

INFLUENCE OF OCCLUSAL VERTICAL DIMENSION ON CERVICAL SPINE MOBILITY IN SPORTS SUBJECTS

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ABSTRACT

Introduction: In the scientific literature, a number of studies have reported conflicting results regarding the effects of occlusal vertical dimension (OVD) on sports-related skills. The purpose of this study was to increase OVD in sports subjects so as to specifically investigate the influence on cervical spine mobility. In particular, we measured cervical range of motion (ROM) before and after increasing OVD in individuals, either with or without malocclusion, analyzing both sports and sedentary subjects.

Materials and methods: Participants were divided into two groups: a sports group (SG) and a control group (CG), each including 18 subjects. The SG was composed of sports subjects (age: 20.11 ± 3.45 yrs; BMI: 25.39 ± 2.32 kg/m²), whereas the CG consisted of age-matched sedentary subjects (age: 25.78 ± 2.26 yrs; BMI: 24.88 ± 2.87 kg/m²). Cervical range of motion (ROM) was evaluated, by way of an accelerometer (Moover®, Sensor Medica®), before (pre-test) and after (post-test) increasing OVD.

Results: The main finding of this study was that sports subjects showed no significant difference, compared to control subjects, in cervical ROM in response to increased OVD. Moreover, we found that sports and sedentary subjects alike showed no significant change in cervical spine mobility as a result of increased OVD, regardless of whether they were affected by malocclusion (class II) or represented subjects with normocclusion (class I).

Conclusion: In accord with several studies reported in the literature, the findings of our study indicate that occlusal splints failed to significantly improve the physical-performance endpoint measured, i.e. cervical ROM, in sports subjects as compared to sedentary individuals. Due to the paucity of studies, characterized by conflicting results, there is as yet no compelling scientific evidence as to whether OVD positively impacts sports performance or not. Accordingly, we suggest that further scientific investigation, regarding the relationship between sports performance and OVD, be conducted in the field of sport and exercise sciences.

Keywords: sport, the stomatognathic system, cervical spine mobility, exercise.

DOI: 10.19193/0393-6384_2016_5_135

Received April 30, 2016; Accepted July 02, 2016

Introduction

The well-known neurological and biomechanical intercommunication existing between the mandibular and cervical systems implies a close interaction between them⁽¹⁾. In particular, the contact between teeth due to their relative positions, i.e. dental occlusion, determines the position of the mandible^(2,3).

Considering the strict correlation between the stomatognathic and the musculoskeletal systems, disorders of the former and of the mandible have been reported to be able affect the spine^(4,5). Alterations of the tooth-mandible-tongue complex influence postural attitude⁽⁶⁾, while the temporomandibular joint (TMJ) affects other systems, as well^(7,8). Moreover, symptoms of cervical spine disorders and head, neck and shoulder pain have been

observed in subjects with TMJ dysfunction⁽⁸⁾. This is probably due to the biomechanical correlation between the cervical spine and the TMJ. It has been postulated, but not confirmed, that motor performance during physical activity may be influenced by the stomatognathic system and that the position of the TMJ affects muscle activity^(6,9). In addition, some authors have found significant associations between temporomandibular disorders (TMD), cervical spine injury and masticatory muscles^(13,14).

Indeed, subjects affected by TMD have been proven to have considerably worse cervical extensor-muscle function⁽¹⁵⁾, neck pain on movement^(16,17), and cervical muscle tenderness. In addition, such individuals have decreased pressure-pain thresholds in tissues of the neck region⁽¹⁸⁾. The neurophysiologic connections between the cervical spine and the temporomandibular area, including the convergence of trigeminal and upper cervical afferent inputs in the trigeminocervical nucleus^(19,20) could justify the link to cervical spine impairment. It could also affect posture in sports and sedentary subjects, as suggested by the evident relationships between cervical spine and TMD disability and the positive correlation of the reciprocal dose-response relation with, both severity and frequency of, spinal pain and TMD⁽²¹⁾. Several conflicting studies, reported in the literature, have investigated whether occlusal vertical dimension (OVD) affects sport-related skills⁽²²⁻²⁴⁾. The OVD corresponds to the height of the lower face when the dental arches are in maximum intercuspation⁽²⁵⁾. According to Dawson's definition, a passive and an active OVD may be distinguished. The latter is characterized by contracted elevator muscles in the mandible⁽²⁶⁾.

The purpose of our study is to investigate the influence of OVD on cervical spine mobility in sports subjects. In particular, we measured cervical range of motion (ROM) before and after increasing OVD in sports and sedentary subjects.

Materials and methods

Participants

Forty subjects, including 38 males and 2 females, were eligible for the study, but only the males were recruited in order to have an homogeneous sample. All subjects were administered a questionnaire about health status and personal data. After the preliminary interviews and screening, only 36 males were deemed suitable for our study based on the following inclusion criteria: 15-30 years of age (1

subject excluded); ≥ 3 consecutive years of sports background, for sports subjects (1 subject excluded), according to the standards of sports-specific studies; or ≥ 3 consecutive years of a sedentary lifestyle, for sedentary subjects⁽²⁷⁾.

Participants were assigned to one of two groups: a sports group (SG) and the control group (CG) which included 18 subjects each. The SG was composed of sports people (age: 20.11 ± 3.45 yrs; body weight: 79.78 ± 8.86 kg; height: 1.77 ± 0.05 m; BMI: 25.39 ± 2.32 kg/m²) and the CG consisted of age-matched sedentary subjects (age: 25.78 ± 2.26 yrs; body weight: 77.72 ± 9.40 kg; height: 1.77 ± 0.08 m; BMI: 24.88 ± 2.87 kg/m²). All subjects participated voluntarily in the study. However, given that some of the subjects were minors, in those cases a parent also provided written informed consent to participate in this study, which was approved by the Ethical Board of the University of Palermo and conformed to criteria for the use of persons in research as defined in the Declaration of Helsinki. Researchers clarified the aim of the study and the scientific procedures to be used prior to allowing participants to enter the experimental study.

Anthropometric measurements

Anthropometric measurements were performed according to the evaluation procedures reported in several studies by Battaglia et al.^(28,29). In particular, body weight was measured using a Seca electronic scale (maximum weight recordable: 300 kg; resolution: 100 g; Seca, Hamburg, Germany), with the subjects wearing only undergarments. Height was measured by a standard stadiometer (maximum height recordable: 220 cm; resolution: 1 mm), with subjects barefoot and standing upright. Body mass index (BMI) was calculated as body weight divided by height squared (kg/m²).

Cervical ROM measurement

Cervical ROM was evaluated via a non-invasive technique by way of a Moover® (Sensor Medica®; Guidonia Montecelio, Roma, Italia) accelerometer, a wireless electronic, computer-aided measuring device using freeStep® software (Sensor Medica®; Guidonia Montecelio, Roma, Italia). The Moover® accelerometer permits measurements of range of motion, acceleration values, total amount of motion on the X,Y and Z planes.

The cervical ROM evaluation protocol was standardized and participants were allowed to become familiar with the experimental procedures

used. Each individual was seated in a standardized chair (length: 38 cm; breadth: 40 cm; height: 45 cm) with their backs at 90-degree angles and sacrum and shoulder blades adhering to the backrest, feet flat on the floor, hands on thighs and head in a neutral position. The device to gauge cervical ROM was positioned medially, at the level of the frontal bone of the skull, above the bridge of the nose, then fastened to the head via a strap. Verbal commands were given to the subjects to perform neck movements until the maximal ROM. We first assessed mobility in the transverse plane, followed by the frontal plane, and finally the sagittal plane. Subjects performed three different and consecutive movements: maximal left and right rotation (LRR), maximal left and right lateral flexion (LRLF), maximal flexion-extension (FE) movements. All assessments were performed three times and the average values for each were used for purposes of statistical analysis. No warm-up was allowed for before measurements.

Evaluations of cervical ROM were consecutively performed two times in each individual: under pre-test and post-test conditions. During the pre-test phase, each subject performed movements with his mouth closed, whereas for the post-test phase a rigid wax 1-cm-thick occlusal rim was inserted between the dental arches so as to increase the OVD. The software recorded cervical angles of LRR, LRLF, FE movements in degrees. The same investigator took all the measurements.

Dental occlusion-class evaluations

The term occlusion refers to the relationship between the upper and lower teeth, that is, the anatomical position of contact between the two dental arches, which coincides with the maximum dental intercuspation, i.e. with the final phase of the masticatory function, in optimum conditions.

The permanent occlusal relationship, properly called occlusion, begins to take shape with the eruption of the upper first permanent molars which represent the guide for tooth occlusion. The key to occlusion is the relative position of the first molars⁽³⁰⁾. On the sagittal plane, dental occlusion classes are classified according to the criterion adopted by Edward H. Angle, which is based on the relationship of the first permanent molars. This classification includes three bite classes:

Class I: by definition, correct occlusion or normocclusion, whereby the mesiobuccal cusp of the maxillary first permanent molar occludes with the mesiobuccal groove of the mandibular first perma-

nent molar, while the cusp of the first maxillary canine is located between the mandibular canine and its adjacent first mandibular premolar.

Class II: incorrect occlusion or distocclusion (overbite), in which the maxillary first molar occludes mesially with the first mandibular molar, while the maxillary canine, instead of aligning with the lower one, is anterior to it. It is characterized by mandibular retrognathism, which, in turn, is divided into two subtypes: Class II Division 1, in which the incisors are directed forwards, usually with the anterior teeth protruding, associated with a lingual dysfunction; Class II Division 2, in which the incisors are retroclined.

Class III: defined as an incorrect occlusion, or mesiocclusion (underbite), whereby the lower first molar occludes mesially with the upper first molar, while the lower front teeth are more prominent than the upper ones. It is characterized by mandibular prognathism with a low position of the tongue.

Occlusion class was assessed with the subjects standing with a natural head posture, called orthoposition, i.e. the physiologic head position.

Statistical analysis

Statistical analysis was performed by one of the authors, who is a biostatistician and epidemiologist. Results were expressed as means \pm standard deviations and all data were coded onto Excel files. Statistical analysis was performed using GraphPad Prism® software (Microsoft® Windows®, version 5.0; La Jolla, CA). Repeated measures ANOVA was used, with significance level set at $p \leq 0.05$, to compare differences between pre- and post-intervention performances.

Results

The two groups were similar in their anthropometric characteristics, as measured by BMI (SG: 25.39 ± 2.32 kg/m² vs. CG: 24.88 ± 2.87 kg/m²; $p > 0.05$) and occlusion-class distribution. In particular, CG included; 10 subjects in occlusal class I; 7 subjects occlusal class II and only 1 subject in class III. Similarly, in the SG, 7 subjects were: occlusal class I, 11; occlusal class II; no participants were in occlusal class III. For this reason, the single, unmatched occlusal class III subject in the CG group was excluded from the data analysis.

Regarding cervical ROM analysis at pre-test, the sports and sedentary groups showed similar total ROM. Moreover, we found that the SG showed no

significant difference in cervical ROM in response to increased OVD when compared to the control group. As is shown in table 1, there were no increases in LRR, LRLF, FE for SG ($p>0.05$), compared to the control group, from pre- to post-test conditions.

In particular, Manfredi et al.⁽³²⁾ reported on the explosive force variation of basketball players in response to the use of occlusal bites. Although their data showed a significant difference between subjects with and without the occlusal bite, both in play-

	Left Rotation			Right Rotation			Total Rotation		
	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)
CG	68.14±9.03	68.80±9.70	0.96	67.05±9.39	66.26±8.97	-1.18	135.19±18.42	135.06±18.67	-0.1
SG	68.48±5.94	68.74±7.10	0.38	73.05±10.37	72.85±9.22	-0.27	141.53±16.31	141.59±16.32	0.04
	Left Lateral Flexion			Right Lateral Flexion			Total Lateral Flexion		
	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)
CG	40.21±7.11	41.96±6.60	4.34	41.38±8.26	39.89±7.67	-3.58	81.59±15.38	81.85±14.28	0.32
SG	42.35±7.82	43.51±7.13	2.73	40.21±6.99	41.66±6.37	3.61	82.56±14.81	85.17±13.50	3.16
	Flexion			Extension			Total Flexion-Extension		
	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)
CG	49.83±11.82	53.09±10.11	6.54	68.11±10.30	62.81±11.56	-7.78	117.94±22.13	115.90±21.67	-1.73
SG	47.78±12.54	51.59±8.62	7.98	66.38±12.20	64.15±11.87	-3.36	114.16±24.74	115.74±20.48	1.39

Legend: ROM, Range of Motion OVD, Occlusal Vertical Dimension CG, Control Group SG, Sports Group.

Table 1: Study of cervical ROM in response to increased OVD.

Likewise, data analysis according to occlusal class (I or II) of the SG subjects revealed no statistically significant ROM variations in response to increased OVD (Table 2). Of note, the CG in occlusal class II showed an interesting increase ($p>0.05$) in the average values of rotation (pre-test: 131.10 ± 21.02 vs. post-test: 137.86 ± 17.42 ; Δ : $+5.15\%$), with respect to SG subjects belonging to the same class (pre-test: 142.58 ± 18.05 vs. post-test: 143.68 ± 18.49 ; Δ : $+0.77\%$).

Discussion

The main finding of this study was that sports subjects showed no significant difference in cervical ROM in response to increased OVD, when compared to controls. Furthermore, our results indicate that neither sports nor sedentary subjects affected by malocclusion (class II) revealed any significant variation in cervical spine mobility, compared to those with normocclusion (class I), in response to increased OVD. These findings are concordant with several negative studies reported in the literature^(31,32) investigating the use of occlusal splints to significantly improve physical performance in athletes, compared to sedentary subjects. In fact, the results of a number of studies illustrate how persons do not always obtain benefits during physical performance by using a bite⁽³¹⁾.

ers and in control subjects, no statistically significant differences between the two groups were found. That being said, there are, however, several studies in literature that have reported increased sport-related skills in response to the use of occlusal splints⁽²²⁻²⁴⁾. During contact-sports competitions and training, many professional athletes wear occlusal splints in order to reduce the frequency of dental accidents. Custom-made mouthguards are, indeed, highly recommended by a variety of dental associations for prevention of oro-facial and dental injuries during sports-related activities^(33,34).

Medical and dentistry studies have ascertained that occlusal factors can influence body balance and, consequently, athletic performance. Researchers who evaluated the relationships between performance and occlusion in athletes have considered two aspects: the fact that wearing a splint improved body posture and that correct occlusion or wearing splints increased muscular force⁽²²⁾. Despite the data in literature reporting improvements in sports performance in response to a balanced cranial-occlusal system, the results are still controversial⁽¹²⁾. Several kinds of occlusal splints, of differing materials, structures and thicknesses, have been used in a host of studies in order to evaluate the relationship between sports performance and occlusion. Various studies have confirmed a positive correlation between the use of the bite and increased performance.

	Left Rotation			Right Rotation			Total Rotation		
CG	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)
I	68.99±7.88	68.91±11.70	-0.12	67.84±9.70	64.60±8.88	-4.78	136.83±17.59	133.51±20.59	-2.43
II	65.97±11.12	69.41±7.48	5.22	65.13±9.90	68.44±9.95	5.09	131.10±21.02	137.86±17.42	5.15
	Left Rotation			Right Rotation			Total Rotation		
SG	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)
I	67.39±4.61	67.16±4.37	-0.34	72.50±9.58	71.16±8.19	-1.85	139.89±14.19	138.31±12.56	-1.12
II	69.18±6.77	69.75±8.45	0.83	73.40±11.28	73.93±10	0.72	142.58±18.05	143.68±18.49	0.77
	Left Lateral Flexion			Right Lateral Flexion			Total Lateral Flexion		
CG	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)
I	38.24±6.97	42.01±5.62	9.86	39.20±9.62	38.44±8.18	-1.94	77.44±16.59	80.45±13.80	3.89
II	42.47±7.45	41.93±8.72	-1.28	43.64±5.90	41.10±7.42	-5.83	86.11±13.35	83.03±16.14	-3.58
	Left Lateral Flexion			Right Lateral Flexion			Total Lateral Flexion		
SG	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)
I	42.20±4.66	41.60±3.42	-1.42	38.94±6.65	40.57±4.02	4.18	81.14±11.31	82.17±7.44	1.27
II	42.45±9.54	44.72±8.68	5.35	41.02±7.39	42.35±7.61	3.26	83.46±16.93	87.07±16.29	4.32
	Flexion			Extension			Total Flexion-Extension		
CG	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)
I	45.48±10.28	55.59±9.76	22.23	67.43±10.70	60.28±13.79	-10.6	112.91±20.98	115.87±23.56	2.62
II	53.39±11.55	49.14±10.81	-7.95	67.69±10.59	64.11±6.14	-5.28	121.07±22.14	113.26±16.94	-6.45
	Flexion			Extension			Total Flexion-Extension		
SG	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)	Pre-test(°)	Post-test(°)	Δ(%)
I	46.04±14.86	46.83±6.54	1.71	63.11±9.28	62.27±13.65	-1.34	109.16±24.14	109.10±20.19	-0.05
II	48.88±11.46	54.62±8.64	11.74	68.45±13.76	65.35±11.12	-4.54	117.34±25.22	119.96±19.75	2.24

Legend: ROM, Range of Motion OVD, Occlusal Vertical Dimension CG, Control Group SG, Sports Group.

Table 2: Study of cervical ROM in response to increased OVD according to occlusal class.

Greenberg et al⁽²³⁾, for example, showed a correlation between mandibular position and upper body force. In particular, these authors published a clinical study based on the principle that increasing the OVD by occlusal devices seemed to be able to increase muscular force. Moreover, many researchers report that different dental occlusal devices may affect gait stability during static and/or dynamic postures^(3,6,24). To date, however, the literature shows how these data have not always confirmed, when the results are not correlated with the possible dysfunctional conditions of the subjects. In agreement with the results of a study by Lai⁽³¹⁾, which showed that the use of occlusal splints improved sports performance in dysfunctional subjects, we found it noteworthy that improvements in cervical spine ROM were demonstrated in our subjects affected by malocclusion (class II) compared to those with normocclusion.

However, these results were not statistically significant. The principal limit of our study was the small sample size that did not permit any statistically significant conclusions. For these reasons, these results might not be evenly spread to all sports people. In all probability, gnathological postural intervention in athletes could have greater impact on sports performance in those cases in which the athlete suffers from postural pathologies or TMD. There is a close interaction between the cervical and mandibular systems, due to the existing biomechanical and neurological interactions⁽¹⁾. It is well-known that spine posture and craniomandibular system influence each other^(4,5).

A recent systematic review showed that muscular-related TMD determines important changes in cervical posture⁽³⁵⁾.

Few researchers have investigated cervical spine mobility in athletes with TMD^(13,17).

One study demonstrated that TMD entails an increased fatigability of cervical muscles during neck extensor muscle endurance tests⁽³⁶⁾. Among the several treatments currently indicated for sufferers of TMD, an important role is played by occlusal devices that improve TMD symptoms in patients⁽³⁷⁾. In conclusion, due to the paucity of studies and their contrasting results, there is as yet no compelling scientific evidence as to whether OVD positively impacts sports performance or not. Mouthguards, bites and/or similar occlusal devices are increasingly recommended by dentists during professional and amateur sports-related activities. As suggested by several authors, we too deem it necessary that further scientific investigation, regarding the relationships among sports performance, OVD and TMD, be conducted in the field of sport and exercise sciences.

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Acknowledgments/Disclosures

The authors have no conflicts of interest to report regarding this work. We would like to thank all the participants involved in the study

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