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ORIGINAL ARTICLE

# Beneficial effects of aerobic training in adolescent patients with moderate idiopathic scoliosis

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**Abstract**
*Aim and Methods* The major aim of this study was to determine whether after 6 weeks of aerobic training adolescent idiopathic scoliosis (AIS) girls who suffer from mild scoliotic curvatures ($n = 6$) behaved in a similar way than healthy controls ($n = 6$) in different biochemical, anthropometric, and cardio respiratory parameters.
*Results* The maximal power output and the power output achieved at the anaerobic threshold (AT), during the maximal exercise test, were significantly increased in both experimental groups, when compared with resting conditions. The training program caused significant changes in body composition (i.e., a decrease in body fat %) only in the scoliotic group. Regarding the cardio respiratory measurements, $VO_{2max}$ was increased by 17% in AIS group and 10% in the healthy group.
*Conclusions* Our results suggest that physical activity should be encouraged in scoliotic girls with mild curvatures.

**Keywords** Maximal oxygen consumption · Anaerobic threshold · Body fat · Life expectancy

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## Introduction

Several studies have shown the decrease in the capacity to produce aerobic work in young subjects with mild to moderate adolescent idiopathic scoliosis (AIS) (when scoliosis exceeds 25°) [1–3]. These abnormalities may lead to an increase in the energy required for walking or performing other physical activities [4]. However, the frequency and the relevance of the restricted work capacity is uncertain and a matter of controversy. Chong was the first author to introduce the exercise tests in the studies with AIS patients to amplify their possible respiratory alterations undetectable in rest conditions [5]. Maximal aerobic power ($VO_{2max}$) has mostly been the province of exercise physiologists wishing to provide a measure of athletic potential or to characterize subjects in exercise-related research. It is also used clinically to determine a patient's exercise capacity [6]. $VO_{2max}$ is the maximum amount of oxygen that can be used by the working muscles [6]. Large-scale epidemiological studies of subjects with and without cardiovascular disease demonstrate that low aerobic exercise capacity is a stronger predictor of mortality than other established risk factors such as: diabetes, smoking, body mass index greater than 30, hypertension or COPD [7, 8]. It has been reported that scoliotic children have a low capacity to perform aerobic work. Their aerobic capacity starts to decline when scoliosis exceeds 25° [2]. In 1981, it was postulated that the low aerobic capacity in patients with AIS is related to their physical inactivity [9]. It is well known that those types of patients usually avoid participation in physical activities and very often avoid physical education classes in school [2].

The major aim of this study was to determine whether an exercise training protocol induces beneficial effects in AIS girls. For this purpose, we studied the beneficial effects of 6-week aerobic training in AIS girls who suffer from mild scoliotic curvatures on different biochemical, anthropometric, and cardio-respiratory parameters.

## Materials and methods

### Sample

Six young girls aged between 12 and 15 years with adolescence idiopathic scoliosis (scoliosis Cobbs angle 28.1° ± 2.1° and Risser 1.7 ± 1.8) volunteered for this study. All the AIS patients selected had right thoracic primary curve (Lenke type I) [10]. Six healthy girls matched in age and without spinal deformity participated in the study as a control group. All of the girls were informed of the purpose, protocol and procedures prior to acceptance into the study. The scoliotic group was recruited following the diagnosis of their condition by physicians of an Spanish hospital. Spinal deformity was measured from anteroposterior radiographs in standing position. None of the girls used braces.

The control group was selected from a secondary education institute between courses of 2°, 3° and 4° complying with the inclusion criteria. All the girls in the study were non-smokers and free from any known illnesses (apart from the scoliosis) as ascertained by the medical doctors. Girls underwent a complete physical examination before the exercise tests to discard any type of incapacity or pathology that could contraindicate the test. None of the girls in both groups was active in athletics. The usual physical exercise program included in the educational curriculum of these students comprises a variety of sports activities for 2 h, twice a week. Volunteers exceeding these limits for any reason were excluded from the study. The Committee on Ethics in Research of the hospital where the study was developed granted ethical approval.

### Measurements

Anthropometric measurements, blood analysis, cycle ergometer test, and spirometer measurements were performed at the beginning and at the end of the training program. Table 1 shows the basic anthropometric characteristics and biochemical parameters determined in blood.

### Testing procedures

Testing of the training group was performed during the first (before training) and last (after training) visit of the subjects to the training area. These occasions included only testing of the subjects, but not training. Estimation of body fat was calculated according to Durnin and Rahaman [11] using the method of body skinfolds. The Fukuda Sagnyo ST-90 spirometer was used for the measurement of forced

**Table 1** Anthropometric characteristics and biochemical parameters before and after the training protocol in AIS girls and healthy controls

| | AIS group ($n = 6$) | | Healthy group ($n = 6$) | | ANOVA | Effect of condition ($p$ value) | Effect of training ($p$ value) | Interaction training × condition |
|---|---|---|---|---|---|---|---|---|
| | Before | After | Before | After | | | | |
| Age (years) | 13.5 ± 1.9 | | 15.0 ± 0.8 | | | | | |
| Height (cm) | 159.7 ± 7.9 | 159.7 ± 7.8 | 165.9 ± 13.1 | 165.8 ± 13.1 | | | | |
| Weight (kg) | 50.4 ± 11.2 | 49.9 ± 12.1 | 60.4 ± 6.3 | 59.8 ± 5.4 | | | | |
| BMI (kg/m$^2$) | 19.5 ± 3.3 | 19.5 ± 3.7 | 21.9 ± 1.5 | 21.6 ± 1.2 | | | | |
| Body fat (%) | 15.1 ± 4.9 | 14.2 ± 4.7 | 15.9 ± 3.6 | 14.4 ± 5.0 | <0.05 | NS | <0.05 | NS |
| Degree of the curve (Cobb) | 28.1 ± 2.1 | 28.1 ± 1.8 | | | | | | |
| T-Chol (mg/dL) | 170.0 ± 39.0 | 170.0 ± 32.0 | 168.0 ± 23.0 | 169.0 ± 31.0 | | | | |
| LDL-Chol (mg/dL) | 96.0 ± 23.0 | 92.0 ± 19.0 | 94.0 ± 13.0 | 93.0 ± 15.0 | | | | |
| HDL-Chol (mg/dL) | 58.0 ± 14.0 | 58.0 ± 13.0 | 59.0 ± 12.0 | 59.0 ± 15.0 | | | | |

The values are presented as mean ± SD

*BMI* body mass index, *Cobb* scolisis Cobbs angle, *NS* not significant vital capacity (FVC, Us), forced expiratory volume in one second (FEV1, 1/1 s) and the ratio FEV1/FVC%.

All subjects completed the test until exhaustion to determine $VO_{2max}$. Different ventilator parameters such as the respiratory ratio ($R = VCO_2/VO_2$) were registered "breath by breath" through respiratory valve and face mask (Hans Rudolph, Inc., Kansas City, MO, USA) using the Oxycon gas analyzer (Jaeger). Before each test, the gas analyzer was calibrated for volumes and gas exchange composition. Heart Rate was monitored during the tolerance exercise test by continuous 12-lead ECG. Blood pressure was recorder by auscultation at rest and immediately after maximal exercise and after 1-and 3-min recovery periods.

### Training

The groups performing a cycling training program were subjected to a training program of three sessions per week during a period of 6 weeks with an approximate duration of 1 h per session (Table 2). The training intensity was increased from 65 to 85% $VO_{2max}$. All the girls were trained every day with a Pulsometer 810R Cardio Polar.

### Statistical analysis

For each variable analyzed, a repeated-measures 2-factor analysis of variance was performed. Repeated measures were performed for training (before training compared with after training); the second factor was the condition (AIS or control group). When an interaction effect was found, multiple comparisons using the Tukey post hoc test were performed. The critical level for the analysis of $p$ value was set at 0.05.

## Results

The training program significantly decreased the body fat mass in AIS group ($p < 0.05$), but the decrease did not reach the statistical difference in the healthy group ($p = 0.06$). However, the training program did not modify the plasma lipid profile (Table 1).

**Table 2** Details of the training protocol

| Weeks | $VO_{2max}$ (%) | Time (min) | Training sessions/week |
|---|---|---|---|
| 1 | 65 | 35 | 3 |
| 2 | 70 | 38 | 3 |
| 3 | 75 | 42 | 3 |
| 4 | 80 | 45 | 3 |
| 5 | 85 | 48 | 3 |
| 6 | 85 | 50 | 3 |

Table 3 shows the values before-training and after-training for AIS and healthy subjects, for the pulmonary parameters investigated in the study. It can be seen that aerobic training did not modified the FVC and FEV1. Nonetheless, FEV1/FVC% decreased significantly only in AIS group ($p < 0.05$).

Maximal aerobic power increases in response to training in both AIS and healthy groups. Maximal oxygen uptake was increased by 17% in AIS group ($p < 0.05$) and 10% in healthy group ($p < 0.05$). Metabolic equivalent calculated in metabolic equivalent of Task (METS) was increased after the program training in both groups by 8.7% ($p < 0.05$ in AIS group, and $p < 0.05$ in the healthy group).

Maximal breath frequency (BF) in response to maximal exercise was decreased significantly only in AIS group ($p < 0.05$). In line with other results, maximal respiratory ratio significantly increased after the program training only in AIS groups ($p < 0.05$).

As expected, no difference was found in maximal heart rate in both groups ($p > 0.05$). Nonetheless, HR at the AT was decreased in both groups; the change was statistically significant ($p < 0.05$). Maximal power output relative to body weight increased significantly in response to training in AIS and healthy groups. Consistently, training significantly modified the power output at the AT in both groups ($p < 0.05$).

## Discussion

Exercise training has been considered to be a causative factor of AIS especially among adolescent athletes who are engaged in certain athletic activities [12, 13]. In our study, we measured the degree of the curve according to Cobb and did not find any significant modification after 6 weeks of training in a cycle ergometer (See Table 1). In our view, participating in a training programme is not (positively or negatively) associated with the development of AIS. Our results are in accordance with the previous research in which it has been demonstrated that the participation in competitive sports activities is not associated with the development of AIS [14]. On the contrary, we found very positive adaptations to the training programme in AIS girls. For instance, the percentage of body fat was significantly decreased ($p < 0.05$) in the scoliotic group demonstrating that 6 weeks of aerobic exercise are enough to cause significant changes in the body composition.

Regarding the ventilatory parameters determined in our study, no changes in FVC and FEV1 were found between the experimental groups (scoliotic girls vs. healthy) and after the training protocol. However, the FEV1/FVC % significantly decreased after training in the AIS girls. Our results confirm the ventilatory beneficial adaptations previously reported by other research groups [2]. Mild

**Table 3** Comparison of cardio-respiratory function during maximal exercise tolerance test between AIS girls and healthy controls: effect of an exercise training protocol

| | AIS group ($n = 6$) | | Healthy group ($n = 6$) | | ANOVA | Effect of condition ($p$ value) | Effect of training ($p$ value) | Interaction training × condition |
|---|---|---|---|---|---|---|---|---|
| | Before | After | Before | After | | | | |
| Spirometry at rest | | | | | | | | |
| Forced vital capacity (FVC) (L) | 3.5 ± 0.4 | 3.5 ± 0.4 | 3.7 ± 0.7 | 3.5 ± 0.7 | | | | |
| Forced expiratory volume (FEV1) (L) | 2.9 ± 0.4 | 3.0 ± 0.4 | 2.6 ± 0.7 | 2.9 ± 0.6 | | | | |
| FEV1/FVC (%) | 85.3 ± 4.4 | 83.6 ± 5.2 | 84.2 ± 4.3 | 83.3 ± 7.4 | <0.05 | NS | NS | <0.05 |
| Maximal exercise test | | | | | | | | |
| Maximum oxygen uptake ($VO_{2max}$) (L/min) | 1.8 ± 0.3 | 2.1 ± 0.3 | 2.0 ± 0.3 | 2.2 ± 0.3 | <0.05 | <0.05 | <0.05 | NS |
| Maximum oxygen uptake (mL/kg/min) | 35.9 ± 4.9 | 40.1 ± 3.1 | 37.3 ± 3.1 | 40.2 ± 2.2 | <0.05 | <0.05 | <0.05 | NS |
| METS | 10.3 ± 1.4 | 11.2 ± 1.7 | 9.5 ± 1.6 | 10.8 ± 1.1 | <0.05 | NS | <0.05 | NS |
| Breath frequency (BF) | 53.2 ± 6.7 | 49.1 ± 10.3 | 47.2 ± 8.3 | 46.0 ± 6.3 | <0.05 | <0.05 | NS | <0.05 |
| Respiratory ratio (R), $VO_2/VCO_2$ | 1.0 ± 0.1 | 1.1 ± 0.1 | 1.1 ± 0.1 | 1.0 ± 0.1 | <0.05 | NS | NS | <0.05 |
| Heart rate at maximal exercise (bpm) | 186.6 ± 11.5 | 187.6 ± 9.4 | 192.0 ± 7.3 | 191.0 ± 6.7 | | | | |
| Heart rate at AT (bpm) | 149.5 ± 4.3 | 146.5 ± 4.5 | 154.6 ± 8.1 | 150.8 ± 8.6 | <0.05 | <0.05 | <0.05 | NS |
| Maximal power output (W/kg) | 2.7 ± 0.5 | 2.9 ± 0.3 | 2.9 ± 0.1 | 3.0 ± 0.7 | <0.05 | <0.05 | NS | <0.05 |
| Power at AT (W/kg) | 1.7 ± 0.4 | 1.9 ± 0.2 | 1.8 ± 0.5 | 2.0 ± 0.6 | <0.05 | NS | <0.05 | NS |

The values are presented as mean ± SD

*AT* anaerobic threshold, *NS* not significant

scoliotic patients reported by DiRocco and Vaccaro [1] and Barrios et al. [3] do not show any obstructive sign causing ventilatory restrictions during rest conditions and have no ventilatory limitations of exercise capacity. Our results, as shown in Table 3, confirm these data.

No abnormal ECG-changes were recorded at rest, during, or after exercise. Exercise training did not modify the heart rate at maximal exercise neither in the AIS nor in the healthy groups. However, the maximal power output, as well as the power output achieved at the anaerobic threshold during the maximal exercise test, was significantly increased in the scoliotic and in the healthy girls after training. These results reflect beneficial metabolic adaptations after the training protocol in all the experimental groups [2, 15].

Regarding the maximal oxygen consumption, Table 3 shows similar $VO_{2max}$ values in the group of scoliotic adolescents (35.9 ± 4.9 mL/kg/min) and in the healthy girls (37.3 ± 3.1 mL/kg/min). These findings differ from Barrios et al. [3], but they are in accordance with those reported by Leech et al. [16] who reported similar maximal oxygen uptake among scoliotic adolescents with light curves and healthy peers. During the past two decades, exercise capacity and activity status have become well-established predictors of cardiovascular and overall mortality [7, 17]. In 1995, Pate et al. observed a 7.9% reduction in mortality for every 1-min increase in treadmill time during an exercise test [17]. These findings demonstrate that both a relatively high degree of fitness at base line and an improvement in fitness over time, yield marked reductions in death risk. Physical fitness is best assessed by a measure of $VO_{2max}$, which is viewed as an index of energy expenditure [18]. We determined the $VO_{2max}$ during a maximal exercise test in our experimental groups. $VO_{2max}$ was increased by 17% in AIS group ($p < 0.05$) and 10% in the healthy group ($p < 0.05$). Our results are in accordance with those reported by Bjure et al. [15]. These authors found increments in the $VO_{2max}$ (~22%) after 3 months of exercise training in girls with different degrees of curvature. Metabolic equivalents calculated in METS were also significantly increased after the training program in our study. One MET is defined as the energy expended in sitting quietly, which is equivalent to body oxygen consumption of approximately 3.5 ml per kilogram of body weight per min for an average adult. Thus, 1 MET is equivalent to a resting oxygen uptake of about 250 mL per min for an average man and 200 mL per min for an average woman [18]. In 2002, it was demonstrated that every one MET increase in exercise performance is associated with a 12% improvement in survival which confirms the presence of a graded, inverse relation between exercise capacity and mortality from any cause [7]. Several years ago, it was reported that life expectancy and the aerobic capacity are decreased in nontreated scoliosis [15]. We consider that the significant increase in $VO_{2max}$ and in the metabolic equivalents found after training in the scoliotic girls is of main importance in the clinical practice. Scoliotic children have no particular cardio-respiratory disease when young, but this is very likely to occur when the child become an adult [2]. Their capacity to perform aerobic work starts to decline when scoliosis exceeds 25° [2]. They usually avoid participation in physical activities and very often avoid physical education classes in school [2].

In conclusion, our results show beneficial adaptations in anthropometric and cardio respiratory parameters after a training program in AIS girls. Thus, we consider that physical activity should be encouraged in scoliotic girls with mild curvatures. We are aware of some limitations of our study. For instance, the number of subjects is low and this limitation can decrease the power of the statistical analysis performed. Moreover, it should be taken into account that the low scoliotic degree (<30°) of our selected group of subjects could have an influence in the positive effect of the exercise training reported in our study. More research is needed to extend our conclusions to subjects with more severe curves.

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**Conflict of interest** None.

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