Influence of Vision and Dental Occlusion on Body Posture in Pilots

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Introduction: Air force pilots have great postural control, movement coordination, motor learning, and motor transformation. They undergo abnormal stresses during flight that affect their organs and systems, with consequences such as barodontalgia, bruxism, TMJ dysfunctions, and cervical pain. The aim of this study was to evaluate the influence of dental occlusion and vision on their body posture. ***Methods:*** In collaboration with the "A.Mosso" Legal Medical Institute (Aeronautica Militare), two groups, consisting of 20 air force and 20 civilian pilots, were selected for the study using a protocol approved by the Italian Air Force. An oral examination and a force platform test were performed in order to evaluate the subjects' postural system efficiency. A MANOVA (Multivariate analysis of variance) analysis was performed by using the Wilkes' criterion, in order to statistically evaluate the influence of each factor. ***Results:*** Both the sway area and velocity parameters are very strongly influenced by vision: the sway area increases by approximately 32% and the sway velocity increases by approximately 50% when the pilot closes his eyes. Only the sway area parameter was significantly influenced by the mandibular position: the mandibular position with eyes open changed the sway area by about 51% and with eyes closed by about 40%. No statistically significant differences were found between air force and civilian pilots. ***Discussion:*** The results of this analysis show that occlusion and visual function could influence posture in air force and civilian pilots.

Keywords: posture, computerized occlusal analysis, stabilometric platform, occlusion, temporomandibular disorders (TMD), temporomandibular joint (TMJ), occlusal splint, bruxism, aviation dentistry.

AIR FORCE AND CIVILIAN pilots undergo stresses during flight that affect their organs and systems (17), allowing them to be considered as a special class of individuals. In fact, both air force and civilian pilots are often affected by several oral pathologies, which specifically characterize this category of the population.

Barodontalgia, the dental pathology that is diagnosed with the highest frequency, occurs in 11% of air force aircrews at a rate of 5 episodes/1000 flights (26). Another pathology, frequently reported during the WWII period, deals with fracturing of restorations during high-altitude flying and is called "Dental Barotrauma" (27).

Air force pilots are also likely to experience bruxism, an oral parafunction consisting of continuous clenching or grinding of the teeth (9). A study by Lurie et al. performed in 2007 showed that 69% of Israeli air force pilots who were analyzed were affected by bruxism, while the percentage for nonpilots is normally between 5 and 10%; the authors suggested the utility of a protective treatment for the teeth (15). Manfredini et al. (16) found that bruxism is correlated with muscle disorders such as TMJ pathologies. Some studies even correlated the back pain of helicopter pilots with the typical in-flight vibrations of the aircraft (14,25) and evaluated the influence of the in-flight forces and helmet weight on the neck muscles of F16 pilots (13).

These preliminary remarks indicate the need for assessing the usefulness for the pilot to have a gnathological checkup and follow up therapy consisting of application of an occlusal splint in order to protect his stomatognathic system (8). This is because some authors have observed (19) that temporomandibular disorders (TMD) are craniocervical mandibular system disorders which can affect human posture.

The results concerning the possible relationship between occlusion and body posture (12,23) are conflicting (7,18). Some researchers have demonstrated a significant connection, in terms of functional anatomy and physiopathology, between the dysfunctions of the stomatognathic apparatus and the craniocervical structures (5). Other authors do not consider this relationship scientifically trustworthy; they think it is difficult to conclude that there is a direct cause-effect correlation between malocclusions and postural diseases (21).

During a flight, the pilot's postural system undergoes intense forces, requiring a perfect organization and balance of all the structures involved, particularly of the craniocervical region (1). In fact, a study (20) evaluating the influence of the cervical region and stomatognathic system on postural control concluded that cervical rachis disease and stomatognathic dysfunction significantly influence balance control, and that computerized stabilometry allows the measurement of the degree of ascending and descending correlation between posture and the stomatognathic system. Thus an ill-chosen occlusal therapy with occlusal splint could damage the posture, predisposing one to painful symptoms that are often

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experienced by pilots due to vibrations transmitted by the aircraft (10,11).

A proper oral clinical examination using the T-Scan III device (TekScan, Boston, MA) allows for a computerized analysis of the dental occlusal loads and the construction of a precision-balanced occlusal splint. The T-Scan is a computerized system capable of analyzing the distribution of the masticatory forces when the sensor is inserted between the dental arches (2).

The aim of this paper is to verify the influence of dental occlusion on the pilot's posture. This will confirm the importance of following a careful and accurate protocol during the construction of the occlusal splint that protects the pilot's stomatognathic system, allowing a perfect balance of the craniocervical system to be achieved, and thus prevent the onset of painful dorsal and cervical symptoms (6).

The collaboration with the "A. Mosso" Legal Medical Institute of the Italian Air Force (Aeronautica Militare) in Milan allowed for the development of this protocol on a group of pilots, using Italian Air Force equipment.

METHODS

Subjects

A total of 40 patients of the "A.Mosso" Legal Medical Institute were enrolled in the study (ages 18-49 yr). Of this group 20 were air force pilots (men, mean age 35.15 ± 8.14 yr) and 20 were civilian pilots (men, mean age 34.23 ± 9.13 yr).

The Italian Air Force approved the protocol for ethics and all of the volunteers signed an informed consent form. An oral examination of the subjects was carried out in order to identify dental occlusion abnormalities such as molar or canine Angle class different from an Angle I relationship, malocclusions, malalignment, malposition of teeth, median line deviation, signs of bruxism, or TMJ dysfunctions. All the volunteers had to meet the following criteria: good general health according to a medical history, absence of trauma or surgery that could influence posture, absence of visual or vestibular problems, absence of any other disorder able to influence posture, absence of evident postural problems, presence of at least 28 teeth, absence of cast restorations and extensive occlusal restoration, and absence of temporomandibular disorders (TMD). Three civilian pilots with a TMJ dysfunction were excluded from the study.

The exams revealed that for air force pilots, 60% were affected by bruxism; 70% Angle I molar relationship, 10% Angle II molar relationship, 20% Angle III molar relationship. For civilian pilots, 55% were affected by bruxism; 65% Angle I molar relationship, 15% Angle II molar relationship, 20% Angle III molar relationship.

Equipment and Procedure

The volunteers, who were all physically fit and unaware of the aim of the study, underwent a posturographic and stabilometric analysis using a force platform ("Postural Health Station" from D.L. Medica S.p.A. Milano). This platform is characterized by load cells with an internal circuit that changes electrical resistance when a force is applied. The force plate is a trustworthy instrument in the analysis of body posture (22).

In accordance with the guidelines of the French Posturology Association, each recording lasted 51.2 s and was performed under the following conditions: mandibular rest position, mandibular centric occlusion position, mandibular position using cotton rolls. The test was repeated twice in each of these three positions, once with both eyes open (EO) and once with both eyes closed (EC) (3). For the "cotton rolls" mandibular position, cotton rolls 8 mm thick and 37 mm long were positioned between the dental arches distal to the canines. Quiet conditions were maintained during the exam, eliminating any disturbing element that could affect the posture. The force plate was positioned so that the subjects faced the wall perpendicularly at a distance of 150 cm. The subjects were required to remain as still and relaxed as possible, with their arms hanging free beside their trunk, and facing the wall without concentrating on a precise point on it. Moreover, all subjects were asked to avoid alcohol, sports, and conservative therapies during the 24 h prior to the clinical recordings. A standardized protocol was followed for the placement of the subject on the force plate: a hand was placed under the subject's foot, lifting and moving it until the following conditions, relative to markers painted on the surface of the platform, were satisfied: feet angle of 30° following the principal red line, calcaneal tendon positioned according to the length of the foot expressed in French points, and centered on the principal red line, malleolus positioned according to the angled red line, second toe projection on the principal red line, foot outline matching the areas drawn on the surface of the platform.

From the results obtained, two parameters have been evaluated: SWAY AREA and SWAY VELOCITY. The posturo-stabilometric platform is able to record the position of the center of foot pressure (COP) and analyze its movements. The sway area represents the area surrounded by the movements and oscillations of the COP. The sway velocity is the COP mean speed of movement and it is easily obtained by dividing the total length of the oscillations (sway length parameter) by the time duration of the test, hence it can be considered equal to the sway length.

Statistical Analysis

Distribution of the parameters recorded sway area and velocity of the COP oscillations were summarized as means and SD, with respect to test position, i.e., at mandibular rest position, mandibular position of centric occlusion, and mandibular position using cotton rolls, whether the eyes were open or closed, and the session of the examination.

Because of the supposed moderate correlation between dependent variables, MANOVA (Multivariate analysis of variance) analysis was performed using the Wilkes' criterion in order to statistically evaluate the effective influence of each factor. MANOVA groups

TABLE I. COMPARISON OF AIR FORCE AND CIVILIAN PILOTS, FOR PARAMETERS SWAY AREA AND SWAY VELOCITY, UNDER VARIOUS CONDITIONS (MEAN AND SD).

		AIR FORCE PILOTS			CIVILIAN PILOTS		
PARAMETER	CONDITIONS*	MEAN	SD	CI 95%	MEAN	SD	CI 95%
SWAY AREA (mm^2)	REST EO	127.40	76.91	90.7 – 164.1	120.18	58.09	88.4 – 152.0
	REST EC	145.95	72.63	96.1 – 195.7	156.35	92.44	107.4 - 205.2
	CENTRIC EO	150.60	107.16	93.3 – 207.9	111.53	63.58	78.8 – 144.2
	CENTRIC EC	208.45	135.74	140.2 - 276.6	183.82	117.94	118.3 - 249.3
	COTTON EO	161.75	97.16	110.6 - 212.8	188.81	150.81	101.5 - 276.1
	COTTON EC	210.60	177.66	119.7 - 301.5	210.31	143.24	128.7 - 291.9
SWAY VELOCITY ($mm \cdot s^{-1}$)	REST EO	6.15	1.87	5.2 – 7.1	6.35	0.90	5.5 – 7.2
	REST EC	9.50	3.74	7.6 – 11.4	9.06	1.66	7.9 – 10.2
	CENTRIC EO	5.95	1.32	5.2 – 6.6	5.65	1.36	4.9 – 6.4
	CENTRIC EC	9.50	3.70	7.6 – 11.4	8.65	2.14	7.4 – 9.9
	COTTON EO	5.90	1.30	5.2 – 6.5	6.25	1.39	5.1 – 7.4
	COTTON EC	8.90	3.04	7.4 – 10.4	8.56	1.53	7.7 – 9.4

* EO=eyes open; EC = eyes closed.

multiple dependent variables in a weighted linear combination or composite variable, comparing whether or not the independent variable group differs from the newly created group. Essentially, MANOVA takes scores from multiple dependent variables and creates a single dependent variable giving the ability to test for the above effects. Statistical reports however will provide individual *P*-values for each dependent variable, indicating whether differences and interactions are statistically significant. Obtained *P*-values must be interpreted following this indication: "*P*-value< 0.05 means very strong statistical significance of the results." The statistical MANOVA elaboration of data was done by using the software Minitab 15.

RESULTS

In a preliminary analysis of the results, the mean values (**Table I**) could give some information in order to evaluate the influence of each factor.

The mean values of the sway area (**Fig. 1**) recorded during tests performed with EC were between 145 and 210 mm^2 and about 40 mm^2 larger than the areas recorded during tests performed with EO (between 111 mm^2 and 188 mm^2); the sway area increases by approximately 32% when the pilot closes his eyes.

With EO, the sway area reached the lowest mean value of 111 mm^2 in mandibular rest position and the highest mean value of 188 mm^2 in mandibular position using cotton rolls; changing the mandibular position with EO changed the sway area by about 51%. With EC, the sway area reached the lowest mean value of 145 mm^2 in the mandibular rest position and the highest mean value of 210 mm^2 in the mandibular position using cotton rolls; changing the mandibular position with EC changed the sway area by about 40%.

The sway area mean values for the centric occlusion mandibular position and the mandibular position using cotton rolls are very similar if recorded under the same visual condition. In most of the mandibular and visual combinations, the air force and civilian pilots have very similar sway area values, but in the centric occlusion position, the air force pilots have a larger sway area (about 25-40 mm^2 larger), while in the mandibular position using cotton rolls, the civilian pilots have a larger sway area of about 25 mm^2.

The mean values of the sway velocity recorded during tests performed with EC were between 8.5 and 9.5 $mm \cdot s^{-1}$ and about 3 $mm \cdot s^{-1}$ higher than the velocity recorded during tests performed with EO (between 5.6 $mm \cdot s^{-1}$ and 6.3 $mm \cdot s^{-1}$); the sway velocity increases by approximately 50% when the pilot closes his eyes (**Fig. 2**).

The sway velocity with EO reached the lowest mean value of 5.65 $mm \cdot s^{-1}$ in the mandibular centric occlusion position and the highest mean value of 6.35 mm^2 in the mandibular rest position. Thus, changing the mandibular position with EO changed the sway area by about 12%. The sway velocity with EC reached the lowest mean value of 8.5 mm^2 in the mandibular position using cotton rolls, and the highest mean value of 9.5 mm^2 in the mandibular rest and centric occlusion positions; changing the mandibular position with EC changed the sway velocity by about 11%.

In most of the mandibular and visual combinations, the air force and civilian pilots have very similar sway

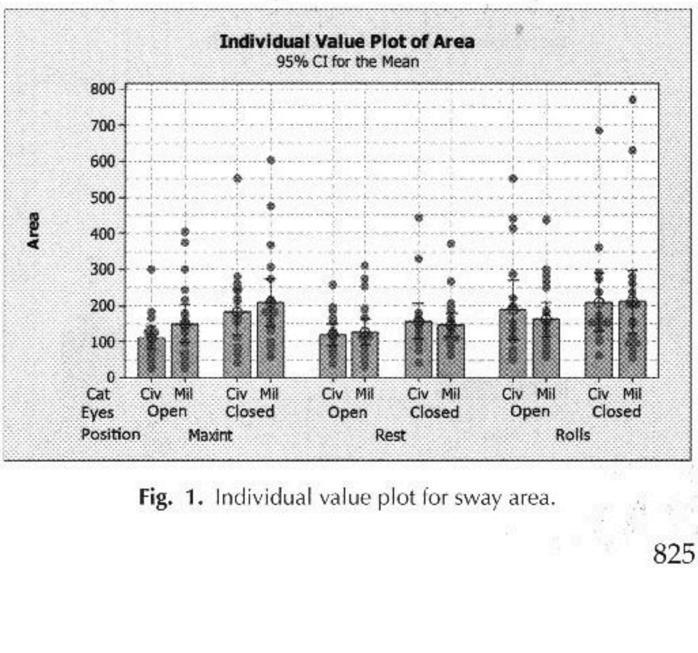

Fig. 1. Individual value plot for sway area.

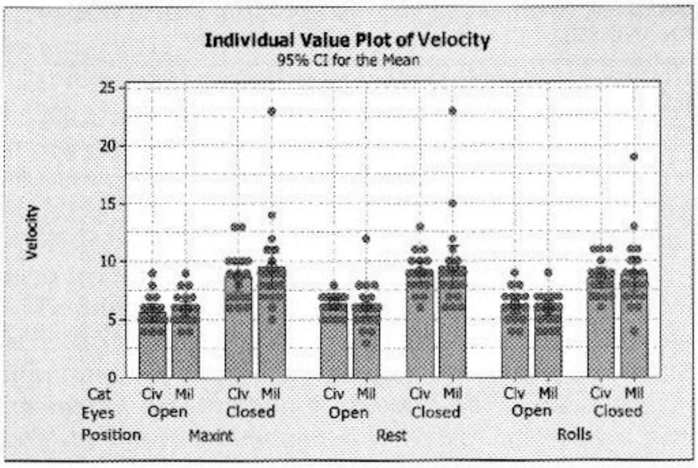

Fig. 2. Individual value plot for sway velocity.

area values, but in the centric occlusion mandibular position, the air force pilots have a greater sway velocity (**Fig. 3**).

Three factors are considered for their ability to influence the sway area and sway velocity: 1) Pilot category (air force, civilian); 2) Condition of the eyes (open, closed); and 3) Mandibular position (rest, centric occlusion, cotton rolls).

The MANOVA statistical analysis revealed that both parameters are very strongly influenced by vision (SWAY AREA P-value = 0.007; SWAY VELOCITY P-value < 0.001). The sway area was the only parameter significantly influenced by the mandibular position (SWAY AREA P-value = 0.019; SWAY VELOCITY P-value = 0576). No statistically significant differences were found between air force and civilian pilots (SWAY AREA P-value = 0.710; SWAY VELOCITY P-value = 0455).

DISCUSSION

The results of the statistical and quantitative analysis demonstrate the existence of a strong correlation between visual function and postural control. Vision influences the sway area and velocity parameters by reducing the values of the sway area and sway velocity, thus improving the balance of the whole body. Indeed, Baldini et al. have demonstrated that vision is an important component of the postural system (7).

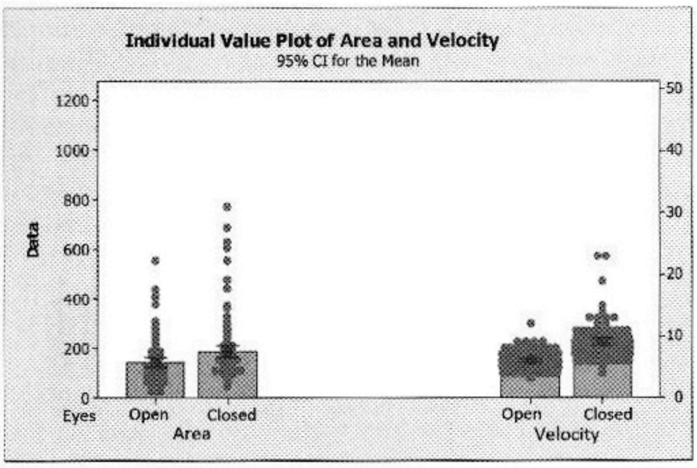

Fig. 3. Individual value plot for visual function.

The mandibular position influences the sway area with good statistical significance, but not the sway velocity, according to what some authors have previously reported (12,23). The pilots' postural balance declined in the centric occlusion mandibular position, thus indicating that dental occlusion had a negative influence on their posture. This is probably due to the condition of the pilots' stomatognathic system, stressed by bruxism and the influence of the in-flight forces. Similar results are observed in air force and civilian pilots, given the absence of statistically significant differences between the two groups.

A case-control study of 10 air force pilots and 30 healthy control subjects, utilizing a force plate exam for evaluating their postural control (4), concluded that pilots have a better postural control than normal individuals in all the occlusal and visual combinations. In a study carried out on a group of astronauts (24), a statistically significant connection was reported among the modifications induced in the electromyographic values of the sternocleidomastoid muscle when a splint was inserted between the dental arches: the greater the muscular symmetry using the splint, the smaller the astronauts' areas of oscillation on the stabilometric platform. In particular, after the splint application, the subjects exhibited an increase in muscular symmetry and consequent reduction of the sway area.

Thus, an inaccurate fabrication of occlusal splints for protecting the stomatognathic system could unbalance the highly specialized postural system of these individuals, predisposing them to an even higher incidence of painful posture-related symptomatologies. In fact, in our therapy protocol, after a proper anamnestic and clinical examination of the health condition of the whole body and the oral cavity of the pilot, the T-Scan III device provides a computerized analysis of the occlusal loads (2) and helps to achieve a perfect balance of occlusal loads when the splint is worn. Last but not least, the analysis of the force platform study allows one to determine the influence of splints on postural balance (8).

In conclusion, vision exercises an important influence on the postural system of air force and civilian pilots: visual function allows for better postural control. The influence of the mandibular position on the postural system can also be confirmed by looking at the modifications induced in the sway area postural parameter.

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