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GNATHOLOGY

Influence of the mandibular position on the active cervical range of motion of healthy subjects analyzed using an accelerometer

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ABSTRACT

Objective: The aim of this study is to analyze the influence of the mandibular positions (habitual rest position, habitual maximum intercuspation, habitual maximum intercuspation with clenching, and mandibular position with cotton rolls) on the active cervical range of motion (ROM) (flexion-extension, lateroflexions, rotations) using an accelerometer in a sample of healthy subjects.

Methods: A total of 21 (14 M, 7 F) healthy volunteers aged from 18 to 27 years (mean age 23.88 ± 2.34 years; mean weight 67.86 ± 11.38 kg; mean height 172.52 ± 9.00 cm) underwent a cervical range of movement examination using a 9-axis accelerometer. A one-way ANOVA analysis was performed in order to statistically evaluate the effective influence of the mandibular position on the recorded parameters.

Results: The analysis showed no statistically significant differences (all p-values > 0.1) with variations smaller than three degrees among the different mandibular positions.

Discussion: The mandibular position seems to have no influence on the active cervical ROM in healthy subjects. Further studies are needed to assess the usefulness of the accelerometer in the cervical analysis of temporomandibular disorder subjects.

KEYWORDS
Head; neck; range of motion; mandible; temporomandibular joint; rotation; ROM; accelerometer

Introduction

Clinical observation and recent studies in healthy and patient groups supported a close functional relationship between the mandibular and head-neck motor system.[1–5] In fact, there is a close anatomical, biomechanical, and neurophysiological relationship between masticatory and cervical regions,[6,7] and it is widely accepted that the upper cervical region has an influence on postural control mechanisms. These reported findings highlighted the functional coupling of the mandibular and cervical systems and suggested a possible role on postural stability.[8–11] Different studies clearly showed the associations between temporomandibular disorders (TMD) and the conditions of the head and neck region.[12,13]

Furthermore, different mandibular positions or the increased activity of the masseter muscles along with intentional forceful clenching have been understood to influence the neck muscle activity [14–17] and even to improve the stability of the neck.[18,19]

Measurement of cervical spine range of motion (ROM) is common within the assessment of spinal and cervical disorders,[20] and it is an objective measure, which is essential to monitor the patient's evolution throughout therapy.[21] There are many methods to non-invasively measure spinal ROM, including simple clinical methods and more complex laboratory systems such as goniometry, inclinometry, and cervical ROM devices. However, they are all only able to provide a single point in time, and the movement across time is lost. More recently, new technologies such as accelerometers and electromagnetic systems were developed to capture the movements of the body parts and measure spinal ROM in the cervical, thoracic, and lumbar spine, and they result in reliable methods in the analysis of spinal ROM.[21–23]

The aim of this study is to analyze the influence of the mandibular position on the active cervical ROM using an accelerometer in a sample of healthy subjects.

Materials and methods

Subjects

A total of 21 (14 M, 7 F) volunteers aged from 18 to 27 years (mean age 23.88 ± 2.34 years; mean weight 67.86 ± 11.38 kg; mean height 172.52 ± 9.00 cm) were

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Figure 1. The accelerometer positioned on the forehead of a subject immediately before the cervical ROM test.

enrolled in the study and analyzed at the University of Rome, Tor Vergata, Italy and Vita-Salute San Raffaele University of Milan, Italy. The volunteers signed a consent form after being fully informed about the nature of the study. The study was conducted in accordance with the Helsinki declaration and approved by the ethical committee of the institutions.

An oral, cervical, and anamnestic examination of the subjects was performed to include only volunteers meeting the following inclusion criteria: good general health according to a medical history; absence of neck disorders or neck pain; absence of muscle pain/stiffness; absence of movement limitations in the upper quadrant; absence of headache, migraine, otolaryngology diseases, sinusitis, hormonal disorders, or other systemic diseases; no active orthodontic or dental treatment; absence of cervical problems; presence of at least 28 teeth; absence of cast restorations and extensive occlusal restorations; absence of Angle Class III; absence of TMD according to RDC/TMD, and absence of any symptom of TMD at the clinical examination.

Equipment, procedure, and statistical analysis

A 9-axis accelerometer (Microlab, Vimercate, Italy) connected to a computer with Bluetooth technology was used in order to evaluate the cervical ROM. A 9-axis accelerometer is a fusion between three sensors, a 3-axis acceleration sensor, a 3-axis gyroscope, and a 3-axis geomagnetic sensor. The result is a device able to give a reliable absolute reference of heading, pitch, and roll.[21,23,24] The instrument was placed on the forehead of each subject using a head strap.

A physiotherapist and a dentist expert in the gnathological field defined the test procedure, and the subjects were informed how to correctly execute the exercises and were also asked to warm up with five repetitions of all cervical movements before the exam. The subjects sat upright on the chair with their head parallel to the horizontal Frankfurt plane with the back supported by the chair. The head and neck were free to move.

- Head flexion/extension: the subjects were asked to look up to the ceiling and bend their head back as far as possible and then to bend the head forward, aiming for their chin on their chest.
- Head rotation left/right: the subjects were asked to look right and left, turning their head as far as possible, aiming to put their chin in line with their shoulder.
- Head lateral bending left/right: the subjects were asked to look straight ahead and bend their head right and left, aiming to bring their ear towards their shoulder.

Other movements (in the thoracic spine, shoulders) were avoided by the subjects with the help of an operator behind him or her; another operator managed the software (Figure 1). After one test trial, one effective trial/measurement of each CROM movement was carried out using an accelerometer SysMotion (Microlab srl, Vimercate, Italy) in four different mandibular positions in a random order; mandibular positions were numbered from 1 to 4 and then randomly drawn before each test.

The neck exercises head flexion/extension, head rotation left/right, head lateral bending left/right were done in the following mandibular positions: habitual rest position (no tooth contact), habitual maximum intercuspation (light touch), habitual maximum intercuspation with clenching, and mandibular position with cotton rolls 8 mm thick and 37 mm long positioned between the dental arches distal to the canines. The subjects had a rest pause of 3 min after three exercises done in each mandibular position; the operators were not blind to the mandibular position of the subjects.

Every movement of the neck was carried out with an average tempo (about one movement per second). This velocity can be standardized or trained by the examiners who asked the subject to repeat the test if they did not approve its execution. The subjects were asked to complete five complete movements for each exercise.

The following parameters were analyzed:

- RANGE R (Range of head rotation)
- ASY R (Difference between right and left rotation angles)
- RANGE L (Range of head lateral bending)
- ASY L (Difference between right and left lateral bending angles)
- RANGE F (Range of head flexion/extension)

The flexion/extension asymmetry parameter was not evaluated because of the physiological asymmetry of the flexion/extension movement.

The normality of the distribution of the data was ensured by a Shapiro-Wilk Test, and a one-way ANOVA analysis was performed in order to statistically evaluate the effective influence of the mandibular position. A significance level of 0.05 was adopted.

Results

Table 1 displays the mean CROM in each mandibular position. Analyzing the results obtained, it can be observed that the mandibular position does not seem to affect the active cervical ROM because of the low variations of a maximum of 6° in range among the different mandibular positions confirmed by the absence of statistically significant results of the ANOVA (all p-values > 0.6).

No influence was found on the symmetry of the active cervical ROM between the left and right sides ($p > 0.1$) with variations smaller than 3° among the different mandibular positions. The complete results of the ANOVA analysis are displayed in Table 1.

Discussion

Assessment of ROM is an important step when evaluating the patient cervical function, and ROM is an objective

Table 1. Descriptive statistics and significances (ANOVA) of recorded data.

Parameter	Condition	Mean	SD	ST ERR	Lower CI 95%	Upper CI 95%	*p*-Value
ASY R	CLENCH	9.82	7.14	1.56	6.58	13.07	0.674
	COTTONS	6.79	7.48	1.63	3.38	10.19	
	MAX INT	8.81	9.16	2.00	4.64	12.99	
	REST	8.82	8.67	1.89	4.87	12.77	
RANGE R	CLENCH	143.75	16.01	3.49	136.46	151.04	0.753
	COTTONS	141.10	16.04	3.50	133.79	148.40	
	MAX INT	146.04	17.75	3.87	137.96	154.12	
	REST	146.04	18.23	3.98	132.91	149.51	
ASY L	CLENCH	3.00	2.42	0.53	1.90	4.10	0.137
	COTTONS	4.13	2.95	0.64	2.79	5.47	
	MAX INT	4.33	3.52	0.77	2.73	5.93	
	REST	5.30	3.57	0.78	3.68	6.93	
RANGE L	CLENCH	84.15	14.81	3.23	77.41	90.89	0.971
	COTTONS	84.56	12.56	2.74	78.85	90.28	
	MAX INT	82.67	12.61	2.75	76.63	88.41	
	REST	83.73	12.70	2.77	77.95	89.51	
RANGE F	CLENCH	113.50	16.31	3.56	106.08	120.93	0.743
	COTTONS	119.54	18.03	3.93	111.34	127.75	
	MAX INT	117.10	18.02	3.93	108.90	125.31	
	REST	115.62	19.76	4.31	106.62	124.61	

Notes: RANGE R: Range of head rotation, ASY R: Difference between right and left rotation angles, RANGE L: Range of head lateral bending, ASY L: Difference between right and left lateral bending angles, RANGE F Range of head flexion/extension, CLENCH: habitual maximum intercuspation with clenching, REST: habitual Rest Position (no tooth contact), MAX INT: habitual Maximum Intercuspation (light touch), COTTONS: mandibular position with cotton rolls between the dental arches.

measure, which is essential for monitoring the patient's evolution throughout therapy.[21]

Numerous valid tools are currently available to measure cervical ROM as inclinometers and goniometers, but recently some studies used accelerometers for this purpose with excellent results,[21–23] and Ambusam et al. [24] demonstrated the excellent intra-rater reliability of an accelerometer in the analysis of the head excursion during typing tasks.

In this study, a 9-axis accelerometer was applied in the analysis of the active cervical ROM in different mandibular positions; this device is a fusion between three sensors able to give a reliable absolute reference of heading, pitch, and roll. The analysis of recorded data showed the absence of an influence of the mandibular position on the active cervical ROM of healthy subjects for all the considered movements (rotation, lateral bending, and flexion/extension).

Other studies [18,19] used an accelerometer to analyze the influence of the mandibular position on the cervical area, showing that clenching can influence head accelerations and movements, improving the stability of the neck during sports activities. To the authors' knowledge, this is the first reported study to examine the influence of different mandibular positions on the active cervical ROM in healthy subjects in a frontal and horizontal plane, using a 9-axis accelerometer. A recent study [25] used an accelerometer built in an iPhone™ to investigate the influence of three different mandible positions, including conscious occlusion, tongue tip against the anterior hard palate, and habitual rest position, on sagittal plane cervical spine ROM as well as the flexion-rotation test (FRT) in asymptomatic subjects. Grondin et al. [25] found, in agreement with the present study, the absence of an influence of the mandibular/tongue position on the sagittal cervical ROM. However, they also reported a significantly lesser value of ROM during FRT, which is a passive test for the mobility between the 1st and 2nd cervical vertebrae (C1-C2). The FRT is a different test, incomparable with active neck movement, which may lead to different results.

On the contrary, some studies have found a significant association between TMD and cervical spine impairment in addition to evidence of dysfunction of muscles and joints around the jaw.[26–28] People with TMD had significantly worse cervical extensor muscles function and neck pain on movement,[29–31] and Grondin et al. [26] found a significantly reduced passive upper cervical rotation ROM in subjects with TMD, compared with asymptomatic controls. Thus, it is important to assess if the mandibular position is able to influence the cervical ROM in healthy subjects too, as a physiological response.

There is a direct anatomical relationship between the muscles of the cervical spine and temporomandibular region and neurophysiologic connections between the cervical spine and temporomandibular area, creating a close biomechanical link between these areas. Eriksson et al. [1] reported that during normal mouth opening, extension occurs at the cervical-cranial junction, and restriction in the upper cervical spine may decrease a patient's mouth-opening capacity.

From the results of this study, it could be concluded that the mandibular position is not able to influence the active cervical ROM in healthy subjects, notwithstanding the possible different masseter activities that can be related to different mandibular positions.[15,32] Even clenching wasn't able to determine changes in the active cervical ROM and ROM symmetry. Thus, this relationship could be limited to the subjects with TMD.

In this study, there were maximum variations among mean active cervical ROMs in different mandibular positions of 6° that are limited, considering that ROM goniometry data are typically susceptible to ±5° error.

Limitations of this study are the small sample size that could determine the absence of significant correlations and the observation of the only active cervical ROM.

Also, considering the previous literature, the accelerometer could be an interesting instrument in the analysis of this biomechanical link, and more studies are needed to evaluate the relationship between these structures. Further studies are needed about the usefulness of the analysis of the cervical ROM and its asymmetries in subjects with TMD and in the management of their gnathological treatment.

Conclusions

From the results of this study, together with previous literature, mandibular position seems to be unable to influence the active cervical ROM in healthy subjects. The accelerometer could be a useful instrument to analyze the influence of the dental occlusion on the cervical area movements and to improve the exchange of information between the gnathologists and physiotherapists in the treatment of TMD subjects with cervical involvement.

Contributors

Study conception and design: Baldini A, Nota A; acquisition of data: Nota A, Tecco S, Ballanti F; analysis and interpretation of data: Nota A, Tecco S; critical revision: Ballanti F, Cozza P; coordination of the study: Cozza P, Baldini A.

Disclosure statement

No potential conflict of interest was reported by the authors.

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