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Effects of Spinal Fusion for Idiopathic Scoliosis on Lower Body Kinematics During Gait*

Karen M. Kruger, PhD[a,*], Christina M.R. Garman, PhD[a], Joseph J. Krzak, PhD[a,b,c], Adam Graf, MS[a,b], Sahar Hassani, MS[b], Sergey Tarima, PhD[d], Peter F. Sturm, MD[e], Kim W. Hammerberg, MD[b], Purnendu Gupta, MD[b], Gerald F. Harris[a,b]

[a]*Orthopaedic & Rehabilitation Engineering Center, Marquette University, 1250 W Wisconsin Ave, Milwaukee, WI 53233, USA*
[b]*Motion Analysis Laboratory, Shriners Hospitals for Children, 2211 N Oak Park Ave, Chicago, IL 60707, USA*
[c]*College of Health Sciences, Midwestern University, 555 31st, Downers Grove, IL 60515, USA*
[d]*Division of Biostatistics, Medical College of Wisconsin, 8701 W. Watertown Plank Rd, Milwaukee, WI 53226, USA*
[e]*Division of Orthopaedic Surgery, Cincinnati Children's Hospital Medical Center, 3333 Burnet Ave, Cincinnati, OH 45229, USA*

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Abstract

Study Design: Prospective.
Objectives: The purpose of this study was to compare gait among patients with scoliosis undergoing posterior spinal fusion and instrumentation (PSFI) to typically developing subjects and determine if the location of the lowest instrumented vertebra impacted results.
Summary of Background Data: PSFI is the standard of care for correcting spine deformities, allowing the preservation of body equilibrium while maintaining as many mobile spinal segments as possible. The effect of surgery on joint motion distal to the spine must also be considered. Very few studies have addressed the effect of PSFI on activities such as walking and even fewer address how surgical choice of the lowest instrumented vertebra (LIV) influences possible motion reduction.
Methods: Individuals with scoliosis undergoing PSFI (n = 38) completed gait analysis preoperatively and at postoperative years 1 and 2 along with a control group (n = 24). Comparisons were made with the control group at each time point and between patients fused at L2 and above (L2+) versus L3 and below (L3−).
Results: The kinematic results of the AIS group showed some differences when compared to the Control Group, most notably decreased range of motion (ROM) in pelvic tilt and trunk lateral bending. When comparing the LIV groups, only minor differences were observed, and the results showed decreased coronal trunk and pelvis ROM at the one-year visit and decreased hip rotation ROM at the two-year visit in the L3− group.
Conclusions: Patients with AIS showed decreased ROM preoperatively with further decreases postoperatively. These changes remained relatively consistent following the two-year visit, indicating that most kinematic changes occurred in the first year following surgery. Limited functional differences between the two LIV groups may be due to the lack of full ROM used during normal gait, and future work could address tasks that use greater ROM.
Level of Evidence: Level II.

Keywords: Adolescent idiopathic scoliosis; Posterior spinal fusion; Gait; Lowest instrumented vertebra; Kinematics

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IRB approval: All participants freely consented in accordance with an institutionally approved IRB protocol.

*Corresponding author. Marquette University, 1515 W. Wisconsin Ave, Olin Engineering 305, Milwaukee, WI 53233, USA. Tel.: (414) 288-4440; fax: (414) 288-0713.

E-mail address: karen.kruger@marquette.edu (K.M. Kruger).

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Introduction

Scoliosis is the most common orthopaedic disorder among children and adolescents and the 3D deformation of the spine changes the mechanics of the whole body. Posterior spinal fusion and instrumentation (PSFI) is the standard of care for correcting spine deformities in individuals with adolescent idiopathic scoliosis (AIS), allowing the preservation of body equilibrium while maintaining as many mobile spinal segments as possible [1,2]. The effect of surgery on body shape, pain, and decompensation phenomenon has been well documented [3]; however, there is still uncertainty on how AIS and subsequent spinal fusion to varying levels affects functional outcomes such as walking, particularly in segments other than the trunk.

Standing coronal and sagittal radiographs are the standard means of preoperative analysis and postoperative assessment of surgical results of spinal fusion [4]; however, this static assessment does not address the associated changes in functionality that may occur following fusion. Changes to trunk mobility have been measured via dynamic assessment following this procedure [5]. To date, there is not sufficient robust evidence to judge the influence of scoliosis deformity on kinematic parameters during walking [6].

Gait analysis was first used to define normal spinal and pelvis motion by Thurston and Harris in 1976 [7]. In a gait analysis of the head, trunk, and pelvis, Kramers−de Quervain et al. observed significant asymmetry in the trunk's rotational behavior in the transverse plane during double limb stance in 10 females with AIS whereas head and pelvic rotation followed a symmetric pattern [8]. While several investigators have studied gait following spinal fusion in scoliosis [9-11], it is not clear if trunk and lower extremity kinematics are impacted in follow-ups beyond the first year postoperatively. Past work has shown individuals with AIS to have decreased pelvic, hip, and knee ranges of motion during gait compared to healthy, control subjects, although the restriction of motion was relatively small [12]. Following surgery, the spine has been shown to become stiffer with decreased spinal range of motion (ROM) [9]. Short-term follow-ups post spinal fusion have shown slight increases to pelvic and hip frontal motion [11]; however, the longer-term effects of surgery on lower body gait kinematics are still unclear.

Even fewer clinical studies address how surgical choice of the lowest instrumented vertebra (LIV) influences possible reductions in motion. The lowest level to fuse the vertebra is a continued topic of clinical debate and a majority of the work addressing LIV has focused on trunk motions. Appropriate selection of the LIV is crucial to ensure positive outcomes after surgical management of patients with AIS. Failure to do so can lead to curve decompensation and "adding on" of additional vertebrae to the deformity [13]. Because of the mobility of the lumbar spine and the propensity for symptomatic degeneration, selection of the optimal LIV is believed to play a significant role in the ultimate clinical outcome of the patient. The concept of ''saving a level'' by stopping the fusion short must be weighed against the potential to leave an uncorrected or unbalanced spine [14]. Although several publications have described the contribution of LIV to trunk mobility [5] and volitional weight shifting [15], no studies have compared gait outcomes between varying LIV.

The goal of PSFI surgery is the preservation of body equilibrium while maintaining as many mobile spinal segments as possible. Ultimately, the purpose of this study was to (1) compare pre-, one-year, and two-year post-surgery conditions among patients with scoliosis undergoing PSFI to assess effects on temporospatial and trunk and lower body kinematics during gait compared to typically developing subjects and (2) determine if the location of the LIV had any impact on the results. We hypothesized that the spinal fusion would result in stiffer gait (as measured by joint ROM) and that individuals with PSFI to more distal LIV (L3 and below) would experience more joint stiffening during gait.

Materials and Methods

This was a prospective study performed on 38 individuals with AIS (5 males, 33 females, age 15.0 ± 2.1 years) undergoing PSFI (Table 1). The AIS Group consisted of a sample of convenience between October 2007 and August 2012 at a single specialized pediatric orthopaedic institution (Figure 1). A consecutive series of 120 patients had a PSFI, of which 38 patients agreed to participate in the AIS Group. The average age at the time of the PSFI was 15.0 years ± 2.1 years. Participants were excluded if they required fusion outside T12 through L4. None of the participants had an L5 vertebra above the intercrestal line or L5 sacralization. Because of safety concerns, participants were excluded if they could not walk/stand independently. Patient demographics are defined in Table 1. The LIV was determined by the operating surgeon using the standing radiograph, intersection of the center sacral vertical line, and correction of the LIV on traction and bending films. The goal was to have the LIV centralized, horizontalized, and neutralized postoperatively.

Gait analysis was performed on all patients preoperatively and at postoperative years 1 (mean, 1.15 years; range, 0.8−1.5 years) and 2 (mean, 2.2 years; range, 1.8−3.4 years). All participants freely consented in accordance with an institutionally approved IRB protocol. This group was split into two subgroups, L2+ (fusions to L2 and above, 14 subjects) and L3− (fusions to L3 and below, 24 subjects), to evaluate the effect of LIV on trunk and lower extremity gait.

Gait data were collected at 120 Hz using a passive marker 14 camera (MX model) motion capture system (Vicon; Oxford Metrics, Oxford, UK) on a 10-m walkway.