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ORIGINAL ARTICLE

Cervical spine segmental vertebral motion in healthy volunteers feigning restriction of neck flexion and extension

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Abstract The purpose of this study was to obtain comparative data concerning the percentage contribution of segmental cervical vertebral motion to the cervical range of motion (ROM) in healthy volunteers under two conditions: (1) normal, voluntary neck flexion and extension and (2) feigned restriction of neck flexion and extension. Each healthy subject's angular motion over forward cervical flexion and extension was measured first by X-ray analysis during normal, voluntary motion. Then the subjects were asked to pretend that they had a 50% restricted neck range due to pain or stiffness and thus to move in both flexion and extension only as far as about 50% of their normal range. A total of 26 healthy subjects (ten males and sixteen females, age 28.7±7.7 years) participated. The total angular motion from C2 to C7 was normal in the unrestricted condition and was significantly reduced in the feigned restriction condition ($p<0.001$). The percentage contribution of each of the functional units C2–C3 to C6–C7 to this rotation was different between the normal unrestricted and the feigned restricted conditions. In the feigned restricted neck flexion and extension, a shift occurred in the pattern of how each segment contributes to the total angular range. A greater percentage contribution was made by C2–C3 and C3–C4 than under normal conditions ($P<0.01$), and the percentage contribution to total rotation made by C6–C7 became much less under the feigned restricted movements than under normal, unrestricted neck range ($p<0.001$). Thus, simulated or feigned restricted neck ROM affects the percentage contribution of the functional units C2–C3 to C6–C7 by showing a higher percentage contribution of the upper cervical segments and less contribution to the angular rotation by the lowest cervical segment. Feigners of restricted neck range thus produce a pattern different from nonfeigning subjects.

Keywords Whiplash injuries · Neck pain · Range of motion · Cervical vertebra · X-ray

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Introduction

Previously in this journal, Puglisi et al. [1] published the results of an X-ray analysis study showing that chronic

whiplash patients with restricted range of neck motion have similar proportions of contribution of the segmental vertebral motions compared to healthy subjects. That is, the full range of angular rotation accomplished by neck flexion and extension is achieved partly by angulation in the segments C2–C3 through C6–C7. Although Puglisi et al. [1] found chronic whiplash patients to have a reduced total angular rotation through flexion and extension compared to healthy subjects, the percentage contribution to the total range was the same for the measured vertebral segments in both groups. It is not known, however, whether deliberate feigning of restricted neck range affects the percentage contribution of vertebral segments. Thus, the purpose of the study was to examine the percentage contribution of each vertebral segment to neck flexion and extension in a group of health volunteers asked to feign restricted neck range of motion.

Materials and methods

Subjects

Healthy volunteers were recruited by appeal to colleagues at a local university hospital for subjects interested in participating in a neck X-ray study. We excluded subjects under age 18 or over 50, with known or radiographic evidence of spondyloarthropathy, congenital disorder, or who were found to have significant X-ray findings such as spondylolisthesis or indications of rheumatoid arthritis. Subjects with a known history of neck injury or recall of neck or dorsal spine pain in the last 12 months were also excluded, as well as female subjects who were pregnant or unsure about pregnancy. Signs of disc degenerative changes were not exclusion criteria, particularly as these signs are common in most people after the age of 35. This study was conducted according to the ethics approval from the Scientific Committee of Attikon University Hospital, National and Kapodistrian University of Athens, and each participant provided written, informed consent after the procedures of the study were explained.

Flexion and extension X-ray measurements

Subjects in this study acted as their own controls of normal vs feigned restricted neck range of motion. The parameters describing rotational motion are derived from X-rays obtained in a fashion that matches typical clinical practice and the radiographic technique is exactly as described in a previous publication [1]. A first set of normal, unrestricted range in flexion and extensions was obtained. This set of X-rays was immediately reviewed by a radiologist for any of the aforementioned exclusion criteria as seen on X-ray. Subjects not excluded were then given the following instructions to obtain X-rays under the condition of feigned restricted neck range. “We would now like to repeat the forward and backward neck movements, but on this occasion we want you to pretend that your neck is painful and that you cannot move it as far forward and backward as you normally could. Move your neck about half as far as you think you normally could and then stop there for the X-ray. We will do this with you bending your neck forward, and then with you bending your neck backward, each time trying to pretend you cannot go more than about half of what you normally would.” With these instructions, X-rays were then obtained as stated previously.

The analysis of the X-rays was conducted by a single author (FP), with good inter-rater reliability and as per the previously published and established procedure of tracing the superimposition of the flexion and extension X-rays [1]. We chose the functional units C2–C3, C3–C4, C4–C5, C5–C6, and C6–C7 because the images of C1 and T1 are often not readily visible on standard films. Once the absolute rotation angle is known for each vertebral pair, the total angular rotation from C2 to C7 for all pairs combined is calculated from the sum of these [1].

Statistical analysis

We used an unpaired t test (α=0.05) to compare the total range of motion and segmental motion measurements for both conditions (normal range vs feigned restricted range). From our previous study, we found the mean total flexion–extension range, and the mean percentage contribution of each functional unit was not different between genders or the age groups 20–30, 30–40, and 40–50 years, so we grouped both genders and all ages together in this study as well [1]. We also corrected p values for the presence of multiple comparisons.

Sample size

Assuming that a clinically significant difference will be a 20% difference between full voluntary effort and feigned neck restriction in segmental motion degrees with a beta error of 20% and alpha set at 0.05, we calculated that we would need about 26 subjects to participate under the two conditions to be compared.

Results

A total of 26 healthy subjects (10 males and 16 females, age 28.7±7.7 years) were studied. The ranges of motion in flexion and extensions, as well as the percentage contribution of each segment are shown in Table 1. In this table, we

Table 1 Angular motion of vertebral functional units C2–C3 to C6–C7 in subjects (N=26) under two conditions: (1) normal, unrestricted flexion and extension, and (2) feigned, restricted flexion and extension

Condition	C2–C3	C3–C4	C4–C5	C5–C6	C6–C7
Normal, unrestricted motion	9.6±3.2 (12.8±5.1%)	15.6±4.8 (20.6±5.5%)	18.6±4.7 (24.4±3.9%)	18.3±4.9 (23.8±4.2%)	14.2±5.6 (18.4±6.0%)
Feigned, restricted motion	7.7±2.1 (18.6±8.9%)	12.4±4.0 (27.9±7.9%)	12.6±5.4 (26.0±6.5%)	9.8±6.0 (19.0±9.1%)	4.2±3.7 (8.4±5.4%)
P values for difference in mean percentages	0.0062	0.0004	n.s.	n.s.	<0.0001
Confidence intervals (95%) for the differences above	−9.74<CI<−1.86	−11.0<CI<−3.6	−4.51<CI<1.31	0.95<CI<8.65	6.90<CI<13.10
Healthy subjects (previous study subjects [1])	9.7±2.8 (13.9±3.9%)	14.4±3.7 (20.6±4.7%)	16.9±3.8 (24.0±4.3%)	16.8±4.4 (23.9±5.0%)	12.7±5.2 (17.6±6.0%)
Whiplash patients (previous study subjects [1])	10.0±3.0 (12.9±3.3%)	15.7±3.5 (20.1±3.5 %)	17.9±4.0 (22.8±3.3%)	18.9±4.6 (24.1±4.4%)	16.2±4.9 (20.2±4.5%)

Also shown are the results from healthy subjects (N=126) and chronic whiplash patient (N=129) from a previous study with identical measures [1]
Measures of absolute angular motion for each functional unit C2–C3 to C6–C7 are shown in degrees, mean±SD. The mean percentage contribution of each functional unit to the mean total flexion–extension angular motion of C2–C7 is shown in percentage (%) below each absolute mean angular rotation per functional unit
n.s. Not significant

also included the same data from our previous study of a different healthy control group of similar age and gender distribution and from a cohort of chronic whiplash patients.

The total angular rotation from flexion to extension as measured from X-ray analysis (76.3±13.9°) is the same in normal condition as per our previous study of healthy subjects (79.4±13.8°) [1]. As expected, under the condition of feigned restriction of neck range, the total angular rotation over C2 to C7 was reduced to 46.7±15.9° (p<0.001).

The feigned restricted condition resulted in an overall absolute reduced range in motion from flexion to extension when compared to the normal condition, but more importantly, the percentage contribution of each functional unit from C2–C3 to C6–C7 changed in pattern. It appears that when asked to feign restricted neck range, the subjects' efforts resulted in a greater percentage contribution to angular rotation in the upper cervical segments (C2–C3 and C3–C4), a pattern distinct from normal neck range motion and what we previously reported to be the case for chronic whiplash patient [1].

Discussion

In this study of X-ray analysis of normal vs feigned, restricted neck flexion and extension in healthy subjects, we have shown that the pattern of how each vertebral segment from C2–C3 to C6–C7 contributes to the total angular rotation from flexion to extension changes when subjects are asked to feign restricted neck range (Fig. 1). When subjects feign restricted neck range, a change occurs from the normal pattern in that the upper cervical segments

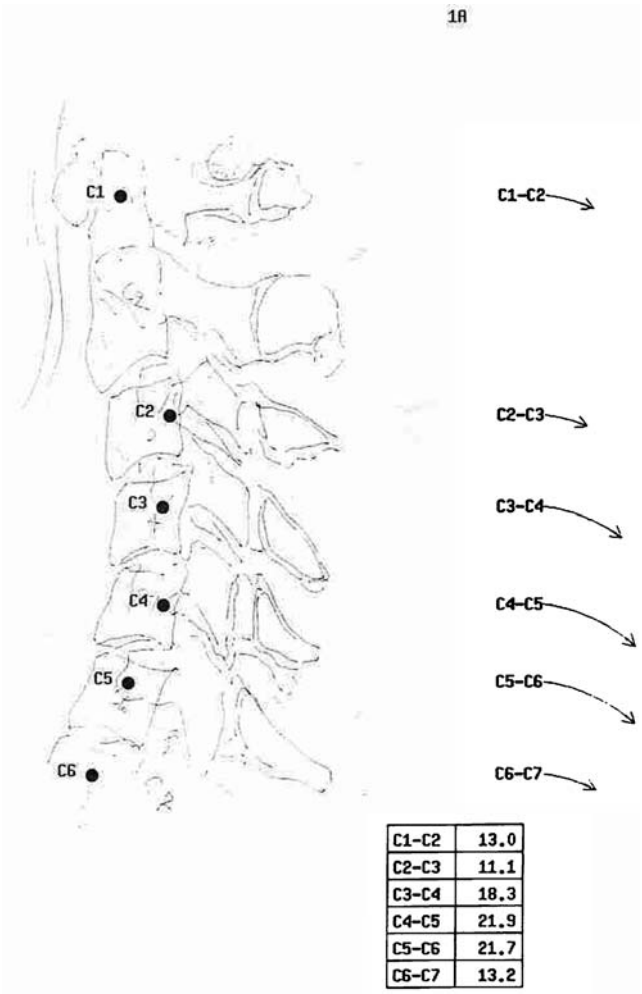

Fig. 1 An illustration of the individual vertebral pair contribution to neck range from flexion to extension for one subject. The figures listed for each pair C2–C3 to C6–C7 indicate the absolute contribution (in degrees) the vertebral segment pair makes to the total measured angular rotation from flexion to extension

contribute more to the total angular rotation from flexion to extension and the C6–C7 segment contributes much less than it does in the normal state of flexion and extension.

There are a number of limitations to this study. First, we did not control or train the subjects in their attempts at feigning restricted neck range; thus, the subjects may have produced very unusual patterns of neck flexion and extension because of this. Another limitation is that the healthy subjects, by virtue of not having neck pain, may still produce a feigned pattern that is quite different from the one that they might produce if they had neck pain and tried to additionally exaggerate the degree of neck restriction. A study with neck pain patients asking them to give their best effort and then to intentionally exaggerate their neck restriction might resolve this issue.

The Quebec Task Force grading system for whiplash-associated disorders utilizes the criterion of restricted neck range of motion (ROM) in the diagnosis of grades 1 and 2 [2]. It is a common clinical practice, therefore, for clinicians and therapists to assess neck ROM in whiplash patients and for neck ROM to be measured as a sign of progress, even though the best methodology is controversial [3]. In addition, neck pain may occur after placebo collisions without any biomechanical trauma [4]. If neck ROM is to remain relevant, there is not only a greater need to assess its value in prognosticating and evaluating recovery, but especially in medicolegal cases to be concerned about exaggeration or simulation of restricted ROM. To address this problem, measuring segmental vertebral motion may be more helpful than total ROM, as flexion and extension in the sagittal plane is commonly examined as part of the X-ray assessment of whiplash patients in the clinical setting.

More studies are needed. The next step is to have a group of neck pain (or whiplash) subjects attempt to exaggerate currently existing restricted neck ROM and undergo similar analyses. If feigning subjects are again substantially different from, for example, healthy controls in their percentage contribution pattern of each functional unit C2–C3 to C6–C7, then this will help confirm that identifying the pattern of segmental vertebral motion is a useful validation for reported restriction of neck ROM.

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