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Study and influence of exercise program on respiratory function of adults with kyphosis

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Adolescent idiopathic kyphosis causes not only spinal deformities but also rib cage abnormalities that lead to abnormal residual volume and pulmonary capacity revealed in pulmonary function testing (PFT). The objective of this study was to analyze the impact of a physical activity program on respiratory function in surgical patients with kyphosis.

From October 2006 to October 2007, a total of 34 patients (age range, 22–42 years) with kyphosis and a thoracic curvature between 45° and 88° were examined prospectively at a sports medicine clinic belonging to National Iranian Oil Company (N.I.O.C.). The patients underwent clinical and radiographic examinations of the vertebral deformity, chest radiography, PFT, evaluation of peak expiratory flow rate, and 6-min walk tests (6MWTs) before and after joining a physical activity program for 4 months.

The improvements in FVC, inspiratory capacity, FEV_1, expiratory reserve volume, and performance assessed by 6MWT were observed after activity. General condition of patients improved after the exerscise program. This was reflected by both PFT and 6MWT results.

Key words: *adults, measurements of pulmonary volume, physical activity, scoliosis, spirometry*

Abbreviations

kyphosis – excessive backward curvature of the top part of the spine,
$FEF_{25–75\%}$ – forced expiratory flow,
HR – heart rate,
IC – inspiratory capacity,
6MWT – 6-min walking test,
PEF – peak expiratory flow,
PFT – pulmonary function testing,
RR – respiratory rate,
SpO_2 – peripheral oxygen saturation.

1. Introduction

Patients with kyphosis present abnormal pulmonary capacity which has been revealed in pulmonary function testing (PFT) [1]–[5]. A number of studies [6]–[10] have shown a strong correlation between abnormal pulmonary function and the severity of the spinal deformity. However, other factors, such as the distortion of the rib cage associated with the vertebral deformity, may also contribute to the altered ventilation mechanics and to the reduced capacity of these individuals who should take part in physical activities. Progressive and chronic muscle weakness contributes to the lack of cardiorespiratory and musculoskeletal conditioning. These associated factors play an important role in final reduced pulmonary volumes [11]–[17].

Pulmonary problems have been more frequently reported in adolescents with spine curvature > 45°. Lethal cardiorespiratory abnormalities are known to develop in these patients who demand surgical correction of the spinal deformities [18]–[21].

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Despite the extensive literature describing pulmonary abnormalities in patients with kyphosis, there is a lack of reports on the contribution of physical and pulmonary activity to the condition of such patients. Thus, the objective of this study was to evaluate the impact of physical activity on the respiratory function of patients with kyphosis.

2. Materials and methods

From October 2006 to October 2007, a total of 34 adults from the spine division of the sports medicine clinic belonging to National Iranian Oil Company (N.I.O.C.) were examined. They were between the ages of 22 and 46 years. 31 patients were male and 3 patients were female. They all needed surgical correction of kyphotic spinal curvature > 45° and had no history of pulmonary and cardiovascular problems (the figure). The patients took part in the study, provided that they gave a formal informed consent. Exclusion criteria were as follows: spinal curvature < 45°, unwillingness to comply with the exercise program as designed, and current or previous heart and lung diseases.

View larger version:

Plain lateral anterior radiograph of spine showing a single right thoracic curve of 53°

The patients were included in the study protocol at random, in the order in which they are presented to the activity service, as long as they fulfilled the inclusion criteria. All of the patients complied with the activity program, missing on average 1.6 sessions (ranging from zero to three absences) during the entire period of the program (the total of 50 sessions).

All of the patients underwent clinical and radiographic examinations of the vertebral deformity, chest radiography, PFT, evaluation of the peak expiratory flow (PEF) following exercise, and 6-min walk test (6MWT), before and after joining a physical exercise program for 4 months. This exercise protocol was inspired by the works of BOUCHARD and SHEPARD [22] and COVEY et al. [23] who proposed three weekly sessions of 60 min each supervised by a qualified physical activity. The first 10 min of the sessions were for warm-up exercises (stretching and low-energetic-demand aerobic exercises, such as slow and progressive walks); aerobic exercises on a treadmill or stationary bicycle with the patient working at 60–80% of his/her maximum heart rate (HR) [24] lasted 40 min; and the final 10 min of the session were for cooling down and relaxing (stretching and low-energetic-demand aerobic exercises followed by relaxation techniques).

Statistical analysis was performed using the *t*-test, Wilcoxon test, analysis of variance, and Kruskal–Wallis, if applicable, with a significance level of 5%.

3. Results

The types of spinal curvature in the population examined were as follows: a single high right thoracic curve (n = 12); a single high left thoracic curve (n = 1); combined high right thoracic curve and lower left lumbar curve (n = 20); and combined high left thoracic curve and lower right lumbar curve (n = 1). The angular value of the thoracic deformities ranged from 45° to 88°, with mean initial and final value of 60° and median initial and final value of 59°. The angular value of the kyphosis ranged from 9° to 69°, with an initial and final mean of 39° and initial and final median of 40°. The rib hump measured in the Adams test ranged from 23 to 86 mm, with initial and final mean of 55 mm and initial and final median of 52°. Using the degree of vertebral rotation measured on plain radiographs according to the criteria of NASH and MOE [25], 7 patients were classified as stage I, 24 patients were classified as stage II, and 3 patients were classified as stage III. Plain chest radiographs obtained for all the patients were analyzed by experienced independent radiologists. No lung abnormalities were found.

3.1. PFT

All the measured parameters of PFT were significantly lower in the population examined than the standard for age and gender, both before and after the exercise program. A significant improvement in the FVC, FEV_1, PEF, slow vital capacity, inspiratory capacity (IC), and expiratory reserve volume were observed after rehabilitation (table 1). The same trend of improvement was observed for the forced expiratory flow ($FEF_{25–75\%}$), FEV_1/FVC ratio, and $FEF_{25–75\%}$/FVC ratio, although these differences were not statistically significant (table 2).

3.2. 6MWT

A significant decrease in respiratory rate (RR) and HR were observed after the training program (table 3).

Table 1. PFT data of 34 patients with kyphosis subjected to preoperative physical activity

Patient No.	Baseline FVC, L	Final FVC, L	Baseline FEV_1, L	Final FEV_1, L	Baseline $FEF_{25–75\%}$, L/s	Final $FEF_{25–75\%}$, L/s	Baseline PEF, L/s	Final PEF, L/s
1	2.56	2.73	2.13	2.31	2.17	2.45	3.54	5.52
2	2.18	2.40	2.08	2.22	2.35	2.45	3.05	5.49
3	3.65	3.49	2.24	2.01	1.33	1.13	4.23	4.66
4	2.24	2.22	2.11	2.15	3.75	3.95	4.83	5.48
5	1.90	2.35	1.38	2.04	0.97	2.31	3.48	5.87
6	2.63	2.68	2.34	2.54	2.79	3.54	4.29	4.92
7	2.32	2.30	1.96	1.94	2.12	2.08	3.58	5.16
8	1.78	1.91	1.76	1.80	2.60	2.37	4.94	4.44
9	2.60	2.53	2.44	2.34	3.10	2.72	4.25	4.15
10	3.30	3.34	2.85	3.12	2.83	3.36	5.18	5.77
11	1.82	1.99	1.82	1.89	3.82	3.37	4.44	6.26
12	1.92	2.06	1.75	1.76	2.13	1.82	5.00	4.69
13	1.51	1.52	1.07	1.05	0.76	0.72	2.41	2.22
14	2.07	2.36	1.80	1.92	2.30	1.83	3.83	3.34
15	2.62	2.81	2.36	2.49	3.08	2.98	6.43	6.95
16	1.69	1.66	1.46	1.50	1.69	2.04	3.13	3.51
17	3.14	3.30	2.84	2.83	3.40	3.13	5.05	5.95
18	1.81	2.10	1.80	2.06	2.87	2.50	3.38	2.68
19	2.94	3.33	2.37	2.55	2.41	2.09	4.09	6.01
20	1.48	1.93	1.40	1.76	1.62	2.41	3.14	3.64
21	2.54	2.48	2.10	1.99	1.97	1.95	4.94	5.97
22	2.51	2.62	2.04	2.21	1.98	2.26	3.57	4.41
23	2.35	2.98	1.37	2.85	1.21	3.47	1.55	4.24
24	2.07	2.50	2.03	2.42	2.77	3.16	3.38	5.73
25	3.12	3.20	2.48	2.71	2.63	2.99	4.48	6.12
26	2.72	2.82	2.19	2.03	2.06	1.60	3.74	3.26
27	2.41	2.52	1.85	1.92	1.60	1.62	3.11	3.34
28	2.61	2.81	2.24	2.38	2.47	2.58	5.09	5.95
29	4.46	4.70	3.87	3.70	4.20	5.08	7.69	7.32
30	3.13	3.18	2.93	2.89	3.83	3.83	5.63	7.17
31	1.78	2.23	1.72	2.04	2.36	2.51	3.14	3.34
32	2.58	2.49	2.41	2.48	3.01	3.20	4.89	5.38
33	2.88	2.96	2.88	2.92	4.17	5.03	5.03	5.81
34	2.48	2.59	2.41	2.45	3.41	3.42	5.06	5.82

Other parameters, such as the index of perceived effort, an increase in peripheral oxygen saturation (Sp_{O_2}), and 6MWT distance improved significantly after kyphosis (table 4).

Table 2. Statistical analysis of PFT results for population with kyphosis*

Variables	Baseline	Final	Baseline median	Final median	Descriptive level, *p* value
FVC, L	2.46 ± 0.64	2.62 ± 0.61	2.50	2.53	0.000†
FEV_1, L	2.13 ± 0.55	2.27 ± 0.51	2.11	2.22	0.009†
$FEF_{25–75\%}$, L/s	2.52 ± 0.88	2.70 ± 0.96	2.44	2.51	0.072
Slow vital capacity, L	2.43 ± 0.66	2.57 ± 0.60	2.47	2.48	0.001†
IC, L	1.76 ± 0.47	1.88 ± 0.43	1.67	1.84	0.004†
Expiratory reserve volume, L	0.64 ± 0.29	0.71 ± 0.29	0.60	0.64	0.049†
FEV_1/FVC	0.87 ± 0.11	0.88 ± 0.09	0.88	0.91	0.338
$FEF_{25–75\%}$/FVC	1.05 ± 0.36	1.06 ± 0.33	1.07	1.02	0.921
PEF, L/s	4.22 ± 1.17	5.02 ± 1.29	4.24	5.43	0.000†

* Data are presented as mean ± SD, unless otherwise indicated.
† Statistically significant.

Table 3. 6MWT data of 34 surgical candidates with kyphosis subjected to preoperative physical activity

Patient No.	Baseline distance, m	Final distance, m	Baseline Borg score*	Final Borg score*	Baseline HR, beats/min	Final HR, beats/min	Baseline RR, breaths/min	Final RR, breaths/min
1	411	584	16	12	123	98	28	24
2	406	579	17	15	118	104	25	24
3	408	529	12	11	109	99	32	28
4	399	504	14	12	106	98	29	26
5	403	514	17	14	115	102	28	25
6	412	563	16	13	99	92	26	24
7	304	432	18	15	126	108	28	26
8	305	423	18	16	124	112	34	30
9	409	517	16	13	110	99	26	24
10	401	558	16	13	122	110	24	22
11	282	351	18	15	116	108	36	32
12	398	489	16	14	124	103	36	28
13	305	493	15	12	132	118	36	34
14	395	451	15	12	98	91	28	26
15	411	592	17	15	99	92	24	22
16	361	418	19	16	134	112	34	30
17	448	597	15	13	96	92	24	22
18	385	496	19	16	118	99	30	28
19	428	593	14	11	98	92	28	24
20	389	472	16	14	116	99	30	26
21	402	518	17	14	110	98	28	26
22	407	543	18	16	112	96	26	24
23	402	596	16	13	96	90	26	22
24	315	453	16	13	102	94	24	22
25	439	599	14	11	94	90	26	22
26	413	537	16	13	99	91	28	26
27	428	529	16	14	102	92	28	24
28	439	593	14	12	99	89	25	22
29	481	612	15	11	95	84	24	20
30	442	601	15	12	96	88	26	22
31	482	548	18	15	104	96	28	24
32	439	592	18	15	98	86	24	20
33	468	598	17	15	92	85	22	20
34	407	512	17	14	90	84	26	24

* From 6 to 20 points.

Table 4. Statistical analysis of results of 6MWT for population before and after physical activity*

Variables	Baseline	Final	Baseline median	Final median	Descriptive level, *p* value
RR, breaths/min	27.85 ± 3.75	24.79 ± 3.33	28	24	0.000†
HR, beats/min	108 ± 12.31	96.79 ± 8.67	105	96	0.000†
Sp_{O_2}, %	97.85 ± 1.04	98.85 ± 0.70	98	99	0.000†
Borg score, 6 to 20	16.21 ± 1.59	13.53 ± 1.58	16	13.5	0.000†
Distance walked, m	400.71 ± 49.00	529 ± 65.19	407	533	0.000†

* Data are presented as mean ± SD, unless otherwise indicated.
† Statistically significant.

Table 5. PEF measurement before and after physical activity*

Variable	Baseline	Final	Baseline median	Final median	Descriptive level, *p* value
PEF after exercise, L/min	290.59 ± 73.98	350.59 ± 54.60	310	360	0.000†

* Data are presented as mean ± SD unless otherwise indicated.
† Statistically significant.

3.3. PEF after exercise

The measurement of PEF after exercise showed a significant increase after the 4-month exercise program (table 5).

3.4. Multivariance analysis using analysis of variance

Groups were compared according to the type of vertebral curvature presented: single thoracic curve and combined major thoracic and minor lumbar curves. No statistically significant differences were observed between the groups for any of the variables studied.

4. Discussion

Kyphosis is prevalent in female patients [22], [26], and the most common deformity is the single high kypho in thoracic curve [8], [20], [26]–[30]. The current study conforms to these findings.

Several studies [3]–[8], [10], [27], [31]–[35] that have focused on the factors that influence the onset of restrictive disease in kyphosis reveal that the greater the spinal deformity, the stronger the effect of compressive force on the lungs with consequent smaller lung volumes [10]. In the current series, both baseline and post-exercise PFT parameters were lower than those attributed to the normal population of the same age and gender. Spinal deformity should be preferably evaluated by a combination of parameters, such as vertebral rotation, rib cage deformities, and possible limitations of the respiratory muscles, which when combined distort the mechanics of the chest and cause impaired pulmonary function to different degrees [11]–[17].

Several authors [2], [4], [15], [17], [18], [36]–[38] have reported the difficulties encountered by patients with kyphosis in performing physical activities. According to SHNEERSON [4], up to 80% of the patients with such difficulties have ventilation problems. A direct relation between the decrease in maximum aerobic capacity and FVC has also been reported [4], [8], [15]. It has also been observed that physical conditioning improves the FCV and IC of patients and positively influences the maximum aerobic capacity with improvement in HR and RR as well [30].

Studies [31], [37] that have analyzed pulmonary volumes before and after surgical correction in patients with spinal deformities have not shown any significant improvement. In fact, a trend towards a decrease in PFT parameters has been reported in the first 2 years after corrective surgery [37], [38]. These findings emphasize the need to improve the respiratory capacity of such patients prior to surgery.

LACASSE et al. [39] state that global physical activities in patients with COPD improve peripheral muscle function and reduce the index of perceived effort, but the authors also call attention to the need for associated specific respiratory muscle rehabilitation for final improvement in the overall pulmonary function. This study [39] refer to patients with COPD and not rib cage abnormalities, but the same rationale regarding the importance of physical conditioning in long-term patients can be transferred to kyphosis patients.

The current study revealed a significant increment in FVC, IC, forced expiratory volume, and FEV_1, even though no specific respiratory muscle training was done. This can be explained by the standard training offered, which has been poorly defined in other studies [15], [27]–[30] devoted to patients with kyphosis. The current program allowed optimum ventilation efficiency with a small increase in Sp_{O_2}. Although our study was not designed to establish improvement in ventilation/perfusion, it is expected that an increase in Sp_{O_2} and a decrease in HR and RR may lead to improved ventilation/perfusion after exercise [40]–[42]. Studies specifically designed for this purpose could better illustrate such an association.

The small increase in the $FEF_{25–75\%}$ was not significant due to the weak reproducibility of this index [34]. The FEV_1/FVC and $FEF_{25–75\%}$/FVC coefficients did not show any significant differences either, but this may be explained by the similar increases in all these parameters.

The increase observed in the distance walked during 6MWT is also a predictive factor of the improvement in the tolerance and capacity to exercise [43], [44], especially when associated with a decrease in the index of perceived effort. The absolute values of the latter parameter show a linear correlation with physiological factors and, when associated with increments in Sp_{O_2}, are directly correlated with cardiorespiratory conditioning [45], [46]. We found no reports in an available literature on the use of 6MWT for the evaluation of patients with kyphosis; however, in this study, a significant increase in the distance walked during this test was observed after completion of the 4-month exercise protocol.

There was no significant modification in the physical characteristics of spinal and secondary deformities, such as rib cage hump, vertebral rotation, and angular values of the kyphosis after the 4-month training period. Thus, these parameters did not influence the final respiratory function *n* nor physical capacity of our patients.

5. Conclusions

The physical activity proposed by the exercise protocol was beneficial to patients, improving their pulmonary capacity and residual volume, and performance of 6MWT, and decreasing the perceived effort, HR, and RR, suggesting that patients with kyphosis who are surgical candidates may benefit from preoperative physical exercise.

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