

## Retrospective Study

## Effect of pelvic fixation on ambulation in children with neuromuscular scoliosis

Luke Drake, Hamdi Sukkarieh, Tyler McDonald, Eldrin Bhanat, Elisa Quince, Myles Atkins, Patrick Wright, Jaysson Brooks

**Specialty type:** Orthopedics

**Provenance and peer review:**

Unsolicited article; Externally peer reviewed.

**Peer-review model:** Single blind

**Peer-review report's scientific quality classification**

Grade A (Excellent): 0

Grade B (Very good): B

Grade C (Good): C, C

Grade D (Fair): 0

Grade E (Poor): 0

**P-Reviewer:** Meng FZ, China; Moshref RH, Saudi Arabia

**Received:** March 29, 2022

**Peer-review started:** March 29, 2022

**First decision:** June 16, 2022

**Revised:** June 29, 2022

**Accepted:** July 31, 2022

**Article in press:** July 31, 2022

**Published online:** August 18, 2022



**Luke Drake, Hamdi Sukkarieh, Eldrin Bhanat, Patrick Wright,** Department of Orthopaedic Surgery, University of Mississippi Medical Center, Jackson, MI 39110, United States

**Tyler McDonald,** Department of Orthopaedic Surgery, University of South Alabama, Mobile, AL 36608, United States

**Elisa Quince,** School of Medicine, William Carey College of Medicine, Hattiesburg, MI 39401, United States

**Myles Atkins,** School of Medicine, Morehouse School of Medicine, Atlanta, GE 30310, United States

**Jaysson Brooks,** Department of Orthopaedic Surgery, UT-Southwestern, Dallas, TX 75219, United States

**Corresponding author:** Jaysson Brooks, MD, Assistant Professor, Department of Orthopaedic Surgery, UT-Southwestern, 2222 Welborn Street, Dallas, TX 75219, United States. [jaysson.brooks@tsrh.org](mailto:jaysson.brooks@tsrh.org)

## Abstract

### BACKGROUND

The effect of posterior spinal fusion (PSF) incorporating the pelvis on an ambulatory patient's ability to mobilize after the fusion is not well understood.

### AIM

To see whether a posterior spinal fusion with pelvic fixation using iliac or sacral alar iliac screws in ambulatory neuromuscular scoliosis (NMS) patients influences postoperative ambulatory ability.

### METHODS

A retrospective review of all patients with NMS that underwent PSF with fixation incorporating the pelvis between January 1, 2012 and February 29, 2019. A total of 118 patients were eligible, including 11 ambulatory patients. The primary outcome was the maintenance of ambulatory status postoperatively. Secondary outcomes included postoperative curve magnitude, pelvic obliquity, and complications, comprising infections, instrumentation failure, and any unplanned returns to the operative room.

## RESULTS

The ambulatory function was maintained in all 11 ambulatory NMS patients. One patient had an improvement in functional status with equipment-free ambulation postoperatively. An average postoperative follow-up was 19 mo. The overall complication rate was 19.4% ( $n = 23$ ) with no significant differences between the groups in infection ( $P = 0.365$ ), hardware failure ( $P = 0.505$ ), and reoperation rate ( $P = 1.0$ ). Ambulatory status did not affect complication rate ( $P = 0.967$ ).

## CONCLUSION

Spinal fusion to the pelvis in ambulatory patients with NMS provides effective deformity correction without the reduction in ambulatory capabilities.

**Key Words:** Pelvic fixation; Ambulation; Neuromuscular scoliosis; Pediatrics; Posterior spinal fusion; Pelvis

©The Author(s) 2022. Published by Baishideng Publishing Group Inc. All rights reserved.

**Core Tip:** Neuromuscular scoliosis (NMS) represents a medically and surgically complex disorder that can have a profound impact on the patient's quality of life and the ability of their caretakers to provide adequate care. The purpose of this study is to determine whether posterior spinal fusion with pelvic fixation using iliac or sacral-alar iliac screws in ambulatory NMS patients affects postoperative ambulatory ability.

**Citation:** Drake L, Sukkarieh H, McDonald T, Bhanat E, Quince E, Atkins M, Wright P, Brooks J. Effect of pelvic fixation on ambulation in children with neuromuscular scoliosis. *World J Orthop* 2022; 13(8): 753-759

**URL:** <https://www.wjgnet.com/2218-5836/full/v13/i8/753.htm>

**DOI:** <https://dx.doi.org/10.5312/wjo.v13.i8.753>

## INTRODUCTION

Neuromuscular scoliosis (NMS) represents a medically and surgically complex disorder that can have a profound impact on the patient's quality of life and the ability of their caretakers to provide adequate care[1,2]. In patients with retained mobility, progression of the neuromuscular disease may result in a loss of their ability to ambulate. Conversely, in non-ambulatory and wheelchair-bound patients, it can lead to difficulty in sitting balance, resulting in hand-dependent sitting, development of decubitus ulcers, and hygiene-related issues[2-4]. The primary goal for patients with NMS is to prevent major curve progression while restoring coronal and sagittal alignment over a balanced pelvis[2,4,5]. To achieve this goal, spinal instrumentation must often be extended into the pelvis. Historically, the fusion of the spine to the pelvis has been taboo, recommended only when pelvic obliquity was  $> 15$  degrees or in low lumbar curves in which the sacrum is affected by the curve[3,6-8]. In 2002, Tsirikos *et al*[4] published their study on cerebral palsy patients who underwent a posterior spinal fusion (PSF) with extension to the pelvis using a unit rod. In their 24 ambulatory patients that underwent PSF to the pelvis, only one patient lost ambulatory function secondary to heterotopic ossification of her hips. This study showed, for the first time, that ambulatory patients who undergo fusion to the pelvis retained mobility after surgery. Recently, a study by Menger *et al*[9] has reported the effects of using PSF with pedicle screws and S2 sacral alar-iliac screws in ambulatory patients with any diagnosis of pediatric scoliosis. Of their 25 patients, only one patient had a decline in postoperative ambulation. However, no study to date has specifically evaluated outcomes in ambulatory children with NMS after a PSF using modern instrumentation. This study aimed to determine whether PSF with pelvic fixation using iliac or sacral-alar iliac (SAI) screws in ambulatory NMS patients influences postoperative ambulatory ability.

## MATERIALS AND METHODS

An institutional review board approval was obtained for this study (IRB# 2018-0161). An informed consent exemption was also obtained through a waiver. A retrospective review of all patients with NMS who underwent PSF between January 1, 2012 and February 29, 2019 at a single academic children's hospital was performed, yielding 169 patients. Patients were excluded if their fusion did not extend to the pelvis using iliac or SAI screws, yielding a total of 118 patients for the study. The primary outcome was the maintenance of ambulatory status postoperatively. Secondary outcomes included postoperative curve magnitude, pelvic obliquity, and complications, comprising infections, instrumentation failure,

and any unplanned returns to the operative room (UPRORs). Statistical analysis was performed using IBM SPSS Statistics, Version 26.0 (Armonk, NY). Pearson's Chi-Square and Leven's test for equality were used as appropriate for all categorical data. Significance was set at an alpha level of 0.05.

## RESULTS

A total of 118 patients, including 11 ambulatory patients, were enrolled in the study. Detailed demographic and diagnosis data of ambulatory and non-ambulatory patients with NMS are included in [Table 1](#).

No ambulatory patient with NMS became non-ambulatory after PSF with pelvic fixation. In one case, a 19-year-old male that underwent PSF from T1 to the pelvis with SAI screws had an improvement with the ability to ambulate in the clinic free of mobility aids. [Table 2](#) outlines the differences between major curve magnitude (MCM) and pelvic obliquity (PO) for both groups preoperatively and postoperatively and the average change for both parameters.

The major curve magnitude was similar between the groups. However, the preoperative PO was significantly larger in the non-ambulatory *vs* the ambulatory group (15.5 degrees *vs* 7.8 degrees,  $P < 0.0001$ ). Furthermore, when comparing the total change of MCM and PO between the ambulatory and non-ambulatory groups, no significant difference was found (MCM  $P = 0.181$ ; PO  $P = 0.143$ ). SAI screws were used in 114 patients, iliac bolts were used in 2 patients, and iliac screws were used in 2 patients. The type of pelvic fixation used did not affect postoperative ambulatory status ( $P = 0.965$ ), and all ambulatory patients had pelvic fixation consisting of SAI screws.

The total complication rate for all patients enrolled was 19.4% ( $n = 23$ ). The complication profile for the entire patient population and ambulatory and non-ambulatory groups is summarized in [Table 3](#). No statistically significant difference was found in reoperation, injection, or hardware failure rates between the two groups. All patients with hardware failure required revision of spinal fixation. Overall, the patient's ambulatory status did not affect the overall postoperative complication rate ( $P = 0.967$ ).

A small subset of our patients had previous spinal correction surgery, including three ambulatory and ten non-ambulatory patients. Prior surgery performed included the use of vertical expandable prosthetic titanium rib (VEPTR) rods (6), an extension of previous posterior spinal fusion (4), previous staged anterior spinal fusion (2), and the use of growing rods (1). Within this small subgroup, previous surgery did not affect ambulation ( $P = 0.209$ ), postoperative infections ( $P = 0.180$ ), or hardware failure (0.538). Prior surgery significantly affected the need for reoperation ( $P = 0.001$ ), despite no significant difference in infection or hardware failure rates. Prior surgical procedures also significantly affected curve magnitude ( $P = 0.044$ ) and PO ( $P = 0.015$ ).

## DISCUSSION

The effect of PSF with pelvic fixation in children with the ability to ambulate has long been an unclarified question. This study focused on the outcomes of patients with NMS who underwent PSF with extension to the pelvis using either SAI or iliac screws. In our study, we found that all patients could ambulate at the same or higher function after PSF with extension to the pelvis. Additionally, we found no significant difference between ambulatory and non-ambulatory groups in complications, UPRORs, hardware failure, or postoperative infections.

To date, this is only the second investigation to report on ambulatory patients with NMS undergoing PSF with fixation to the pelvis using modern pelvic fixation constructs. When comparing our results with the current literature, our findings are consistent. Tsirikos *et al*[4] have evaluated the ambulatory status of 24 NMS patients that underwent PSF incorporating the pelvis using a unit-rod construct. Only one patient in their study lost the ability to ambulate after fusion to the pelvis, and this was secondary to heterotopic ossification of the hips and unrelated to the spinal fusion. Patient- and caregiver-reported outcome questionnaires were also used to assess the postoperative function. Improvements in sitting ability, head and trunk balance, physical appearance, and respiration were noted without any change in ambulatory ability. Furthermore, 12 patients in their study underwent preoperative and postoperative gait analysis. They did not find any significant difference in postoperative gait mechanics in any of these patients. However, patients in their study received a unit rod in contrast to our cohort, where the majority had SAI or iliac screws for pelvic fixation. Menger *et al*[9] have evaluated the effect of PSF with extension to the pelvis in 25 ambulatory children with scoliosis from various diagnoses. Their patients included idiopathic, syndromic, neuromuscular, and congenital scoliosis, of which neuromuscular scoliosis only comprised 28%. They found that all patients retained the ability to ambulate postoperatively, with only one patient noting a decreased ability after fusion. Patient-reported outcomes showed that 25% of the patients noted a change in ambulatory ability while PROMIS T scores completed by most patients fell within one standard deviation of normal, showing only mild ambulatory deficit compared to the normal population. Our study supports these findings, showing no change in ambulation in our patient population.

**Table 1 Patient demographics**

	Ambulatory	Non-ambulatory	Total	P value
Gender				0.405
Female	4	53	57	
Male	7	54	61	
Race				
Black	2	70	72	
White	8	32	40	
Hispanic	0	2	2	
Asian	0	1	1	
Other	1	2	3	
Age at surgery	16.91 (4.93)	13.32 (3.32)	13.65 (3.63)	0.122
Average follow-up	18.43	18.43	19.14	
Diagnosis				
Cerebral palsy	5	85	90	
Post-traumatic spinal cord injury	0	10	10	
Spina bifida	0	7	7	
Myopathy	2	0	2	
Muscular dystrophy	1	2	3	
Spinal muscular atrophy	0	2	2	
Alexander’s disease	0	1	1	
Charcot marie tooth	1	0	1	
Pelizaeus merzbacher disease	0	1	1	
Lennox gastaut syndrome	1	0	1	
Geroderma osteodysplasia	1	0	1	

**Table 2 Preoperative and postoperative deformity measurements**

	Preoperative		Postoperative		Average correction	
	Major curve magnitude	Pelvic obliquity	Major curve magnitude	Pelvic obliquity	Major curve magnitude	Pelvic obliquity
Ambulatory	60.1 (28-110)	7.8 (2-14)	26.9 (12-61)	4.7 (0-15)	33.2	3.1
Non-ambulatory	70 (12-140)	15.5 (0-47)	26.4 (2-81)	8.3 (0-37)	43.6	7.2
P value	0.221	0.000	0.912	0.122		

Mean values with range within parentheses, all values in degrees.

Adult spinal deformity literature provides further insight into the effects of pelvic fixation with PSF. A study by Kondo *et al*[10] has investigated the pre- and postoperative physical function of 30 patients who underwent long spinal fusion from the thoracic spine to the ilium. They found that all patients had significantly improved pain, balance, and 6-minute walking test after PSF. Furthermore, they found that patients with significantly worse preoperative sagittal balance and pelvic tilt had greater improvements in gait speed, gait endurance, and dynamic balance compared to patients with less significant sagittal imbalance or pelvic tilt. Yagi *et al*[11] have investigated the difference between the effect of PSF to the pelvis with iliac screws and the upper instrumented vertebrae in 30 adult female patients. Gait analysis was obtained preoperatively and at 12-18 mo postoperatively, showing an improvement in gait pattern and gait ability. Additionally, Edwards *et al*[12] have investigated the difference in long PSF from the thoracic spine to either L5 or the pelvis in 95 adult patients. Their findings were consistent, showing improved Scoliosis Research Society 24 patient-reported outcomes for both groups and no significant

**Table 3** Complication profile between ambulatory and non-ambulatory groups

	Reoperation rate	Infection rate	Hardware failure rate
Overall	18.6	12.7	5.9
Ambulatory	18.2	0	9.1
Non-ambulatory	18.7	14	5.6
<i>P</i> value	0.239	0.365	0.505

All values in percentages.

difference between them. Our findings, although in a vastly different patient population, are consistent with the results of these studies.

Our study had several limitations. First, ambulatory patients with NMS requiring PSF were rare at our institution and only comprised 9.3% of our total patient population. It is possible that a significant difference might be found between ambulators and non-ambulators with NMS with a larger number of patients. Second, gait lab analysis was not available for the included patients, making it difficult to compare the effects of pelvic fixation on postoperative ambulation more objectively. Finally, by not having long-term postoperative follow-up in all patients, it is possible that some patients had a change of ambulatory status unknown to our institution. Despite these limitations, our study is the first in the literature to evaluate the effect of pelvic fixation on postoperative ambulatory status in patients receiving PSF using modern pelvic fixation instrumentation, demonstrating that the postoperative complication profile remains unchanged compared to non-ambulatory controls.

## CONCLUSION

In conclusion, we found that it is safe for ambulatory patients with NMS to undergo PSF incorporating the pelvis using modern constructs. Additionally, posterior spinal fusion with extension to the pelvis has no significant effect on complications, UPRORs, hardware failure, or postoperative infections.

## ARTICLE HIGHLIGHTS

### **Research background**

Ambulatory patients with neuromuscular scoliosis are a rare subset of patients in which treatment does not compromise their ability to ambulate.

### **Research motivation**

Insufficient research has been done to support the effects of posterior spinal fusion incorporating the pelvis on the ability to ambulate in ambulatory patients with neuromuscular scoliosis.

### **Research objectives**

To report the effect of posterior spinal fusion incorporating the pelvis on the ability to ambulate after fusion in patients with neuromuscular scoliosis.

### **Research methods**

This is a retrospective analysis of patient function outcomes after undergoing posterior spinal fusion incorporating the pelvis over a seven-year period at our children's hospital.

### **Research results**

Of the eleven patients fitting this criterion, no patient lost their ability to ambulate after undergoing posterior spinal fusion incorporating the pelvis.

### **Research conclusions**

According to our findings, there is no effect on the ambulatory function of neuromuscular patients after posterior spinal fusion incorporating the pelvis.

### **Research perspectives**

Although more evidence is needed, the experience at our institution would support that posterior spinal

fusion incorporating the pelvis does not affect the patients' ability to mobilize in ambulatory neuromuscular scoliosis patients.

---

## FOOTNOTES

**Author contributions:** Drake LC performed study design, x-ray measurements, statistical analysis, and manuscript preparation; Sukkarieh H contributed to study design and manuscript preparation; McDonald TC contributed to study design and manuscript preparation; Bhanat E contributed to statistical analysis and manuscript preparation; Quince E contributed to x-ray measurements and statistical analysis; Atkins M contributed to x-ray measurements and statistical analysis; Wright P contributed to study design and manuscript preparation; Brooks JT contributed to study design, statistical analysis, and manuscript preparation

**Institutional review board statement:** The study was reviewed and approved by the University of Mississippi Medical Center Institutional Review Board [Approval No. 2018-01610].

**Informed consent statement:** Patients were not required to give informed consent to the study because the analysis used anonymous clinical data that were obtained after each patient agreed to treatment by written consent.

**Conflict-of-interest statement:** Brooks JT is a paid consultant of DePuy-Synthes, A Johnson & Johnson Company; paid consultant of OrthoPediatrics; and a paid presenter or speaker of Medtronic Spine. The remaining authors declare no conflicts of interest.

**Data sharing statement:** Statistical code and dataset are available from the corresponding author at [jaysson.brooks@tsrh.org](mailto:jaysson.brooks@tsrh.org). Participants did not give informed consent for data sharing.

**Open-Access:** This article is an open-access article that was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution NonCommercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <https://creativecommons.org/licenses/by-nc/4.0/>

**Country/Territory of origin:** United States

**ORCID number:** Jaysson Brooks 0000-0002-8523-1750.

**S-Editor:** Wang LL

**L-Editor:** A

**P-Editor:** Wang LL

---

## REFERENCES

- 1 Yoshida K, Kajiura I, Suzuki T, Kawabata H. Natural history of scoliosis in cerebral palsy and risk factors for progression of scoliosis. *J Orthop Sci* 2018; **23**: 649-652 [PMID: 29705176 DOI: 10.1016/j.jos.2018.03.009]
- 2 McCarthy JJ, D'Andrea LP, Betz RR, Clements DH. Scoliosis in the child with cerebral palsy. *J Am Acad Orthop Surg* 2006; **14**: 367-375 [PMID: 16757676 DOI: 10.5435/00124635-200606000-00006]
- 3 McCarthy RE. Management of neuromuscular scoliosis. *Orthop Clin North Am* 1999; **30**: 435-449, viii [PMID: 10393765 DOI: 10.1016/s0030-5898(05)70096-1]
- 4 Tsirikos AI, Chang WN, Shah SA, Dabney KW, Miller F. Preserving ambulatory potential in pediatric patients with cerebral palsy who undergo spinal fusion using unit rod instrumentation. *Spine (Phila Pa 1976)* 2003; **28**: 480-483 [PMID: 12616161 DOI: 10.1097/01.BRS.0000048649.72919.6B]
- 5 Benson ER, Thomson JD, Smith BG, Banta JV. Results and morbidity in a consecutive series of patients undergoing spinal fusion for neuromuscular scoliosis. *Spine (Phila Pa 1976)* 1998; **23**: 2308-2318 [DOI: 10.1097/00007632-199811010-00012]
- 6 Akesen B, Atici T, Eken G, Ulusaloglu AC. The comparison of the results after spinal fusion with or without iliac screw insertion in the treatment of neuromuscular scoliosis. *Acta Orthop Traumatol Turc* 2018; **52**: 435-437 [PMID: 30266422 DOI: 10.1016/j.aott.2017.12.005]
- 7 Modi HN, Suh SW, Song HR, Fernandez HM, Yang JH. Treatment of neuromuscular scoliosis with posterior-only pedicle screw fixation. *J Orthop Surg Res* 2008; **3**: 23 [PMID: 18544164 DOI: 10.1186/1749-799X-3-23]
- 8 Van Zundert J, Vanelderden P, Kessels AG. Re: Chou R, Atlas SJ, Stanos SP, *et al.* Nonsurgical interventional therapies for low back pain: a review of the evidence for an American Pain Society clinical practice guideline. *Spine (Phila Pa 1976)* 2009; **34**: 1078-93. *Spine (Phila Pa 1976)* 2010; **35**: 841; author reply 841-841; author reply 842 [PMID: 20357643 DOI: 10.1097/BRS.0b013e3181d2ad36]
- 9 Menger R, Park P, Marciano G. Ambulatory capacity following fusion to the sacrum with pelvic fixations pediatric spinal deformity patients. *Spine Deform* 2020 [DOI: 10.1007/s43390-020-00238-7]
- 10 Kondo R, Yamato Y, Nagafusa T. Effect of corrective long spinal fusion to the ilium on physical function in patients with

- adult spinal deformity. *Eur Spine J* 2017; **26**: 2138-2145 [DOI: [10.1007/s00586-017-4987-9](https://doi.org/10.1007/s00586-017-4987-9)]
- 11 **Yagi M**, Fujita N, Tsuji O, Nagoshi N, Yato Y, Asazuma T, Ishii K, Nakamura M, Matsumoto M, Watanabe K. Effect of the upper instrumented vertebral level (upper vs lower thoracic spine) on gait ability after corrective surgery for adult spinal deformity. *Spine J* 2018; **18**: 130-138 [PMID: [28669859](https://pubmed.ncbi.nlm.nih.gov/28669859/) DOI: [10.1016/j.spinee.2017.06.026](https://doi.org/10.1016/j.spinee.2017.06.026)]
  - 12 **Edwards CC 2nd**, Bridwell KH, Patel A, Rinella AS, Berra A, Lenke LG. Long adult deformity fusions to L5 and the sacrum. A matched cohort analysis. *Spine (Phila Pa 1976)* 2004; **29**: 1996-2005 [PMID: [15371700](https://pubmed.ncbi.nlm.nih.gov/15371700/) DOI: [10.1097/01.brs.0000138272.54896.33](https://doi.org/10.1097/01.brs.0000138272.54896.33)]



Published by **Baishideng Publishing Group Inc**  
7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, USA  
**Telephone:** +1-925-3991568  
**E-mail:** [bpgoffice@wjgnet.com](mailto:bpgoffice@wjgnet.com)  
**Help Desk:** <https://www.f6publishing.com/helpdesk>  
<https://www.wjgnet.com>

