Functional Outcomes in Duchenne Muscular Dystrophy Scoliosis

Comparison of the Differences Between Surgical and Nonsurgical Treatment

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Background: While most studies of Duchenne muscular dystrophy scoliosis focus on technical and radiographic indices, functional status is a more important factor to consider in the management of Duchenne muscular dystrophy. The objectives of the current study were to compare the pulmonary function, radiographic outcome, and functional recovery, with use of validated questionnaires, in surgically and nonsurgically treated patients with Duchenne muscular dystrophy who have scoliosis.

Methods: Sixty-six patients (forty treated surgically and twenty-six treated nonsurgically) with a minimum follow-up of two years were included in this study. Forced vital capacity, radiographic parameters (the Cobb angle, lordosis, and pelvic obliquity), and functional status, according to the modified Rancho scale and manual muscle test, were measured preoperatively and at the time of the final follow-up. The Muscular Dystrophy Spine Questionnaire (MDSQ) was completed at the final follow-up evaluation.

Results: Pulmonary function, functional scores (manual muscle test and modified Rancho scale), and radiographic measurements, except for lordosis, were similar for both groups at the time of the initial consultation ($p > 0.05$). At the time of the final follow-up, all radiographic parameters were significantly improved in the surgical group compared with the nonsurgical group. The mean score (and standard deviation) on the manual muscle test was not significantly different between the surgical and nonsurgical groups ($23.2 \pm 8.3$ versus $22.8 \pm 6.3$; $p = 0.828$). The mean score on the modified Rancho scale also showed similar results in the groups ($3.9 \pm 0.3$ and $4.04 \pm 0.3$, respectively; $p = 0.088$). The surgical group had higher mean MDSQ scores than the nonsurgical group ($35.1 \pm 14.7$ and $26.9 \pm 9.9$, respectively; $p = 0.008$). Both groups showed a decrease in forced vital capacity at the time of the final follow-up, but the deterioration of forced vital capacity was significantly slower ($p = 0.035$) in the surgical group ($268 \pm 361$ mL) than in the nonsurgical group ($536 \pm 323$ mL).

Conclusions: Surgery in patients who had Duchenne muscular dystrophy with scoliosis improved function and decreased the rate of deterioration of forced vital capacity compared with patients treated conservatively. However, the muscle power and forced vital capacity decreased in both groups.

Level of Evidence: Therapeutic Level II. See Instructions for Authors for a complete description of levels of evidence.

Scoliosis is a progressive and major problem of Duchenne muscular dystrophy$^1$. Deformity progression may be very rapid and compromise respiratory and cardiac function$^2$. Nonoperative treatment failed to control curve progression in 94% of patients with scoliosis$^3$. Nevertheless, the effects of spinal surgery on respiratory function are still controversial. Some studies have noted that spinal arthrodesis had no effects on the natural deterioration of respiratory function associated with Duchenne muscular dystrophy scoliosis$^4$$^5$. However, Galasko et al.$^7$ found that, on average, forced vital capacity decreased.

Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. None of the authors, or their institution(s), have had any financial relationship, in the thirty-six months prior to submission of this work, with any entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. Also, no author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete Disclosures of Potential Conflicts of Interest submitted by authors are always provided with the online version of the article.
by 8% per year in patients with scoliosis secondary to Duchenne muscular dystrophy who had not had surgery, and other studies\(^{11}\) have supported this finding. Long-term corticosteroid use may delay the progression of Duchenne muscular dystrophy scoliosis and reduce the need for surgery\(^{12,13}\), although adverse effects are frequent and often unavoidable.

Most previous studies\(^{4-10}\) have lacked a postoperative quality-of-life evaluation of the patients and their families. Only one study used questionnaires, but they were nonvalidated questionnaires\(^{12}\). In addition, the concerns of patients, their relatives, and surgeons often differ. Generally, patients are more concerned with how surgery will help them walk, sit, and perform daily tasks in both the short and long term, a need which most functional outcome measurement tools fail to evaluate\(^{4-10}\). Thus, there is much to be investigated in terms of patient functionality after surgery\(^{14,15}\).

In this prospective study, we assessed seventy-seven male patients with Duchenne muscular dystrophy with scoliosis who had been followed at our center for an average of four years. The purposes of this study were to compare the pulmonary function, radiographic outcome, and functional recovery using validated questionnaires for surgically and nonsurgically treated patients with Duchenne muscular dystrophy.

**Materials and Methods**

This study was approved by the institutional review board. A total of seventy-seven patients were referred by the neurology and neuromuscular rehabilitation group at our medical center from 2003 to 2010. The diagnosis of Duchenne muscular dystrophy was based on family history, muscle enzyme assay, electrophysiological studies, and muscle biopsy. The advantages and consequences of the spinal surgery were explained extensively to the patients and their families preoperatively. Forty-five patients underwent instrumented spinal arthrodesis for Duchenne muscular dystrophy scoliosis. Of the seventy-seven patients, thirty-two declined surgery and opted for conservative management.

Prior to surgery, all patients were not able to walk and were limited to wheelchair-bound activity. Posterior and lateral radiographs of the whole spine, made with the patient sitting, were made for all patients at the time of the initial consultation and the last follow-up evaluation. The Cobb angle, lumbar lordosis, and pelvic obliquity were measured by one member of the surgical team. All patients from the surgical group underwent instrumented spinal arthrodesis from the thoracic to the lower lumbar spine (11.1%) or the pelvis (89.9%) with CD Horizon spinal instrumentation (Medtronic, Memphis, Tennessee). Because many of the patients were referred to our institution with relatively severe scoliosis, all patients were actively comanaged with rehabilitation, pulmonary, and cardiac specialists, as most patients had substantial functional and cardiopulmonary deficiencies on presentation. Pulmonary function was evaluated at six-month intervals, specifically accounting for the forced vital capacity. Noninvasive positive-pressure ventilation was initiated upon the recommendation of a pulmonary rehabilitation specialist. Noninvasive positive-pressure ventilation was applied to the patients who complained of dyspnea due to respiratory failure. Both groups were trained with a pulmonary rehabilitation program that involved the use of a noninvasive positive-pressure ventilation machine and air and exercise. No patient was treated with corticosteroids. Pulmonary function tests were carried out with the Jaeger Masterlab system (Masterlab, Jaeger, Wurzburg, Germany). Forced vital capacity was measured by a pulmonary rehabilitation specialist who was not involved in the surgery.

At the initial consultation, functional status was assessed using the manual muscle test\(^{14}\) and the modified Rancho scale\(^{15}\). According to the modified Rancho scale, patients are classified as Class 1 if they are able to walk; as Class 2, if they do not walk but are capable of independent sitting; as Class 4, if they are dependent; and as Class 5, if they are essentially confined to bed. The manual muscle test includes total muscle strength based on a clinical assessment of the strength of eight selected muscle groups, which is done with the patient in a sitting position and with use of a 5-point grading system, ranging from 0 indicating no movement to 5, normal muscle power. The total score for a normal male subject is 80 points (eight muscles times two sides times 5 [normal]). At the time of the final evaluation, the same evaluations were performed.

**Statistical Analysis**

After confirmation of statistical standard normal (Gaussian) distribution using the Kolmogorov-Smirnov (goodness-of-fit) test, a parametric independent \(t\) test was used to compare the forced vital capacity, functional score (manual muscle test and modified Rancho scale), and radiographic measurements of the surgically treated group with those of the nonsurgically treated group. The statistical powers of major parameters in the present study were 0.879 of forced vital capacity, 0.453 of the modified Rancho scale, and 0.852 of the MDSQ. A \(p\) value of <0.05 was considered to be significant.

**Source of Funding**

No external funding sources were utilized in this study.
Forty-five patients (58.4%) underwent surgery, while thirty-two patients (41.6%) were treated nonsurgically. Six patients (three in the surgically treated group and three in the nonsurgically treated group) were lost to follow-up (Fig. 1). There was no perioperative mortality. At the time of the latest follow-up, the overall mortality rate was 4.4% (two of forty-five patients in the surgically treated group and 9.4% (three of thirty-two patients in the nonsurgically treated group (p > 0.4, chi-square test). All deaths were confirmed with the National Bureau of Statistics. Therefore, forty surgical patients were compared with twenty-six nonsurgical patients. At the initial consultation, the mean age (and standard deviation) was 14.9 ± 4.2 years in the surgical group and 14.8 ± 3.6 years in the nonsurgical group (p = 0.998). The patients were followed for a minimum of two years, and the mean follow-up was 46.4 ± 18.7 months and 47.1 ± 23.7 months, respectively (p = 0.882) (Table I). At the time of the final evaluation, the mean age was 19.1 ± 3.6 years in the surgical group and 18.8 ± 3.5 years in the nonsurgical group (p = 0.791). While there were no perioperative deaths, there were twenty pulmonary complications and one deep wound infection. We assessed statistical heterogeneity, and there was no effect of heterogeneity for the Cobb angle and lumbar lordosis on the MDSQ and forced vital capacity.

Radiographic Parameters
At the time of initial consultation, the mean Cobb angle was slightly larger in the surgical group than in the nonsurgical group (65.5° ± 18.7° versus 56.9° ± 14.6°; p = 0.048). At the final evaluation, the mean Cobb angle was significantly smaller in the surgical group than in the nonsurgical group (36.2° ± 16.1° versus 106.1° ± 122.3°; p = 0.007). At the initial consultation, the mean lumbar lordosis was significantly smaller in the surgical group compared with the nonsurgical group (10.1° ± 37.9° versus 26.0° ± 17.6°; p = 0.025); however, at the final evaluation, lumbar lordosis was significantly increased in the surgical group compared with the nonsurgical group (37.9° ± 18.2° versus 18.4° ± 34.3°; p = 0.005). The mean pelvic obliquity was similar at the initial consultation (20.7° ± 11.7° in the surgical group and 18.4° ± 10.5° in the nonsurgical group; p = 0.413), and it was significantly decreased after surgery (11.4° ± 8.7° and 29.0° ± 15.5°, respectively; p < 0.001). At the final evaluation, the Cobb angle, pelvic obliquity, and lumbar lordosis were significantly improved (p = 0.007, <0.001, and 0.005, respectively) in the surgical group compared with the nonsurgical group (Table II).

Pulmonary Function Parameters
At the initial consultation, the mean forced vital capacity was arithmetically larger in the surgical group (1258.0 ± 514.0 mL) than in the nonsurgical group (1164.4 ± 637.4 mL), but the difference was not significant (p = 0.510). Although there were decreases in forced vital capacity in both groups, the mean forced vital capacity at the final evaluation was significantly different (p = 0.033), with more favorable results in the surgical group (913.3 ± 458.4 mL) than in the nonsurgical group (640.4 ± 564.6 mL). Furthermore, the volume of deterioration in forced vital capacity decreased more slowly in the surgical group (267.5 ± 360.7 mL) than in the nonsurgical group (536.2 ± 323.2 mL); the difference was significant (p = 0.035). Initially, ten patients (25%) in the surgical group and seven patients (27%) in the nonsurgical group used noninvasive positive-pressure ventilation, but at the time of final follow-up, thirty-two patients (80%) in the surgical group and twenty-three patients (88.5%) in the nonsurgical group used the noninvasive positive-pressure ventilation (Tables I and II).
Parameters of Activities of Daily Living

The results on the manual muscle tests for both groups were very similar (mean, 27.5 ± 8.7 in the surgical group and 27.1 ± 7.5 in the nonsurgical group; p = 0.827) and deteriorated significantly in both groups during the study period, with no difference between the groups (23.2 ± 8.3 and 22.8 ± 6.3, respectively; p = 0.828) at the final evaluation. At the initial consultation, the mean scores on the modified Rancho scale for the groups were similar (4.0 ± 0.3 in the surgical group and 4.0 ± 0.2 in the nonsurgical group; p = 0.836). At the final evaluation, the mean modified Rancho scale score had improved to 3.9 ± 0.3 in the surgical group and had worsened to 4.0 ± 0.3 in the nonsurgical group; the difference between these scores and the initial scores was not significant (p = 0.088). However, the MDSQ measurements were significantly higher for the surgical group than for the nonsurgical group (mean, 35.1 ± 14.7 and 26.9 ± 9.9, respectively; p = 0.008). Within the MDSQ, higher scores were noted for the surgical group for questions 15 (sit comfortably in a good position, in my wheelchair all day), 16 (shift weight...in my wheelchair), 22 (sit in my chair all day...), 24 (sit at the table for meals), 26 (keep my balance...in my wheelchair), 27 (look good while sitting in my wheelchair), 28 (pain in my hips and back), and 29 (feeling out of breath when I’m sitting crooked) (Table III).

TABLE II Outcomes on Final Evaluation

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Surgical Group</th>
<th>Nonsurgical Group</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient numbers</td>
<td>40</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Age* (yr)</td>
<td>19.1 ± 3.6</td>
<td>18.8 ± 3.5</td>
<td>0.791</td>
</tr>
<tr>
<td>Cobb angle</td>
<td>36.2 ± 16.1</td>
<td>106.1 ± 122.3</td>
<td>0.007</td>
</tr>
<tr>
<td>Lordosis</td>
<td>37.9 ± 18.2</td>
<td>18.4 ± 34.3</td>
<td>0.005</td>
</tr>
<tr>
<td>Pelvis obliquity</td>
<td>11.4 ± 8.7</td>
<td>29.0 ± 15.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Functional outcomes*†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMT score</td>
<td>23.2 ± 8.3</td>
<td>22.8 ± 6.3</td>
<td>0.828</td>
</tr>
<tr>
<td>Modified Rancho score</td>
<td>3.9 ± 0.3</td>
<td>4.0 ± 0.3</td>
<td>0.088</td>
</tr>
<tr>
<td>MDSQ score</td>
<td>35.1 ± 14.7</td>
<td>26.9 ± 9.9</td>
<td>0.008</td>
</tr>
<tr>
<td>Pulmonary parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forced vital capacity* (mL)</td>
<td>913 ± 458</td>
<td>640 ± 564</td>
<td>0.033</td>
</tr>
<tr>
<td>Deterioration of forced vital capacity* (mL)</td>
<td>268 ± 361</td>
<td>536 ± 323</td>
<td>0.035</td>
</tr>
<tr>
<td>End tidal CO2* (mm Hg)</td>
<td>38.4 ± 5.5</td>
<td>39.4 ± 6.7</td>
<td>0.507</td>
</tr>
<tr>
<td>Use of NIPPV‡ (no. [%])</td>
<td>32 (80)</td>
<td>23 (88)</td>
<td></td>
</tr>
</tbody>
</table>

*The values are given as the mean and the standard deviation. †MMT = manual muscle test, and MDSQ = Muscular Dystrophy Spine Questionnaire. ‡NIPPV = noninvasive positive-pressure ventilation.

TABLE III The Most Improved Scores on the MDSQ*

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>Surgical Group</th>
<th>Nonsurgical Group</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Sit comfortably in a good position, in my wheelchair all day</td>
<td>2.1 ± 0.8</td>
<td>1.2 ± 0.8</td>
<td>0.001</td>
</tr>
<tr>
<td>16</td>
<td>Shift weight or change my hip position in my wheelchair</td>
<td>1.3 ± 0.9</td>
<td>0.3 ± 0.8</td>
<td>0.034</td>
</tr>
<tr>
<td>22</td>
<td>Sit in my chair all day without breaks</td>
<td>1.2 ± 1.2</td>
<td>0.4 ± 0.8</td>
<td>0.004</td>
</tr>
<tr>
<td>24</td>
<td>Sit at the table for meals</td>
<td>1.3 ± 1.1</td>
<td>0.6 ± 0.8</td>
<td>0.004</td>
</tr>
<tr>
<td>26</td>
<td>Keep my balance while sitting in my wheelchair</td>
<td>2.4 ± 0.8</td>
<td>1.5 ± 0.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>27</td>
<td>Look good while sitting in my wheelchair</td>
<td>2.4 ± 0.9</td>
<td>1.6 ± 0.9</td>
<td>0.002</td>
</tr>
<tr>
<td>28</td>
<td>Pain in my hips and back</td>
<td>3.2 ± 0.9</td>
<td>2.3 ± 1.4</td>
<td>0.001</td>
</tr>
<tr>
<td>29</td>
<td>Feeling out of breath when I’m sitting crooked</td>
<td>3.4 ± 0.7</td>
<td>2.6 ± 0.9</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*In addition to these questions, questions 28 (“pain in my hips and back”) and 29 (“feeling out of breath when I’m sitting crooked”) were also improved in the surgical group. The other question scores had no significant differences. MDSQ = Muscular Dystrophy Spine Questionnaire. †The values are given as the mean and the standard deviation.
Postoperatively, the forty patients in the surgical group were asked what specific observations they had after surgery. Twenty-six patients (65%) reported that breathing felt easier, and fifteen patients (37.5%) reported easier digestion of food and improved posture. On the other hand, ten patients (25%) complained of substantial loss of neck motion, mostly with head rotation, and nine patients (22.5%) noted increased difficulty in feeding themselves, specifically in bringing food from the table to the mouth because of an elongated trunk height.

**Discussion**

The most important factors in treating Duchenne muscular dystrophy scoliosis are the preservation of pulmonary function and the maintenance of activities of daily living. Although long-term corticosteroid treatment was associated with a significantly decreased risk of scoliosis and an increased ability to walk independently, it was accompanied by serious complications such as lower limb fractures. The results of many studies on treating Duchenne muscular dystrophy scoliosis have revealed many controversies. To reduce the selection bias, all patients in the present study were referred by a nonsurgical team of doctors and the control group was composed of patients who had declined surgery. To reduce the performance bias, all patients in both groups were treated with the same method by neurologic and rehabilitation teams. To reduce the detection bias, all assessments were measured with previously validated evaluation methods.

Several studies have included a comparison of groups analyzing differences between surgical and nonsurgical treatments. Because none of those studies were randomized, the heterogeneity of the control group is very important. Galasko et al. and Eagle et al. only mentioned that there was no difference between the two groups, and Kinali et al. and Alexander et al. reported only the same age for both groups. Furthermore, the follow-up period in the study by Alexander et al. was only one year, and Kinali et al. used a very small number of control patients (eleven). In contrast to other studies, we compared risk factors, including not only age but also the Cobb angle, lumbar lordosis, pelvic obliquity, respiratory function, traditional sitting ability (the modified Rancho scale), and the manual muscle test. In the present study, we assessed statistical heterogeneity using the chi-square test, and proved that there was no effect of heterogeneity. For these reasons, our investigation, although it is not a randomized control study, is a relatively well-controlled prospective study.

Most of our radiographic results were consistent with those reported in the literature. Although most studies did not mention the detailed radiography data, the mean Cobb angle in the surgical group at the initial consultation in our study (65.5° ± 18.7°) was similar to that in other studies (56.4° ± 20.7° reported by Alexander et al. and >50°, by Kinali et al.); however, the mean Cobb angle in the nonsurgical group in the present study (56.9° ± 14.6°) was more severe than that in other studies (34.9° ± 26.5° reported by Alexander et al. and approximately 50°, by Kinali et al.).

Previous studies have examined various measures of strength and function. Although the manual muscle test is a less reliable assessment method than quantitative muscle tests, the manual muscle test remains a basic evaluation tool. The results of the manual muscle test showed no significant difference between the surgical and nonsurgical groups initially and at the final evaluation. Kilmer et al. reported that with a score on the manual muscle test of <3.0 on each muscle-based evaluation, walking was not possible. The mean score on the manual muscle test for the surgical group in the present study was 27.5 ± 8.7 initially and 23.2 ± 8.3 at the final evaluation; these values would be 1.7 (27.5/16) and 1.45 (23.2/16) when evaluated with the method described by Kilmer et al. These results mean that the patients with Duchenne muscular dystrophy in the present study had very weak muscle function; therefore, both groups had similar grades. Carreon et al. noted that there are problems such as floor or ceiling effects in scoliosis evaluation. These problems might be attributable to the prominent floor effect in the manual muscle test. Although two previous studies noted that there was at least a one-grade improvement in the score on the modified Rancho scale following neuromuscular surgery for scoliosis, muscular dystrophy, and cerebral palsy, the difference in the score on the modified Rancho scale in the present study was minimal (mean, 3.9 ± 0.3 in the surgical group and 4.0 ± 0.3 in the nonsurgical group). The reason for these results is likely because the patients in our study had weaker muscle power and larger scoliosis. Therefore, we propose that the classic mean muscle test and the modified Rancho scale were not useful tools in the evaluation methods for advanced Duchenne muscular dystrophy scoliosis.

Although several previous studies have had different objectives and focused on different outcomes, most studies have aimed to investigate whether spinal surgery improves the radiographic parameters. A few studies have described patient-oriented subjective outcomes such as quality of life, self-image, pain, and patient satisfaction. Among those studies, only Bridwell et al. used the objective questionnaire. Fortunately, Wright et al. developed the MDSQ, a spine-specific evaluation tool for Duchenne muscular dystrophy, and demonstrated its reliability and validity. MDSQ values were significantly higher in the surgical group than in the nonsurgical group, with especially significant differences identified not in usual activity but with questions related to sitting ability. The current study is the first, to our knowledge, to evaluate the functional outcome after surgery with use of validated and reliable objective tools. Postoperatively, the results on the MDSQ showed that the activities of daily living, especially sitting ability, were markedly improved after spinal surgery in patients with Duchenne muscular dystrophy scoliosis; however, the MDSQ was not available at the time of the initial consultation.

Forced vital capacity is a relatively objective measurement, and many previous studies have used the percentile of predicted forced vital capacity in their analysis. This predicted forced vital capacity depends on the height of the patient, and direct substitution of arm span for height in patients with spinal deformity is often used, although it is not recommended by some. Furthermore, the arm span of patients with Duchenne muscular dystrophy scoliosis can have joint contractures, and measuring...
or estimating height is prone to error. For this reason, the current study used the direct volume measurement, that is, milliliters rather than percentile of predicted forced vital capacity. There are different reports stating whether forced vital capacity is better or worse after scoliosis surgery. Galasko et al. found that forced vital capacity could be stabilized. Velasco et al. reported that the average rate of decline in forced vital capacity was 4% per year preoperatively, which was reduced to 1.75% per year after surgery. However, other studies have not demonstrated any obvious benefits of surgery in terms of respiratory function. The study by Alexander et al. had some limitations including the fact that the follow-up period was only one year and the preoperative mean forced vital capacity was significantly lower in the surgical group (36.2%) than in the nonsurgical group (54.3%). The study by Kinali et al. had a sufficient follow-up period, but had only eleven control patients. In the current study, the forced vital capacity values were definitely decreased regardless of treatment type, but the mean ratio of deterioration was significantly slower in the surgical group (268 ± 361 mL) than in the nonsurgical group (536 ± 323 mL). To reduce the statistical error, we adjusted the differences in the Cobb angle and lumbar lordosis and still found a significant difference (p = 0.035) and enough statistical power (>80%). One other important parameter of respiration is the usage ratio of the noninvasive positive-pressure ventilation. The usage ratio of noninvasive positive-pressure ventilation was only 26% (seventeen of sixty-six patients) at the initial evaluation, but showed a marked increase to 83% (fifty-five of sixty-six patients) at the final evaluation. The increase in the rate of noninvasive positive-pressure ventilation usage was arithmetically lower in the surgical group than in the nonsurgical group, but the difference was not significant. Within the MDSQ, the last question, number 29 ("feeling out of breath when I’m sitting crooked"), was a subjective feeling about breath, which showed that the patient had a substantial improvement. The objective data, such as a smaller decrease in forced vital capacity, less use of noninvasive positive-pressure ventilation, and a higher score on the MDSQ, together with the patients’ subjective evaluations that breathing felt easy, indicate that spinal surgery might decrease the deterioration of respiratory function.

A limitation of this research is that all patients were hospitalized and were treated with pulmonary rehabilitation by a pulmonary specialist every year for at least a week, and almost all patients were treated with noninvasive positive-pressure ventilation, which could have affected pulmonary function as well.

In conclusion, patients with Duchenne muscular dystrophy scoliosis who have surgery have improvement in activities of daily living compared with patients treated conservatively and the improvement in the activities of daily living is mainly related to sitting ability. The muscle power and forced vital capacity were decreased in both groups at the final evaluation, but the ratio of forced vital capacity deterioration was significantly slowed in the surgical group.

Appendix

A table showing the individual items on the Muscular Dystrophy Spine Questionnaire is available with the online version of this article as a data supplement at jbjs.org.

References