Manipulation Peak Forces Across Spinal Regions for Children Using Mannequin Simulators

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Abstract

Objective: The purpose of this work was to create an exploratory database of manipulation treatment force variability as a function of the intent of an experienced clinician sub-specializing in the care of children to match treatment to childhood category. Data of this type are necessary for realistic planning of dose–response and safety studies on therapeutic benefit.

Methods: The project evaluated the transmitted peak forces of procedures applied to mannequins of different stature for younger and older children. Common procedures for the cervical, thoracic, and lumbar spine and sacroiliac joint were administered to estimate variability by a single experienced practitioner and educator in pediatric manipulation attempting to modulate for childhood category. Results described for peak components in the cardinal axes and for peak total forces were cataloged and compared with consensus estimates of force from the literature.

Results: Mean force values for both components and total force peaks monotonically increased with childhood category analogous to consensus expectations. However, a mismatch was observed between peak values measured and consensus predictions that ranged by a factor of 2 to 3.5, particularly in the upper categories. Quantitative data permit a first estimate of effect size for future clinical studies.

Conclusions: The findings of this study indicate that recalibration of spinal manipulation performance of experienced clinicians toward arbitrary target values similar to consensus estimates is feasible. What is unclear from the literature or these results is the identity of legitimate target values that are both safe and clinically effective based on childhood categories in actual practice. (J Manipulative Physiol Ther 2017;xx:1-8)

Key Indexing Terms: *Chiropractic; Manipulation; Pediatrics; Biomechanics; Simulation*

Introduction

Spinal manipulation is a therapeutic category consisting of manual application of loads to patient tissues. These procedures have been reported to be cost effective,[1] with local effects on pain,[2] joint stiffness,[3,4] and muscle tone,[5-8] as well as multisegmental neural reflexes modulating sensory integration[9] and systemic cytokine levels.[10-12] Several types of maneuvers, including high-velocity, low-amplitude (HVLA) impulse procedures, are used commonly for musculoskeletal complaints in children[13,14] and, by some, for several non-musculoskeletal conditions, such as infantile colic,[3,4] breastfeeding dysfunction,[15,16] otitis media,[17,18] asthma,[19] enuresis,[13,20] and constipation.[21] Recent consensus-based, best practice[14] recommendations call for modulation of procedure forces to accommodate the pediatric patient's stature, developing skeletal and periarticular structures, and patient comfort. Limited documentation exists on the forces typically used in pediatric patients in clinical practice settings, as the majority of biomechanical measures of manipulation procedures have been obtained using adults.[22-26] Recommendations for force dosage for children to date[27] have been based on survey opinions from practitioners who treat children and estimate forces applied[28] as a percentage of those used on adults. Extrapolations from tests of tensile tissue strengths in pediatric and adult spines ex vivo[29] and simulation of clinical procedures applied directly to force plate surfaces by 2 experienced practitioners[30] provide further guidance. Modulated peak force

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Paper submitted October 4, 2016; in revised form October 25, 2016; accepted January 10, 2017.
0161-4754

http://dx.doi.org/10.1016/j.jmpt.2017.01.001

target recommendations for pediatric age groups are summarized in Table 1 along with the extrapolated safe tensile loads as replicated from the review by Todd et al.[27]

Recommendations for force modulation assume that experienced practitioners hold the skill in control of manipulation procedure administration to provide forces scaled to the child on demand. The capacity to intentionally modulate force application during clinical procedures was initially studied by Triano and Schultz[31] and Triano.[32] In that work, experienced clinicians produced comparable displacements and force amplitudes from both left and right sides, although in the mean, the dominant hand was slightly higher. On demand, they were able to modulate forces up or down, producing significant differences in amplitude quantitatively. The criteria of intent for each procedure were based on the provider's subjective sense of the maximum clinically acceptable limit for the patient's stature at one end of a spectrum and the minimum clinically relevant force at the other. More recent work explored the stability of spinal manipulation performance over time and the ability of clinicians to adapt to arbitrary target levels.[33] Using a constant, anthropometric adult mannequin, 41 clinicians with a minimum of 5 years of experience but no specialized training in force modulation were studied. They were measured while applying a single procedure twice, separated by a 4-month interval. Good consistency in performance on force-time profiles ($0.55 \leq$ intraclass correlation coefficient ≤ 0.75) was observed. With a short interval of focused training, providers were able to modulate force toward arbitrary targets, reducing error rates by 23% to 45%, depending on the target. Snodgrass et al[25] evaluated the clinical benefit of arbitrarily defined targets of force amplitude for adult neck pain sufferers. Clinicians were able to provide low (30 N) or high (90 N) forces as needed. Self-reports of pain and independent measures of spinal stiffness both improved more with the higher force levels.

As the cited prior works suggest, experienced clinicians can vary the application of force in adults and can be relatively consistent from time-to-time in its application, at least for a constant-size adult mannequin. However, it remains unclear what force levels are actually used by clinicians working with children and whether the degree of scaling suggested in Table 1 is realistic. The purpose of this study was to obtain an exploratory database addressing these questions using mannequins for simulation purposes and to avoid human subject risk at this early stage of investigation. Such data may serve as guidance for future clinical trials to evaluate clinical effectiveness and the mechanisms of action in the pediatric population.

Methods

The project evaluated the transmitted force-time profiles of procedures applied to mannequins by an experienced chiropractic physician. The physician performing the procedures has 28 years practice experience, board certification in chiropractic pediatrics and conducts a waiting-list pediatric practice specializing in the care of infants. In addition to practice, she has frequently conducted continuing education training programs, including practical hands-on sessions, for manipulation procedures in children. However, prior to involvement with this project, she had no experience with manipulation force measurement or interpretation of force-time profiles. The Canadian Memorial Chiropractic College institutional research ethics board approved this study (No. 162010).

Table 1. *Spinal Manipulation Estimated Peak and Extrapolated Safe Tensile Forces by Childhood Age Range Rounded to the Nearest Newton*

Age Range	Manipulation Force (N)	Safe Tensile Force (N)
<3 mo	11	20
3–23 mo	37	50
2–8 y	56	85
9–18 y	90	135
>18 y	112	165

Source: From Todd et al.[27]

Mannequins

Manipulation procedures were applied to one of two mannequins based on the childhood classification being simulated. The pediatric mannequin (Cititoy, Vancouver, British Columbia, Canada) was 46 cm long from crown to heel and 15 cm wide at the shoulder. The adult mannequin (H.A.M. series; CMCC, Toronto, Ontario, Canada) was 103 cm from crown to upper one-third of the thigh and 46 cm wide at the shoulder. Both mannequins were obtained unmodified from the manufacturer and permitted compression of the thorax and rotation/lateral flexion of the neck approximating realistic movements, although each was light in mass (eg, infant 0.5 kg, adult 48.4 kg) for pragmatic safety measures of handling in the laboratory. The pediatric mannequin served for younger classifications from neonate to young child which are defined by age range under Procedures. The adult mannequin was used as an alternate for simulating older classifications through adolescent.

Procedures

Absent specific guidance from the literature, a rubric of procedures was created for testing based on childhood classification and spinal regions. Definitions adopted for classifications followed those reported by Todd et al[27] and Marchand,[28,29] with modification to account for clinician judgment of need for additional subcategories based on the broad span of some age ranges in the literature. These included neonate, ages 0 to 2 months; infant, 3 to 12 months; toddler, 13 months through 3 years; young child, 4 to 7 years; mid-child, 8 through 11 years; and adolescent,