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Spinal Manipulation Impacts Cervical Spine Movement and Fitts' Task Performance: A Single-Blind Randomized Before-After Trial

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Abstract

Objective: The objective of this study was to determine if active cervical range of motion (ROM) and Fitts' task movement time differences occurred after high-velocity low-amplitude cervical spinal manipulation (SM) across various indexes of difficulty.

Methods: A single-blind randomized before-after trial was performed in a motor performance laboratory. Fifteen volunteers (21-42 years) with asymptomatic palpable intervertebral motion restriction at the C1-C2 level were randomly assigned to an SM group or to a no-intervention (NI) group. A single episode of upper cervical manipulation was performed on the SM group. Active cervical ROM and movement time were measured pre and posttreatment in the SM group and compared to similar measurements in the NI group.

Results: In the SM group, active cervical ROM into rotation increased after the intervention (pre, 74.75° ± 7.63°; post, 78.50° ± 7.23°; t (7) = −3.07; $P < .02$). During the second trial, significant group differences were present in the SM group for movement time in direction congruent conditions ($F_{(8,48)} = 2.83$; $P < .02$; $\eta_p^2 = .320$) and direction incongruent conditions ($F_{(8,48)} = 2.31$; $P < .05$; $\eta_p^2 = .278$) but not for the NI group.

Conclusions: A linear relationship between indexes of difficulty and movement time as predicted by Fitts' law was observed. Significant group effects indicate that SM not only increases cervical active ROM but also facilitates the performance of a cervical spine Fitts' task requiring rotation. This task may be used to quantify motor performance in clinically symptomatic populations with reduced ROM who are appropriate candidates for SM. (J Manipulative Physiol Ther 2010;33:189-192)

Key Indexing Terms: *Range of Motion; Manipulation, Spinal; Outcome Assessment; Chiropractic; Psychomotor Performance; Cervical Manipulation*

Spinal manipulation (SM) is a common manual therapy intervention primarily used to affect joint motion and pain.[1] Presently, a paucity of research examining quantifiable effects of SM on motor performance exists. Motor performance of the cervical spine has been established through the measurement of movement time (MT) when engaged in Fitts' task experiments.[2-4] Fitts' task experiments are derived from the speed-accuracy trade off in target-constrained aiming situations. Fitts' law states that as target size decreases or as

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amplitude between targets increases, the MT will increase linearly and is mathematically described as

$$MT = a + b[\log_2 (2A/W)].$$

In Fitts' law, a is the intercept and represents MT when the index of difficulty [$\log_2$ ($2A/W$)] is zero; constant b represents the change in MT associated with 1-unit change in index of difficulty and thus is the slope; A is amplitude of the distance between targets; and W is the width of the targets. Target aimed head movements have replicated Fitts' law predictions.[2-4] Detrimental Fitts' head movement task performance changes have been associated with aging.[4] Changes were noted not only in Fitts' task performance but also in range of motion (ROM) between a younger and older population. Had changes only been noted in ROM, other degenerative or central slowing mechanisms could be essentially ruled out.

Active cervical ROM (CROM) improvement is observed after a single high-velocity low-amplitude (HVLA) SM intervention.[1] One would postulate that should SM only improve ROM, then no change in performance in a target-constrained rapid-aiming task would be expected. But does this translate to improved performance on a functional motor performance task?

We examined these predictions in the present study by comparing movement performance pre-and post-SM using a previously established cervical spine Fitts' task.[4]

Method

Participants

Fifteen participants with asymptomatic palpable vertebral joint motion restriction at the C1-C2 level were randomly assigned to SM group (n = 8), age 29.1 ± 6.5 years, or no-intervention (NI) group (n = 7), age 26.5 ± 5.7 years. Participants not previously manipulated in the prior 60 days volunteered for the study. We selected students from the college population who were right handed; with corrected to normal vision; had no contraindications to SM; and no radicular symptoms, no neurologic deficits, or a history of cervical spine trauma or surgery. Motion palpation, specifically segmental ROM and end play (C1-C2) into rotation, was used in the evaluation of the cervical spine.[8] Vertebral joint motion restriction location was determined via manual palpation as indicated upon eliciting tenderness.[5] All participants were experimentally naive and provided written informed consent before testing. The institutional review board approved the study protocol and participant consent material that included written informed consent.

Apparatus and Task

Range of Motion. Participants were seated in a padded chair with shoulder straps that isolated ROM to the cervical spine. This was done to isolate musculoskeletal degrees of freedom to the cervical spine and prevent anterior shoulder motion that may be coupled with cervical spine rotation as per Passmore and colleagues.[4] Active CROM was measured with a CROM goniometer (Performance Attainment Associates, St Paul, Minn).[6] Gravity-assisted dials were used to determine sagittal and coronal motion, whereas an induced magnetic field allowed for transverse plane measurement. Flexion, extension, bilateral lateral flexion, and rotation were collected.

Table 1. *Index of difficulty ([$\log_2$ (2A/W)] = ID) per movement orientation*

	Amplitude (mm) = A		
Target width (mm) = W	50	100	200
5.0	4.32	5.32	6.32
7.5	3.73	4.74	5.74
11.25	3.15	4.15	5.19

Fitts' Task. Transparent safety glasses with a reflective/passive marker (7 mm in diameter) on the nasal bridge were worn by participants throughout the task, whereas they were seated in a padded chair with shoulder straps (as described previously) 80 cm from a 22.4 × 22.4-cm computer screen. The location of the reflective marker was measured by the Headmouse Extreme (Origin Instruments Corporation, Grand Prairie, Tex) at a frequency of 45 Hz nominal and a 10-millisecond latency. Generalized Fitts' Law Model Builder Software (version 1.1c) was run on a PC connected to the headmouse, and the software was calibrated to account for screen size and maintain amplitude and target accuracy.[7] Trials began as triggered by the experimenter and concluded with the cursor dwelling for 200 milliseconds within the boundaries of the square target.

Procedure

Participants completed consent, had active CROM measured, and performed cervical spine (CS) Fitts' task. Experimenter 1 collected Fitts' task performance data but was blinded to randomized intervention. Experimenter 2, through a binary number draw randomized participants to conditions, was a licensed Doctor of Chiropractic (>20 years experience), assessed CROM, and delivered HVLA cervical SM to participants. Anecdotally, audible joint cavitation was noted on all SM group HVLA intervention participants.

At the initiation of the task, participants were asked to visually fixate on a box on the computer monitor. A trial commenced when the box became a set of crosshairs, and participants were asked to move the crosshairs using cervical movement to the square target that appeared on the screen as quickly and accurately as possible. The amplitude traveled, and the target size that determine the index of difficulty (ID) (Table 1) for each trial were presented in a random order. This was performed in both leftward and rightward directions with 9 possible ID presentations. When the palpable vertebral joint motion restriction was into the direction of Fitts' task movement, it was considered congruent; when opposite, it was considered incongruent. To elaborate, the direction the

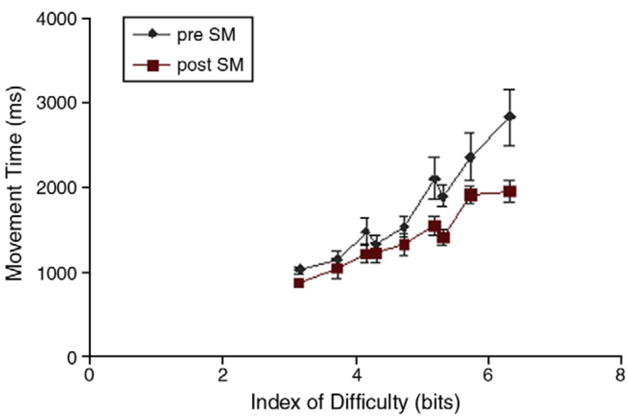

Fig 1. *Spinal manipulation congruent direction 2-way interaction.*

HVLA SM was applied to manipulate the CS would be considered congruent to the Fitts' task, if in both cases, the head rotated in the same direction. Three trials per ID were recorded, and 54 trials were collected. Participants were then randomized to NI or SM groups, where they received HVLA cervical SM or waited 5 minutes. The HVLA cervical SM procedure used was a seated digit pillar pull.[8] Cervical ROM was measured again, and CS Fitts' task was repeated for another 54 trials. The NI group was kept blinded as to whether they may receive SM later during the study, until all trials had been collected.

Dependent Measures and Analysis

Active CROM was measured in degrees. Comparisons were made using separate paired *t* tests, comparing participants pre and post-NI or SM, respectively. These tests were performed for all ROM data recorded that included flexion, extension, bilateral lateral flexion, and rotation.

Movement time was measured in milliseconds. Comparisons were made using separate analysis of variance models to describe the relationship of both SM and NI intervention, respectively, in both congruent and incongruent task movement directions across the 9 different ID conditions. For all statistical analyses, *P* values of .05 were considered significant.

Results

Range of Motion

Characteristics of active CROM performance into right rotation varied from 74.75° ± 7.63° (pre-SM) to 78.50° ± 7.23° (post-SM), in the SM group that attained statistical significance, $t(7) = -3.07$ ($P = .018$). Regardless of intervention or congruency, no other ROM directions or conditions yielded significant differences.

Movement Time

When the task demanded movement congruent to the direction of palpable joint restriction, a 2-way interaction between group and ID was present in the SM group ($F_{(8,48)} = 2.83$; $P < .05$; $\eta_p^2 = .320$) (Fig 1). The same effect was observed when the relationship to task movement and joint restriction direction was incongruent in the SM group ($F_{(8,48)} = 2.31$; $P < .05$; $\eta_p^2 = .278$). No significant interactions were found for the NI group.

Discussion

Measurement cervical spine function in clinical populations traditionally has to do with self-reported measures of changes in health surveys such as Short Form-36v2, Short Form-12v2, or disability indices including Neck Disability Index, Bournemouth Questionnaire, or other subjective measures or reports such as the visual analog scale.[9,10] A commonly used objective quantitative measure is active ROM, but what other objective performance-based outcome measures can be developed? Fitts' task allows investigation of MT, which illuminates the changes in quantifiable aspect motor performance or functionality associated with HVLA manipulation. Changes in functionality can be explained by existing theoretical mechanisms associated with SM. This study investigated head MT and ROM differences between participants who received HVLA upper cervical SM or NI.

The current study found a linear relationship between ID and MT as predicted by Fitts' law was observed for all conditions. The novel findings of interest were the 2-way interactions found for the SM but not for the NI group, which reveal that only for post-SM is MT less impacted by ID compared to pre-SM regardless of the orientation of the restriction to the side of SM delivery. In addition, this study replicated the work of Martinez-Segure and colleagues[1] who found that single episode of SM can significantly improve active CROM into rotation.

Across all ROMs measured and compared, statistical significance was noted into cervical spine rotation in the SM group only. Age-appropriate ROM into rotation in the CS is 72° for the population measured.[6] Even with palpable vertebral motion restrictions (before intervention), age-appropriate ROM was maintained, however, after SM improvement into rotation was noted. This finding may be of value to elite performers or athletes to whom subtle differences in ROM may afford them performance advantage in their given realm of expertise.

These behavioral findings support the concept that the mechanism for SM is not only biomechanical but also neurologic in nature. Thus, it appears that there is a multimodal impact of HVLA SM. Support for a biomechanical perspective as indicated by increased active ROM and support for a neurologic component as indicated through MT performance improvement in the face of changing ID.

Previous studies that focused on the neurologic component of HVLA SM and motor performance include studies that focused on the attenuation of central motor neuron excitability or cortical somatosensory evoked potentials.[5,11] Often, cervical spine neurologic studies are directed to the impact on motor performance in the neurologically relevant upper extremity as demonstrated in tasks involving probe reaction time or upper extremity Fitts' task improvements.[12,13] These sites, while neurologically related to the site of manipulation (cervical spine), are not necessarily directly biomechanically related to the site of manipulation. The current study design allows for comparison of biomechanical and neurologic performance due to the demands of the task and site of manipulation. In comparison of the present cervical spine movement task findings to the upper extremity movement findings of Smith and colleagues,[13] for Fitts' task performance to reveal MT changes as a function of ID, the site of manipulation should also be the site of joint movement relevant to the task. This finding that a rapid cervical spine MT task is less adversely impacted as task difficulty increases may be of value to individuals whose vocation or athletic endeavors demand optimal precision in high-velocity targeted cervical spine movement execution. According to the present study, this holds true when individuals may not present with symptomatic ailment but do have palpable vertebral joint motion restriction in the cervical spine.

Limitations

The current study, while examining the end result of MT and ROM, does not consider the impact of HVLA cervical SM on the quality of performance during the task itself. Further research should be done to examine the kinematics of motor performance after SM. Such studies will serve to more elaborately evaluate online changes in specific aspects of motor control.

We also do not yet understand the duration of time for these changes in performance after SM. The current study measured differences immediately after HVLA SM. Future studies should attempt to discern if and when the effects noted through the administration of SM begin to wash out.

Conclusions

The results of this study are in agreement with literature suggesting that SM can elicit changes in both active ROM and coordinated motor performance.

Practical Applications

- Cervical spine Fitts' task performance improves after HVLA SMT.
- Cervical ROM improves after HVLA SMT.
- Established motor control paradigms have the potential to serve as performance-based outcome measures.
- Individuals without pain may yield performance differences after SM.

In future studies, motor control performance tasks may be used as quantitative baseline and follow-up outcome measures to evaluate the response of clinically symptomatic patients who are appropriate candidates for a course of SM therapy.

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