Research Report

The Influence of Body Size on Linear Measurements Used to Reflect Cervical Range of Motion

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Background and Purpose. *The purposes of the study were to demonstrate that linear measurements of cervical range of motion are confounded by differences in body size when comparisons are made between groups and to introduce an alternative measure of range of motion that adjusts for variation in body size.* ***Subjects.*** *The sample consisted of 42 subjects (25 female, 17 male) with chronic posttraumatic headaches.* ***Methods.*** *Using a tape measure, a physical therapist measured the distance between two anatomical landmarks with the subject's neck in the anatomical neutral position and with the subject's neck fully laterally flexed, rotated, and forward flexed. Range of motion was effected with two measurements: the distance between the landmarks at full flexion/rotation and the proportion of distance traversed between the landmarks.* ***Results.*** *The end-of-range values were significantly correlated with body size. No significant correlations emerged between the proportion-of-distance values and body size.* ***Conclusion and Discussion.*** *Linear measurements of cervical motion are potentially confounded by body size when subjects of nonequivalent size are compared. Proportion-of-distance measurement is presented as a more valid alternative to end-of-range measurement. [Chibnall JT, Duckro PN, Baumer K. The influence of body size on linear measurements used to reflect cervical range of motion. Phys Ther. 1994;74:1134–1137.]*

Key Words: *Cervical vertebrae, Range of motion, Validity.*

Linear measurements are often used to quantify cervical range of motion (ROM). For example, linear measurements are obtained when a tape measure or ruler is used to measure the distance (eg, in centimeters) between two reference points on the body (eg, from the acromial process to the lowest point of the earlobe) after a patient has performed a neck movement (eg, lateral flexion). With this end-of-range (EOR) measurement, smaller values indicate greater ROM.

Although linear measurements of this type are often used for both cervical and trunk ROM,[1–5] we suspected that linear measurements such as EOR might be confounded by variability in body size when comparisons are made between subjects or patients. Consider a hypothetical example. Two patients measured for head rotation receive the same EOR value of 17.5 cm. That is, the distance between the acromial process and the midpoint of the chin is 17.5 cm at full rotation. Suppose, however, that patient A has a resting distance (ie, neck in the anatomical neutral position) between acromial process and chin of 23.0 cm,

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whereas the at-rest distance for patient B is 28.0 cm. If the difference in body size is taken into account in the ROM measure (eg, by dividing the difference between the at-rest and EOR distances by the at-rest distance), it can be argued that patient B actually had greater ROM than patient A. Patient B's chin traversed 37.5% of the total at-rest distance between chin and acromial process. Patient A, however, traversed only 23.9% of the distance between the two landmarks.

Thus, by not taking body size into account, linear measurements such as EOR may underestimate ROM for individuals with relatively larger at-rest distances between anatomical landmarks and overestimate ROM for individuals with relatively smaller distances between landmarks. This phenomenon has implications for the validity of decision making in clinical and research contexts when groups of patients are compared for ROM. When body size varies systematically between groups, differences in aggregate EOR values will reflect not only true differences in ROM, but differences in body size as well. This is not, however, a problem in the case of within-subject measurement (ie, measurements made on the same person at different points in time).

Although the validity of linear measurements such as EOR is potentially suspect under certain conditions, the reliability of such measurements appears acceptable. For example, Hsieh and Yeung,[1] using a tape measure to assess cervical ROM, reported test-retest reliability coefficients (Pearson Product-Moment Correlation Coefficients) for EOR measurements ranging from .78 to .95 across six movements. Moreover, variance ratio tests indicated that, for five of the six movements, the reliability of measurement did not vary as a function of the clinical experience of the tester. Balogun et al,[2] using the procedure of Hsieh and Yeung,[1] reported test-retest reliability coefficients (Pearson correlation coefficients) ranging from .26 to .88 for three physical therapists and six movements (average correlation of .68) and interrater reliability coefficients (Pearson correlation coefficients) ranging from .30 to .92 (average correlation of .75). Measurements of flexion appeared to be somewhat less reliable than those of lateral flexion, rotation, and extension.

In our study, we hypothesized that linear EOR measurements taken with a tape measure would be highly correlated with body size, thus introducing a potential source of error. In addition, we used at-rest and EOR tape measurements to calculate an alternative indicator of ROM: proportion of distance (POD). We hypothesized that POD measurements would eliminate or greatly decrease the influence of body size on ROM values by adjusting for relative differences in body size. The POD values were calculated by dividing the difference between the at-rest and EOR values by the at-rest value. To test the hypotheses, EOR and POD measurements of cervical ROM for five head movements were correlated with indicators of body size. The indicators of body size were the distances between a subject's earlobe and acromial process, chin and acromial process, and chin and sternal notch. We anticipated that EOR measurements would be highly correlated with body size and that POD measurements would be uncorrelated with body size.

Method

Subjects

Subjects were 42 adult women (n=25) and men (n=17) who volunteered for a headache study at a large midwestern medical center. The average age of the sample was 39.6 years (SD=10.5, range=24–69). Average years of education was 12.7 (SD=1.9, range=6–16). All subjects were experiencing chronic headaches ($\bar{X}$=58.2 months, SD=70.9, range=3–276) that were linked temporally with trauma to the head and/or neck as a result of motor vehicle accidents (45.2%), personal violence (16.7%), or other trauma (eg, falls) (38.1%). For 33.3% of the sample, the trauma was job-related. Most subjects (66.7%) received a blow to the head as part of the trauma, although only 26.2% were rendered unconscious as a result of the trauma. Headache classification included tension-type (35.7%), cervicogenic (21.4%), chronic daily (21.4%), migraine (14.3%), and cluster (7.1%). Most subjects were experiencing some type of headache on a daily basis (66.7%) and severe headache (ie, headache that makes it impossible or very difficult to carry out usual daily activities) on a weekly basis (61.0%). All subjects were required to read and sign an informed consent statement prior to participation.

Procedure

The data for this study were collected as part of a larger study examining the role of cervical muscle irritation in the development of chronic headache following head and/or neck trauma. All subjects were evaluated for cervical ROM by a single physical therapist on the staff of the Physical Therapy Department, Saint Louis University Health Sciences Center (St Louis, Mo). Each subject was seated in a chair and directed through a series of neck movements. Following the procedures described by Hsieh and Yeung,[1] lateral flexion was measured from the acromial process to the lowest tip of the earlobe, rotation was measured from the acromial process to the midline of the chin, and forward flexion was measured from the sternal notch to the midline of the chin. Measurements were taken with the head and neck in the neutral position and at the EOR (ie, at full flexion or rotation) and were recorded to the nearest half-centimeter. All movements were made in the same order by all subjects.

Results

These and all subsequent statistical analyses were completed using the SPSS-X.[6] Table 1 displays the means and standard deviations for the EOR, POD, and at-rest measurements for lateral flexion, rotation, and forward flexion. The EOR values reflect the distance (in centimeters) between the two anatomical landmarks at the end

Table 1. *Range-of-Motion (as Determined by End-of-Range [EOR] and Proportion-of-Distance [POD] Measures) and At-Rest (Body Size) Means and Standard Deviations*

Movement	EOR (cm)		POD		At Rest (cm)	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Lateral flexion						
R	13.39	2.48	0.29	0.09	18.80	2.08
L	13.58	2.04	0.29	0.07	19.05	1.95
Rotation						
R	16.04	3.18	0.37	0.11	25.40	2.28
L	15.74	3.22	0.39	0.10	25.64	2.35
Forward flexion	6.01	2.50	0.54	0.17	12.90	1.61

of the movement. The POD values reflect the proportion of distance traversed between the two landmarks during the movement. The at-rest values reflect the distance (in centimeters) between the two landmarks with the subject's head and neck in the neutral position. Body size was reflected by the at-rest distances.

Although the EOR and POD values correlated highly with each other ($r=-.72$ for left lateral flexion to $-.95$ for flexion, $P<.001$), they did not correlate similarly with the neutral values. The EOR measurements were significantly correlated with the at-rest measurements (ie, with body size), whereas the POD values were not (Tab. 2).

Considerable variation in POD scores existed within groups of subjects having identical EOR scores. For example, six subjects received a right lateral flexion score of 13.0, indicating that the distance from the acromial process to the lowest point of the earlobe was 13 cm at full flexion. When body size was taken into account, however, there was large variation in the ROM values (POD= 0.19–0.35), such that subjects with relatively less distance between the acromial process and earlobe had lower ROMs than those with relatively larger distances (Figure). Similar variability in POD values was noted across identical EOR values for the other movements.

Table 2. *Pearson Product-Moment Correlation Coefficients for End-of-Range (EOR) and Proportion-of-Distance (POD) Measures With Indicators of Body Size (At-Rest Measures) for Five Movements*

Measure	Earlobe to Acromion (at Rest) With Lateral Flexion		Chin to Acromion (at Rest) With Rotation		Chin to Sternal Notch (at Rest) With Flexion
	R	L	R	L	
EOR	.72[a]	.74[a]	.47[b]	.59[a]	.57[a]
POD	−.20	−.08	−.05	−.21	−.29

[a] $P<.001$.

[b] $P<.01$.

Discussion

The results suggest that linear measurements of cervical ROM are correlated with body size (as reflected by the distance between specific anatomical landmarks). In the case of EOR measurements, any variation in body size results in an underestimation of ROM for subjects with larger distances between landmarks and an overestimation of ROM for those with shorter distances between landmarks. The POD measure appears to be a better choice for reflecting ROM because it attempts to factor out the influence of body size.

If ROM is quantified using a linear measurement such as EOR and group composition is correlated with body size, significant ROM differences between groups may reflect variation in body size as well as any true differences in ROM. In any situation in which the composition of groups is nonrandom and the groups are compared on ROM (eg, nonequivalent treatment and control groups), the possibility exists that the groups are nonequivalent with regard to body size. Failure to account for this fact may lead to spurious interpretations of apparently significant differences in ROM between the groups. It should be remembered that this caution does not apply in the case of within-subject data, but only when comparisons are made between individual subjects or groups of subjects.

Although POD measurement emerged as a more valid indicator of ROM relative to EOR, it is not perfect. As the correlations with body size indicated, the POD values had some relationship with body size, albeit small and inconsistent. For three of the five movements, the POD measurements shared between 4% and 8% of their variance with the body-size indicators. These values, though, are clearly much lower relative to the EOR values.

Evidence for intrarater reliability of tape measurements was not collected in our study; rather, we relied on the conclusions offered by Hsieh and Yeung[1] and Balogun et al[2] based on

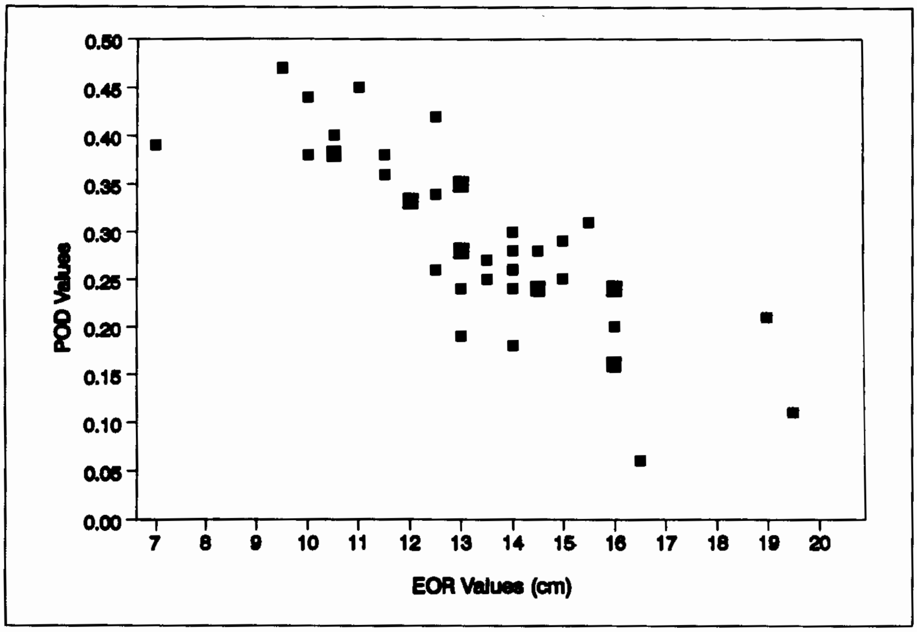

Figure. *Scatter plot of proportion-of-distance (POD) values by end-of-range (EOR) values. Smaller points represent single cases; larger points represent two cases.*

their reliability studies. These researchers demonstrated reasonable reliability for tape measurements performed by a therapist. There was, however, considerable fluctuation in the reliability coefficients between the studies and across movements. Further, the samples for these studies consisted of asymptomatic individuals. The extent to which reliability of measurement can be assumed in our study, therefore, is limited.

Conclusions

The results suggest that POD measurements for quantifying cervical ROM may be more valid indicators of ROM than the commonly used linear EOR measurements. To avoid error associated with body size, POD may be preferred.

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