerobic fitness. Especially lacking are controlled studies on the effects of anaerobic training in children and adolescents with CF. This is somewhat surprising since children's natural activity patterns are characterized by very short vigorous bouts of physical activity, interspersed with varying levels of low-to-moderate intensity.⁶ Therefore, physical activity patterns in children may be more suited for a high-intensity anaerobic training program.

Several studies⁷⁻¹² have shown reduced anaerobic performance in children with CF. In addition, children with CF do not participate in activities with high intensity as much as do healthy control subjects.¹³

It has been shown that healthy children's anaerobic performance can be enhanced through participa-

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tion in structured exercise programs.^{14,15} Rotstein and colleagues¹⁴ reported an increase in aerobic and anaerobic performance after an anaerobic training program. It is not clear whether anaerobic training can improve anaerobic and aerobic fitness in children with CF.

Improvement of anaerobic performance could be important for the daily functioning of children with CF. The aim of this study was therefore to investigate the effects of an anaerobic training program on anaerobic and aerobic performance, lung function, body composition, peripheral muscle strength, and health-related quality of life (HRQOL) of children with CF.

MATERIALS AND METHODS

Subjects

Children with CF were recruited from the Cystic Fibrosis Center at University Medical Center (Utrecht, the Netherlands). Inclusion criteria were as follows: children aged 9 to 18 years with a stable clinical condition (*ie*, no need for oral or IV antibiotic treatment in the 3 months prior to testing); the absence of musculoskeletal disorders; and an FEV₁ of > 30% predicted. Twenty-three patients agreed to participate. Our institutional ethics committee approved the study protocol. Informed consent was obtained from each participant and from his or her parent.

Study Protocol

After the baseline measurements, the tests were repeated within 7 days after the training program was finished, and again 12 weeks later. The study was designed as a randomized controlled trial. After the pretraining tests, the children were randomly assigned by concealed opaque envelopes to either the training group (TG) or the control group (CG). The control subjects were asked to continue their normal daily activities as well as their physiotherapy regime. The primary researcher was blinded for the experimental condition.

Nutritional Assessment

Anthropometric measurements were made prior to exercise testing. Fat-free mass (FFM) was determined in fasting condition using bioelectrical impedance techniques. Body weight (BW) was measured using a platform beam balance (Mettler; Greifensee, Switzerland) with an accuracy of 0.02 kg. Height was measured with a stadiometer (Holtain; Crymich, UK) with an accuracy of 0.1 cm. Body mass index (BMI) was determined (weight/height²).

Pulmonary Function Tests

Pulmonary function tests were performed after the inhalation of 800 µg salbutamol via metered-dose inhaler with a spacer in order to rule out important bronchial hyperreactivity. FVC, FEV₁, and forced expiratory flow between 25% and 75% of expiratory vital capacity were obtained from maximal expiratory flow-volume curves (Masterscreen; Jaeger; Wuerzburg, Germany). Residual volume and total lung capacity were measured in a volume-constant body plethysmograph (Masterlab; Jaeger) and

the residual volume/total lung capacity ratios were calculated from the actual values. Values are expressed as the percentage of predicted values.¹⁶

Peripheral Muscle Strength

Isometric muscle force measurements were performed for four muscle groups (*ie*, shoulder abductors, elbow flexors, hip-extensors, and knee extensors) according to the description of Backman et al.¹⁷ Results for peripheral muscle force are presented as the total maximal muscle force (*ie*, summed maximal force in four muscle groups, since factor analyses showed a single-factor solution [eigenvalue, 2.7; 68% of total variance]).

Exercise Testing

Subsequent anaerobic and aerobic exercise tests were performed on an electronically braked cycle ergometer (Lode Examiner; Groningen, the Netherlands). All subjects were familiar with the different tests and equipment used. During the tests, heart rate was monitored continuously by three-lead ECG (Hewlett-Packard; Amstelveen, the Netherlands) and oxygen saturation by pulse oximetry (200 E; Nellcor; Breda, the Netherlands). Verbal encouragement was given throughout the tests to stimulate maximal performance.

Each subject performed a Wingate anaerobic test (WanT) to assess anaerobic performance.¹⁸ The WanT is a valid and reliable test to evaluate short-term anaerobic power in healthy children, and in children with CF and other chronic illnesses.^{7,11,18,19} The subjects were instructed to start pedaling as fast as possible after a 1-min warm-up against 15-W resistance, while at the same time the full breaking force was applied through an integrated computer program. Anaerobic performance indexes were reported as mean power (MP [power averaged for > 30 s]) and peak power (PP [highest power during the test]).

After the WanT, the subjects rested for at least 45 min before aerobic fitness was assessed by a standard progressive incremental exercise test. Workload was increased by 15 W at 1-min intervals. The *maximal workload* (W_{max}) was defined as the highest workload maintained during 30 s. Continuous respiratory gas analysis and volume measurements were performed breath by breath with a triple V valveless mouthpiece, and were stored in a computerized exercise system (Oxycon Champion; Jaeger). Internal gas and volume calibrations were made before each test. Measurements taken included oxygen uptake ($\dot{V}O_2$), carbon dioxide production, ventilation, and respiratory exchange ratio (*ie*, carbon dioxide production/ $\dot{V}O_2$). The highest $\dot{V}O_2$ achieved during the last 30 s of exercise was taken as the peak $\dot{V}O_2$ ($\dot{V}O_{2peak}$).⁸

Efforts were considered to be at a maximum level if subjects showed clinical signs of intense effort and were unable to maintain speed at > 50 revolutions per minute,²⁰ and if at least one of the following two criteria were met: (1) cardiac frequency of > 180 beats/min; or (2) maximal respiratory exchange ratio of > 1.0.^{21,22} Predicted $\dot{V}O_{2peak}$ values were obtained from an age-matched and gender-matched Dutch reference population.²³

Lactate

Blood samples were drawn 3 min after peak aerobic exercise from an antecubital vein and were collected in tubes (Vacutainer; Becton Dickinson; Franklin Lakes, NJ) and subsequently analyzed (Vitros 250 analyzer; Johnson & Johnson Clinical Diagnostics; Rochester, NY).

Daily Physical Activity

Physical activity was assessed with the habitual activity estimation scale.²⁴ This scale reviews the subject's activity level for 2

weekdays during the previous 2 weeks. The total percentage of time spent being active is presented. The habitual activity estimation scale has been used in studies of children with CF^{25,26} and in other studies of children with chronic disease.²⁷

Quality of Life

Quality of life was measured with a disease-specific HRQOL questionnaire, the CF questionnaire (CFQ). The CFQ consists of a 47-item teen/adult version and a 35-item child version.^{28,29} The CFQ takes into account the different developmental stages, and makes it possible to monitor the health status and quality of life of patients with CF from 6 years of age throughout adulthood.^{28,29}

Anaerobic Training Program

The subjects in the TG trained on an individual basis, and the standardized training sessions were led by the children's own physiotherapist. Specific written instructions in the form of a booklet were given to the physiotherapists. The TG trained 2 days per week for 12 weeks. Each session lasted 30 to 45 min. Guidelines based on a review of anaerobic training studies in children were used.³⁰ The training program consists of eight basic training sessions that were repeated every 4 weeks. The training program is described in more detail at www.chestjournal.org/cgi/content/full/125/4/1299/DC1. Individual scores and changes in training overload were carefully recorded in a logbook. The children were constantly encouraged to exercise at maximal speed.

Statistical Analysis

The data are presented as mean \pm SD. All data were tested for normality with the Shapiro-Wilks test. The analysis of variance for repeated measures was used for within-group and between-group comparisons. Between-group comparisons were made with an unpaired *t* test. Changes within the two groups were analyzed with a two-tailed paired *t* test. Pearson correlation analyses and linear regression analyses were performed for HRQOL with aerobic and anaerobic indexes. Data were analyzed using the a statistical software package (SPSS, version 9.0; SPSS; Chicago, IL).

To achieve a difference in PP per kilogram BW of 10% with an SD of 0.8 W/kg and a statistical power of 80%, it was calculated that eight patients had to be included in each study group.

RESULTS

Twenty-three patients were initially enrolled into the study. Two patients (FEV₁, 37.5 \pm 7.8% predicted) in the CG failed to complete the study because of pulmonary exacerbation, and one patient (FEV₁, 105% predicted) in the TG withdrew from the study for practical reasons. The baseline characteristics of the remaining 20 patients are shown in Table 1, and the baseline results for anaerobic and aerobic performance are shown in Table 2. Both exercise tests were well-tolerated by all patients, and all patients fulfilled the criteria for undergoing a maximal aerobic exercise test. Comparisons between groups revealed no significant differences at baseline.

Table 1—Baseline Characteristics of the TG and the CG*

Characteristics	TG (n = 11)	CG (n = 9)
Age, yr	13.6 \pm 1.3	14.2 \pm 2.1
Height, cm	155.5 \pm 8.2	159.8 \pm 8.5
Weight, kg	41.9 \pm 5.9	47.7 \pm 8.7
BMI, kg/m ²	17.2 \pm 1.0	18.5 \pm 2.3
FFM, kg	27.9 \pm 3.4	31.4 \pm 4.6
FEV ₁ , % predicted	75.2 \pm 20.7	82.1 \pm 19.1
VC, % predicted	85.0 \pm 14.0	93.2 \pm 15.8
FEF ₂₅₋₇₅ , % predicted	54.1 \pm 45.3	51.0 \pm 30.6
RV/TLC, %	37.2 \pm 11.2	32.6 \pm 8.7
Isometric muscle force, nm	648 \pm 118	668 \pm 78
Activity level, %	25.6 \pm 13.7	25.9 \pm 19.1

*Values given as means \pm SD. VC = vital capacity; FEF₂₅₋₇₅ = forced expiratory flow at 25 to 75% of vital capacity; RV = residual volume; TLC = total lung capacity. p Value was not significant for all between-group comparisons.

The adherence of the TG to the exercise training was excellent. The mean attendance rate at the exercise sessions was 98.1 \pm 4.3%. Reasons for absence were holidays and sickness.

Effects of Exercise Training

Body Composition, Pulmonary Function, Muscle Force, and Habitual Physical Activity: At the end of the 12-week training period, a significant within-group increase was found for height (TG, 1.5 \pm 0.9 cm [p < 0.001]; CG, 1.1 \pm 1.0 cm [p < 0.05]) and weight (TG, 0.4 \pm 0.6 kg [p < 0.05]; CG, 0.8 \pm 1.0 [p < 0.05]). Within-group and between-group comparisons revealed no significant differences for body

Table 2—Baseline Results for Anaerobic and Aerobic Performance*

Variables	TG (n = 11)	CG (n = 9)
Anaerobic performance		
PP		
W	547 \pm 178	647 \pm 179
W/kg BW	12.8 \pm 2.5	13.4 \pm 1.6
W/kg FFM	18.7 \pm 3.7	20.3 \pm 3.2
MP		
W	296 \pm 92	365 \pm 104
W/kg BW	6.9 \pm 1.3	7.7 \pm 0.9
W/kg FFM	10.1 \pm 1.8	11.4 \pm 1.8
Aerobic performance		
$\dot{V}O_{2peak}$		
mL/min	1677 \pm 242	1904 \pm 330
mL/kg/min	40.2 \pm 4.2	40.7 \pm 8.3
mL/kg/FFM	60.1 \pm 5.4	60.8 \pm 8.4
% predicted	83.1 \pm 9.1	84.2 \pm 10.4
Wmax, W	140 \pm 20	156 \pm 26
Lactate, mmol/L	6.9 \pm 1.9	9.6 \pm 4.0

*Values given as mean \pm SD. p Values were not significant for all between-group comparisons.

composition, pulmonary function, peripheral muscle force, and habitual physical activity at the end of the training period.

Anaerobic and Aerobic Performance: The changes observed after the 12-week training period for anaerobic and aerobic performance are shown in Table 3. The TG showed significant improvements in absolute PP (11.7%) and MP (12.4%), in PP and MP per kilogram BW (10.9% and 10.1%, respectively), and in PP and MP per kilogram FFM (11.8% and 11.9%, respectively). With respect to aerobic measurements, the TG showed significant improvements in $\dot{V}O_{2peak}$ (5.2 mL/min and 5.7% predicted), W_{max} (7.9%), and serum lactate levels (26.1%), while the increase in $\dot{V}O_{2peak}$ per kilogram FFM (5.2%) was not significant. In the CG, a significant decrease was found for $\dot{V}O_{2peak}$ per kilogram BW (−1.5%) and per kilogram FFM (−5.6%), while other parameters were unchanged.

Quality of Life

At the end of the 12-week training period, a significantly higher score was found in the domain of physical functioning in the TG (70.3 ± 13.8 vs 88.4 ± 9.0 , respectively; $p < 0.001$), but no change was found in the CG (83.2 ± 18.5 vs 87.1 ± 17.9 , respectively; $p = 0.20$) or in other quality-of-life domains.

Regression analysis in the TG indicated that the change in PP accounted for 41% of the variance in

the physical functioning domain ($p < 0.05$). Changes in MP or $\dot{V}O_{2peak}$ were not independent correlates of changes in quality-of-life scores.

Effects of Follow-up Period

Comparing the pretraining period and the end of the follow-up period, a significant increase was found for mean height (TG, 2.8 ± 1.0 cm [$p < 0.001$]; CG, 2.1 ± 1.2 cm [$p < 0.01$]), weight (TG, 1.7 ± 1.5 kg [$p < 0.01$]; CG, 1.7 ± 1.3 kg [$p < 0.01$]), and FFM (TG, 2.0 ± 2.3 kg [$p < 0.05$]; CG, 1.7 ± 1.2 kg [$p < 0.05$]), but no changes were found for habitual physical activity. However, between-group comparisons of changes observed at the pretraining assessment compared with the end of the follow-up period were not significant. BMI, pulmonary function, peripheral muscle force, and habitual physical activity did not change significantly in both groups.

The TG showed significant higher follow-up levels of absolute PP (54.6 ± 47.7 W; $p < 0.001$) and MP (24.9 ± 73.5 W; $p < 0.01$) when compared with pretraining levels. The increase in the CG was not significant compared to baseline values (PP, 21.7 ± 15.6 [$p = 0.34$]; MP, 12.7 ± 34.4 [$p = 0.31$]). All other anaerobic indexes decreased to baseline values.

With respect to aerobic performance, no significant differences were found in the TG between values at baseline and at the end of follow-up period. The CG showed significantly lower $\dot{V}O_{2peak}$ (BW decrease, 1.5 ± 1.7 mL/kg/min [$p < 0.05$]; FFM decrease, 3.0 ± 1.9 mL/kg/min) and serum lactate levels (decrease, 1.2 ± 1.2 mmol/L; $p < 0.05$) when comparing values in the pretraining period and at the end of the follow-up period. At the end of the follow-up period, the domain of physical functioning in the TG (8.3 ± 8.4 ; $p < 0.01$) was still significantly higher compared to pretraining values.

Table 3—Effect of Training Program on Anaerobic and Aerobic Performance*

Variables	TG (n = 11)	CG (n = 9)
Anaerobic performance		
ΔPP		
W	$66.9 \pm 23.8\ddagger$	-3.4 ± 53.7
W/kg BW	$1.4 \pm 0.6\ddagger$	-0.3 ± 1.1
W/kg FFM	$2.2 \pm 1.2\ddagger$	-0.6 ± 2.0
ΔMP		
W	$36.6 \pm 11.8\ddagger$	-6.7 ± 29.9
W/kg BW	$0.7 \pm 0.3\ddagger$	-0.3 ± 0.8
W/kg FFM	$1.2 \pm 0.6\ddagger$	-0.4 ± 1.1
Aerobic performance		
$\Delta \dot{V}O_{2peak}$		
mL/min	$88 \pm 106\ddagger$	-48 ± 63
mL/kg/min	1.5 ± 2.6	$-0.6 \pm 1.9\ddagger$
mL/kg/FFM	1.3 ± 4.6	$-3.2 \pm 2.5\ddagger$
% predicted	$4.7 \pm 5.6\ddagger$	-2.1 ± 2.8
ΔW_{max} , W	$11 \pm 14\ddagger$	-2 ± 5
$\Delta Lactate$, mmol/L	$1.8 \pm 1.4\§$	-1.6 ± 2.9

*Values given as mean \pm SD.

$\ddagger p < 0.001$.

$\ddagger p < 0.05$.

$\§ p < 0.01$.

DISCUSSION

The aim of this study was to investigate the effects of an anaerobic training program in children with CF. In this single-blind, randomized, controlled study, after a 12-week training period, improvements were observed in anaerobic and aerobic outcome parameters and in HRQOL. In addition, at the end of a 12-week follow-up period most outcome parameters decreased to pretraining values, with the exception of anaerobic performance and HRQOL.

To our knowledge, this is the first study to document that children with CF are able to improve their anaerobic exercise capability through a high-intensity training program. These results are in agreement with those of anaerobic training studies in

healthy children.^{14,15,31} The TG increased their PP by 12.2%, which compares favorably with the results of the study by McManus and colleagues³² after an 8-week sprint-running training program performed three times per week in healthy girls (PP, 9.7%). Rotstein and colleagues¹⁴ reported an increase in PP and MP per kilogram BW (14% and 10%, respectively) after a 9-week training program that was performed three times per week. These results are consistent with the increase found in our study (PP/kg BW, 11%; MP/kg BW, 10%). Grodjinovsky and colleagues¹⁵ reported much lower improvements in MP per kilogram BW (3 to 4%) and PP per kilogram BW (4%) after a 6-week anaerobic training program that was performed three times per week in healthy children who were 11 to 13 year old. Although guidelines for anaerobic training in children have not yet been clearly established,³⁰ the outcomes of these findings suggest that a minimal time period of approximately 8 weeks would be likely to induce a substantial improvement in pediatric anaerobic fitness.

Changes in aerobic exercise capacity usually are associated with specific training programs involving several hours per week at submaximal intensity.³³ Although the intensity of our training program may be considered very stressful and the duration of the exercises very brief, anaerobic training resulted in an increase in $\dot{V}O_{2peak}$ (5%). This result is in accordance with those of studies^{14,34} in healthy children that have shown an increase in aerobic capacity of 4 to 7% after anaerobic training. These results may be explained by the fact that resynthesis of adenosine triphosphate during high-intensity exercise depends on both aerobic and anaerobic processes.³⁵ Moreover, in children approximately 40% of energy production in the WanT test comes from aerobic metabolism.³⁰ In addition, although an incremental exercise test explores aerobic capacity and is not a valid tool for assessing anaerobic performance,³⁶ the increase in serum lactate values seen in the TG suggests a larger contribution of anaerobic glycolysis during peak aerobic exercise. In other words, improved anaerobic energy metabolism possibly enhanced aerobic power output. This is supported by the finding that during specific aerobic training a decrease is seen in serum lactate concentration.³⁷

Increased anaerobic performance has been linked to biochemical changes in the muscle of children.³¹ Fournier and colleagues³¹ reported a 21% increase in anaerobic enzyme activity after sprint training. Subsequently, higher serum lactate values in our study provide indirect evidence in support of improvements in biochemical processes associated with anaerobic metabolism as a result of the training program.

Improvements in HRQOL, as measured by the disease-specific CFQ, were seen in the TG. This is consistent with the results of other studies,^{5,38} which found improvements in quality-of-life scores after aerobic training, as measured with a generic measure (*ie*, the quality of well-being scale). Furthermore, as shown in our study and in other studies,^{5,38} changes in HRQOL are related to changes in exercise performance. This emphasizes the need to assess further both HRQOL and exercise performance, which provide valuable information on the multidimensional impact of the disease on patient's quality of life and can make an important contribution to decision making in clinical practice.^{38,39}

In our study, no positive or adverse effects were seen in pulmonary function, FFM, and peripheral muscle strength due to the training program. As could be expected, no change was found in the amount of habitual physical activity, since we asked the participants not to change their activity level during the study period. Until now, the influence of physical training on pulmonary function has not been established clearly. Several studies⁴⁰⁻⁴² have shown improvements in pulmonary function after aerobic training. In contrast, other studies^{1,2,38,43} have failed to detect improvements in pulmonary function. Eventually, all studies show that training is safe for the patients' respiratory condition.

Effects of Follow-up Period

The increases found in the study parameters in the TG decreased to baseline values after the 12-week follow-up period, with the exception of anaerobic performance and HRQOL. Generally, the benefits of exercise disappear if physical activity is discontinued. However, as shown in our study and the studies of others,^{38,41} benefits due to training seem to continue for some time in patients with CF, regardless of follow-up training sessions.

Clinical Implications of Anaerobic Training

Up to now, anaerobic exercise has received little attention compared to that for aerobic exercise, although many activities in daily life as well as sport activities are both aerobic and anaerobic in nature.^{8,9} Regular exercise is an important part of treatment in patients with CF. Adherence to exercise programs depends on individual motivation and variation in activities. The children enjoyed our training program, which motivated them to attend 98% of the training sessions. Our anaerobic training program offered the necessary variation to enhance adherence to it. The increase in anaerobic and aerobic performance and in HRQOL after anaerobic training indicates that this type of training can be in-


cluded in the overall physical rehabilitation of children with mild-to-moderate CF. Ideally, an exercise program for children with CF could be made of aerobic, anaerobic, and strength-training activities. This makes it possible to individually tailor the program according to the preference of the participants, thereby improving the levels of exercise adherence.⁴⁴

In conclusion, our results suggest that children with mild-to-moderate CF can enhance their anaerobic and aerobic performance and HRQOL through participation in a structured anaerobic exercise training program. In addition, aerobic performance increases as well. The improvements in anaerobic performance and HRQOL are maintained through a 12-week follow-up period. Therefore, anaerobic training could be an important component of the rehabilitation program of children with CF.

REFERENCES

- Gulmans VA, de Meer K, Brackel HJ, et al. Outpatient exercise training in children with cystic fibrosis: physiological effects, perceived competence, and acceptability. *Pediatr Pulmonol* 1999; 28:39–46
- Orenstein DM, Franklin BA, Doershuk CF, et al. Exercise conditioning and cardiopulmonary fitness in cystic fibrosis: the effect of a three-month supervised running program. *Chest* 1981; 80:392–398
- Stanghelle JK, Skyberg D, Haanæs OC. Eight-year follow-up of pulmonary function and oxygen uptake during exercise in 16-year-old males with cystic fibrosis. *Acta Paediatr* 1992; 81:527–531
- Nixon PA, Orenstein DM, Kelsey SF, et al. The prognostic value of exercise testing in patients with cystic fibrosis. *N Engl J Med* 1992; 327:1785–1788
- Orenstein DM, Nixon PA, Ross EA, et al. The quality of well-being in cystic fibrosis. *Chest* 1989; 95:344–347
- Bailey RC, Olson J, Pepper SL, et al. The level and tempo of children's physical activities: an observational study. *Med Sci Sports Exerc* 1995; 27:1033–1041
- Boas SR, Danduran MJ, McColley SA. Energy metabolism during anaerobic exercise in children with cystic fibrosis and asthma. *Med Sci Sports Exerc* 1999; 31:1242–1249
- Shah AR, Gozal D, Keens TG. Determinants of aerobic and anaerobic exercise performance in cystic fibrosis. *Am J Respir Crit Care Med* 1998; 157:1145–1150
- Boas SR, Joswiak ML, Nixon PA, et al. Factors limiting anaerobic performance in adolescent males with cystic fibrosis. *Med Sci Sports Exerc* 1996; 28:291–298
- Lands LC, Heigenhauser GJ, Jones NL. Analysis of factors limiting maximal exercise performance in cystic fibrosis. *Clin Sci* 1992; 83:391–397
- Cabrera ME, Lough MD, Doershuk CF, et al. Anaerobic performance, assessed by the Wingate test, in patients with cystic fibrosis. *Pediatr Exer Sci* 1993; 5:78–87
- Lands LC, Heigenhauser GJ, Jones NL. Maximal short-term exercise performance and ion regulation in cystic fibrosis. *Can J Physiol Pharmacol* 1993; 71:12–16
- Nixon PA, Orenstein DM, Kelsey SF. Habitual physical activity in children and adolescents with cystic fibrosis. *Med Sci Sports Exerc* 2001; 33:30–35
- Rotstein A, Dotan R, Bar-Or O, et al. Effect of training on anaerobic threshold, maximal aerobic power and anaerobic performance of preadolescent boys. *Int J Sports Med* 1986; 7:281–286
- Grodjinovsky A, Inbar O, Dotan R, et al. Training effect on the anaerobic performance of children as measured by the Wingate test. In: Berg K, Errikson B, eds. *Children and exercise IX*. Baltimore, MD: University Park Press, 1980; 139–145
- Zapletal A, Samenek TP. *Lung function in children and adolescents: methods and reference values*. Basel-Munich: Karger, 1987
- Backman E, Odenrick P, Henriksson KG, et al. Isometric muscle force and anthropometric values in normal children aged between 3.5 and 15 years. *Scand J Rehabil Med* 1989; 21:105–114
- Bar-Or O. The Wingate anaerobic test: an update on methodology, reliability and validity. *Sports Med* 1987; 4:381–394
- Takken T, van der Net J, Helders PJ. Association of physical fitness with functional ability in children with juvenile idiopathic arthritis [abstract]. *Med Sci Sports Exerc* 2002; 34:S160
- Rowland TW. *Developmental exercise physiology*. Champaign, IL: Human Kinetics, 1996; 29–37
- Gulmans VA, de Meer K, Brackel HJ, et al. Maximal work capacity in relation to nutritional status in children with cystic fibrosis. *Eur Respir J* 1997; 10:2014–2017
- Nixon PA, Orenstein DM. Exercise testing in children. *Pediatr Pulmonol* 1988; 5:107–122
- Binkhorst RA, Saris WHM, Noordeloos AM, et al. Maximal oxygen consumption of children (6 to 18 years) predicted from maximal and submaximal values in treadmill and bicycle tests. In: Rutenfranz J, Mocellin R, Klimt F, eds. *Children and exercise XII*. Champaign, IL: Human Kinetics, 1986; 227–232
- Hay J. Development and testing of the habitual activity estimation scale. In: Armstrong N, ed. *Children and exercise XIX*. 2nd ed. Exeter, WA: Singer Press, 1997; 125–129
- Boucher GP, Lands LC, Hay JA, et al. Activity levels and the relationship to lung function and nutritional status in children with cystic fibrosis. *Am J Phys Med Rehabil* 1997; 76:311–315
- Schneiderman-Walker J, Pollock SL, Corey M, et al. A randomized controlled trial of a 3-year home exercise program in cystic fibrosis. *J Pediatr* 2000; 136:304–310
- Atkinson SA, Halton J, Hay J, et al. Normative values for lumbar spine bone mass in children in relation to age, gender, dietary intake and physical activity [abstract]. *J Bone Miner Res* 1996; 6:627
- Henry B, Grosskopf C, Aussage P, et al. Construction of a disease-specific quality of life questionnaire for cystic fibrosis [abstract]. *Pediatr Pulmonol* 1997; 13(suppl):337–338
- Quittner AL, Sweeny S, Watrous M, et al. Translation and linguistic validation of a disease-specific quality of life measure for cystic fibrosis. *J Pediatr Psychol* 2000; 25:403–414
- Armstrong N, Welsman J. *Anaerobic exercise: growth and maturation*. In: Young people and physical activity. Oxford, UK: Oxford University Press, 1997; 87–93
- Fournier M, Ricci J, Taylor AW, et al. Skeletal muscle adaptation in adolescent boys: sprint and endurance training and detraining. *Med Sci Sports Exerc* 1982; 14:453–456
- McManus AM, Armstrong N, Williams CA. Effect of training on the aerobic power and anaerobic performance of prepubertal girls. *Acta Paediatr* 1997; 86:456–459
- Rowland TW, Boyajian A. Aerobic response to endurance exercise training in children. *Pediatrics* 1995; 96(suppl):654–658
- Williams CA, Armstrong N, Powell J. Aerobic responses of prepubertal boys to two modes of training. *Br J Sports Med* 2000; 34:168–173

- 35 Medbo JI, Tabata I. Anaerobic energy release in working muscle during 30 s to 3 min of exhausting bicycling. *J Appl Physiol* 1993; 75:1654-1660
- 36 Counil FP, Karila C, Varray A, et al. Anaerobic fitness in children with asthma: adaptation to maximal intermittent short exercise. *Pediatr Pulmonol* 2001; 31:198-204
- 37 Gaesser G, Poole D. Blood lactate during exercise: time course of training adaptation in humans. *Int J Sports Med* 1988; 9:284-288
- 38 Selvadurai H, Blimkie CJ, Meyers N, et al. Randomized controlled study of in-hospital exercise training programs in children with cystic fibrosis. *Pediatr Pulmonol* 2002; 33:194-200
- 39 Bradley J, McAlister O, Elborn S. Pulmonary function, inflammation, exercise capacity and quality of life in cystic fibrosis. *Eur Respir J* 2001; 17:712-715
- 40 Heijerman HGM, Bakker W, Sterk PJ, et al. Long-term effects of exercise training and hyperalimentation in adult cystic fibrosis patients with severe pulmonary dysfunction. *Int J Rehabil Res* 1992; 15:252-257
- 41 Zach M, Oberwaldner B, Hausler F. Cystic fibrosis: physical versus chest physiotherapy. *Arch Dis Child* 1982; 57:587-589
- 42 Baker C, Hackney A, Loehr J, et al. Outcome of a 6-week exercise training program in adolescents with cystic fibrosis [abstract]. *Pediatr Pulmonol* 2000; 20(suppl):453
- 43 Jong de W, Grevink RG, Roorda RJ, et al. Effect of home exercise training program in patients with cystic fibrosis. *Chest* 1994; 105:463-468
- 44 Prasad S, Cerny F. Factors that influence adherence to exercise and their effectiveness: application to cystic fibrosis. *Pediatr Pulmonol* 2002; 34:66-72



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