EVALUATION OF PROPRIOCEPTION BY A STANDARD INSTRUMENT FOR MEASUREMENT OF CERVICAL SPINE MOVEMENT – CERVICAL MEASUREMENT SYSTEM

Melita Uremović[1], Marija Bošnjak-Pašić[2], Katarina Sekelj-Kauzlarić[3], Marijana Lisak[2] and Vida Demarin[2]

[1]Zagreb osiguranje; [2]University Department of Neurology, Sestre milosrdnice University Hospital; [3]Croatian Medical Chamber, Zagreb, Croatia

SUMMARY – Whiplash injury is one of the most common injuries in traffic accidents. Patients who suffer a whiplash injury may have sprain and partial rupture of cervical musculature, sprain of the esophagus and larynx, lesions of temporomandibular joints, or injury of proprioception receptors located in the neck. The aim of the study was to estimate whether subjects who had suffered a whiplash injury experienced loss of proprioception, which was defined as the ability of repetitive predetermined head positioning. The study included 60 patients (age range 20-50 years) with whiplash injury and 60 asymptomatic age- and sex-matched control subjects. The patient ability to accomplish a defined head position during rightward and leftward cervical spine rotation at 30° angle was assessed by repeat measurements using Cervical Measurement System three months after medical treatment. The study showed the patients who had sustained a whiplash injury to have statistically significantly poorer results as compared with control subjects ($p>0.001$). Results of the study support the hypothesis that subjects with whiplash injury have worse perception of the head position, which may pose a disturbing problem in their daily activities.

Key words: *Cervical vertebral injuries; Neck pain – physiopathology; Posture; Whiplash injuries – physiopathology; Whiplash injuries – measurement; Accidents; Traffic*

Introduction

The majority of cervical spine injuries are sustained in motor vehicle accidents, accidental falls, during work and sports activities. Accidental falls and car accidents equally cause lesion of the upper part of cervical segment, while the latter mostly cause lesion at the lower part of cervical spine[1]. Recent data show that whiplash injury occurs commonly and most frequently in car accidents. Whiplash injury is a medical term used to describe damage to the neck caused by sudden hyperextension or hyperflexion movement, and is predominantly characterized by soft tissue injury[2]. Crowe was the first to use the term in 1928, referring to "railway vertebrae" in subjects involved in train collision[3]. Gay and Abbot introduced whiplash in 1953 as a term used for neck injury sustained in car collisions from the rear[4].

During the last few decades, a growing incidence of whiplash injuries has been observed in Croatia and worldwide. This might be due to the increased total number of cars *per* inhabitant and obligatory utilization of safety belts that has reduced the number of fatal craniocervical trauma. Safety belt asymmetrically fixes the body at three points, thus increasing the rotatory component of the head and neck movement that might enhance the possibility of cervical segment lesion[5].

Two parties often cause car collisions in traffic when a moving vehicle comes from behind and crashes a nonmoving vehicle. The driver's or passenger's head is usually at a 5- to 25-cm distance from the seat. This common head position is frequently disturbed at the moment of traffic accident, depending on the impulse and

Correspondence to: *Melita Uremović, M.D.*, Zagreb osiguranje, Maksimirska 11, HR-10000 Zagreb, Croatia
E-mail: melita.uremovic@osiguranje-zagreb.hr

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vector of the movement, and may cause a sharp whipping movement of the head and neck or sudden rotation of the head backwards. This may result in sprain and partial rupture of the cervical (neck) muscles, sprain of the esophagus and larynx, lesion of temporomandibular joints, and lesion of proprioceptive receptors located in the neck[6,7].

Proprioceptive receptors located in the neck include muscle spindles densely placed in the intervertebral and dorsal musculature. Afferent fibers of the muscle have greatest influence on postural reflexes because afferent information from all muscle spindles derives information on the length of the muscle as well as on the length change. During muscle contraction, gamma-motor innervation maintains the relative length of the muscle spindle in relation to the length of the muscle. Through this mechanism the central nervous system is constantly informed on the muscle length, even when it is contracted. Due to neck pain and muscle inflammation that occur after whiplash injury, gamma-motor innervation may be inhibited causing incorrect afferent information that may produce distorted proprioception[8].

Perception of head orientation in relation to the body, involving vestibular system and proprioceptive sensors in the neck, is of vital importance in daily functioning[9]. Data on the evaluation of proprioceptive impairment after extremity injuries show positive correlation between the injury severity and inadequate reproduction of the joint position. There are little data on proprioception evaluation after whiplash injury. On the other hand, there is a considerable number of the injured who complain of balance impairment on standing and walking which might be due to lesion of the inner ear or of deep peripheral sensory apparatus involved in proprioception[10].

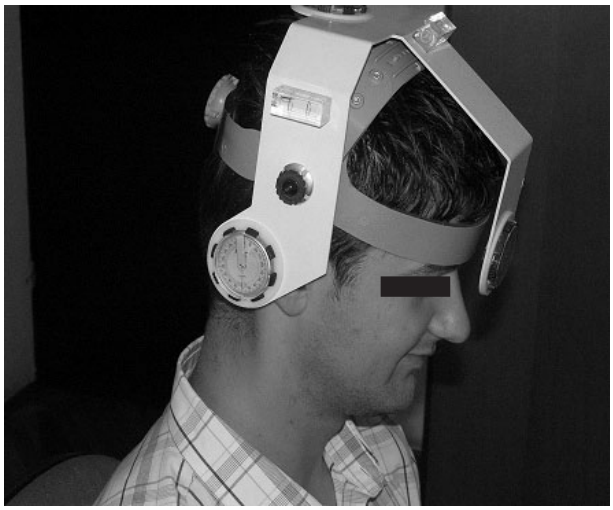

Fig. 1. Cervical Measurement System device

In our study, proprioception was defined as the ability of repetition in safe positioning of cervical segment during defined rightward and leftward rotation of the head at 30° angle.

The aims of the study were: 1) to determine whether proprioceptive loss remains after a whiplash injury; and 2) to introduce a new method in the measurement of defined head positioning by a standard instrument for the measurement of cervical spine motion, Cervical Measurement System (CMS), that has not been utilized for the above mentioned purposes before.

Subjects and Methods

Subjects

The study was conducted at University Department of Neurology, Sestre milosrdnice University Hospital in Zagreb, Croatia, during the year 2002. The study included 60 patients (age range 20-50 years) with whiplash injury sustained in car accidents, treated at the Department. The surgeon diagnosed whiplash injury in the first 48 hours of the accident, according to the Quebec Task Force (QTF) protocol criteria[11]. All subjects were categorized into groups according to QTF protocol degrees II and III, and treated in a manner of good clinical practice as follows: in the acute phase of whiplash injury, bed rest and immobilization of cervical spine with a soft cervical collar worn for 14 days was recommended. Along with neck rest and immobilization, nonsteroidal antiinflammatory treatment with diclophenac sodium (Voltaren rapid®) was prescribed. Medication was administered in tablets in a single dose of 50 mg, three times daily for 14 days. After the immobilization period, patients underwent physical therapy that included exercises for paravertebral musculature strengthening and exercises for cervical spine motility improvement. Physical therapy was administered for 15 days. Transcutaneous Electrical Nerve Stimulation (TENS) therapy was applied at painful sites two times daily for 20 minutes.

Control group consisted of 60 age- and sex-matched subjects, treated at the Department during the year 2002. Control subjects had no history data on previous

Fig. 2. Cervical Measurement System device.

whiplash injury or cervical spine lesions, and had normal x-ray of the cervical spine segment.

Methods

All subjects underwent history procedure and physical examination. Body height and weight were measured. Two examiners performed the measurement of defined head positioning and zero head positioning using the CMS instrument. The validity of CMS was assessed and approved in several studies as a reliable method for the measurement of cervical spine movement[12]. CMS is a plastic instrument fixed to the head of the subject and aligned according to three major axes of motion (Figs. 1 and 2). Movements in the sagittal and frontal axes are measured by means of gravity goniometer, whereas movements in the transversal axis also include compass goniometer. Therefore, all measurements were performed in the room that contained only few metal objects. At the beginning of the measurement procedure, positioning of the head was performed. The subject was sitting comfortably in a chair and maintained an upward position. The head position was neutral and CMS was placed on the head with inclinometers and rotatory compass in zero position. During measurement of the ability of head positioning during rightward rotation at 30° angle the subjects were asked to close their eyes. At first the head was rotated rightward at 30° angle with the eyes closed, and then it was placed back in zero position, also with the eyes closed. After that procedure, the subjects were asked to take the same head position with the eyes closed, consecutively three times over a period of 60 seconds. During the measurement, three different angles were observed. Afterwards, the same procedure was repeated on defined leftward head rotation at 30° angle. We decided to perform three measurements in order to avoid the possibility of subjective simulation. After every measuring procedure, results were marked and if significant deviation occurred, the subjects were asked for full cooperation. On data analysis only the best results were taken into account. The measurement of defined head position at 30° rotation

Table 1a. General data on patient and control groups – men

Variable	n	Minimum	Median	Maximum	Mean	Standard deviation
Patient group						
Age (yrs)	30	20	33	46	32.7	7.60
Height (cm)	30	160	182	192	180.2	7.73
Weight (kg)	30	60	82	105	81.6	10.78
Control group						
Age (yrs)	30	20	33	46	32.7	7.60
Height (cm)	30	163	183.5	197	182.8	7.17
Weight (kg)	30	67	86	110	86.7	11.79
Mann-Whitney U-test						
Age (yrs)	z=0.000	p=1.0000	ns			
Height (cm)	z=1.238	p=0.2158	ns			
Weight (kg)	z=1.653	p=0.0984	ns			

Table 1b. General data on patient and control groups – women

Variable	n	Minimum	Median	Maximum	Mean	Standard deviation
Patient group						
Age (yrs)	30	20	36.5	56	36.0	9.38
Height (cm)	30	156	163.5	178	167.5	5.88
Weight (kg)	30	52	61	80	62.3	8.03
Control group						
Age (yrs)	30	20	36.5	50	36.0	9.38
Height (cm)	30	157	163	172	163.9	4.08
Weight (kg)	30	50	65	75	63.8	6.81
Mann-Whitney U-test						
Age (yrs)	z=0.000	p=1.0000	ns			
Height (cm)	z=1.128	p=0.2594	ns			
Weight (kg)	z=1.000	p=0.3174	ns			

angle was performed because the majority of subjects were not able to accomplish major rotation angle during measurement of cervical spine motility.

Statistical analysis was performed using Statistica 5 software. General data on the patient and control group were expressed as mean and standard deviation. Measurements were compared using Mann-Whitney U-test. Sex differences were tested using χ^2-test. Statistically significant difference was set at $p<0.005$.

Results

Table 1a shows general data on male subjects with whiplash injury and controls. There was no statistically significant difference in body weight and height between the two groups ($p<0.2158$). Table 1b shows general data on female subjects with whiplash injury and controls. There was no statistically significant difference in body weight and height between the two groups ($p<0.2594$). Body height, body weight and age had no influence on results (Table 1a,b).

Figure 3 shows results obtained on measurement during head positioning with rightward rotation at 30° angle, using CMS during three consecutive trials in patient group according to sex. In the first trial, 56.6% of female and 73.3% of male whiplash injury patients managed to achieve the defined angle of head position. In the second trial, only 3.3% of female and none of male patients managed to achieve defined angle of head position. In the third trial, none of female or male patients managed to achieve defined angle of head position. In all three trials, there was no statistically significant dif-

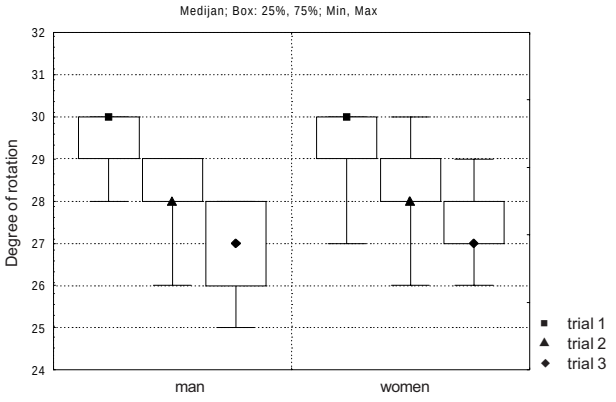

Fig. 3. Results of measurement and sex differences of defined head positioning during rightward rotation at 30° angle by CMS, in three trials

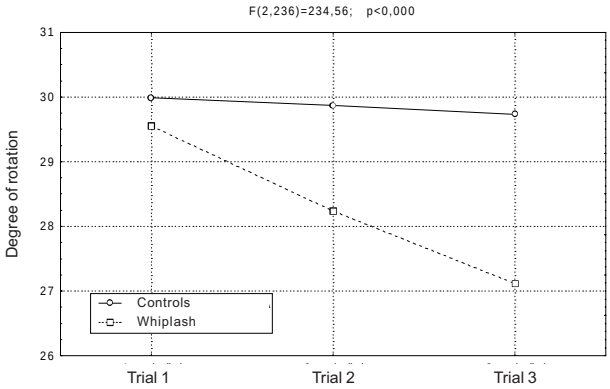

Fig. 4. Analysis of variance with repeat measurement of head positioning during rightward rotation at 30° angle in three trials in patients and controls.

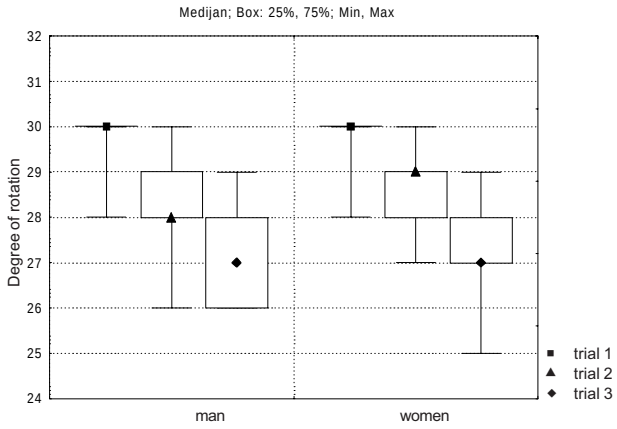

Fig. 5. Results of measurement and sex differences of defined head positioning during leftward rotation at 30° by CMS in whiplash injury patients.

ference between female and male patients during head positioning in rightward cervical spine rotation at 30° angle as assessed by CMS method.

Figure 4 shows analysis of variance of repeat measurements during head positioning and 30° angle rotation of cervical spine in all patients compared with controls. Results yielded a statistically significant difference in head positioning during rightward rotation at 30° angle in all three trials as compared with controls. Only 22.2% of whiplash injury patients managed to achieve defined angle during three trials *versus* 88.3% of control subjects ($p<0.0001$).

Figure 5 shows sex differences in patients with whiplash injury during head positioning and cervical spine leftward rotation at 30° angle as measured by CMS. In the first trial, 76.6% of female and male patients managed to achieve defined angle, while 23.4% of female and male subjects managed to achieve an angle of 29°. In the second trial, 16.6% of female patients and 3.3% of male patients managed to accomplish defined angle, whereas in the third trial none of the patients managed to accomplish the defined angle. In the group of whiplash injury patients, there was no statistically significant sex difference in head positioning during leftward rotation of cervical spine at 30° angle.

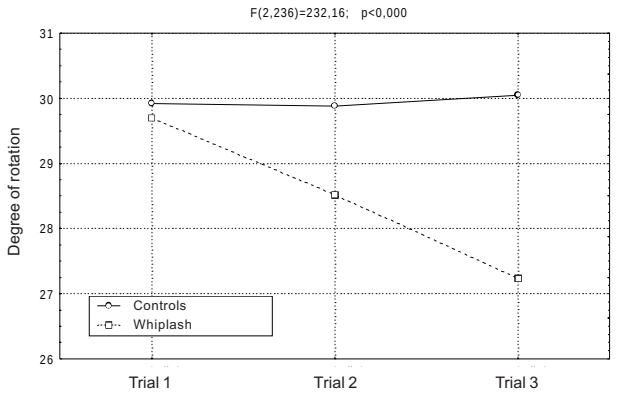

Fig. 6. Analysis of variance with repeat measurement of head positioning during leftward rotation 30°angle during three trials in patients and controls.

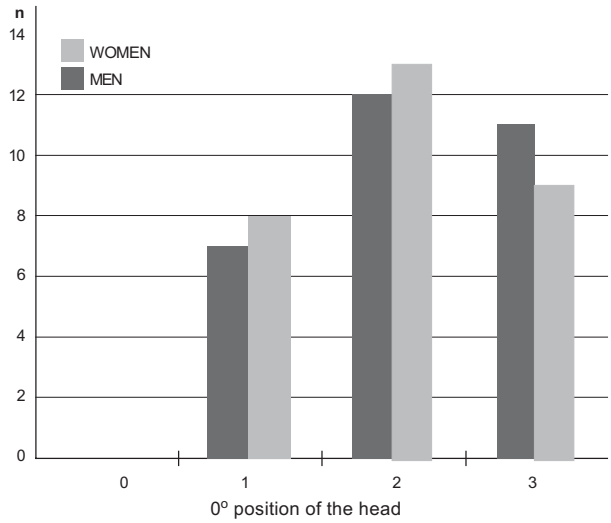

Fig. 7. Results of 0° angle head positioning in whiplash injury patients according to sex.

Figure 6 shows analysis of variance in repeat measurements of head positioning during 30° angle rotation of cervical segment detected in three trials in all patients as compared with controls. Results showed that

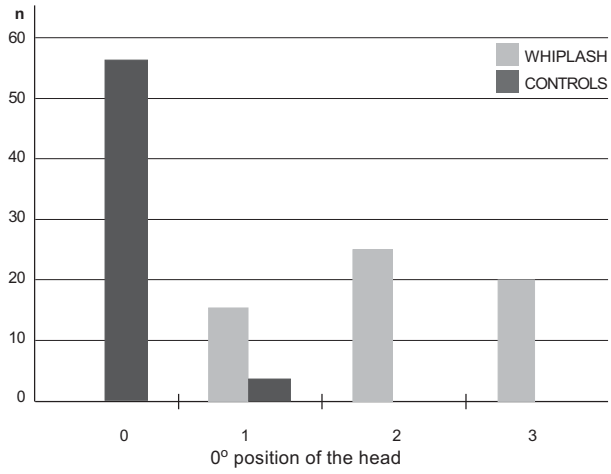

Fig. 8. Results of 0° angle head positioning in patients and controls.

28.8% of all patients with whiplash injury and 89.9% of control subjects achieved defined angle ($p<0.0001$).

Figure 7 presents results of zero head positioning in patients with whiplash injury according to sex.

Figure 8 shows results of zero head positioning in patients with whiplash injury and controls. Results showed that none of the patients with whiplash injury had neutral head position of 0° angle, while 25% had 1° angle, 41.7% had 2° angle and 33.3% had 3° angle detected as neutral angle. In the control group, 93.3% had 0° angle as neutral head position and 6.7% had 1° angle detected as neutral position.

Discussion

Our study demonstrated that the loss of proprioception might be detected by use of CMS in patients with whiplash injury during repeat head positioning measurements. This may be a novelty in measuring motion of the cervical spine segment. Results of CMS measurement of defined head positioning during rightward and leftward rotation at 30° angle in three consecutive trials showed that the injured failed to accomplish defined head angle. The head angle detected was smaller than 30° in the majority of patients, and results were getting worse through the three trial measurements. At the same time, control subjects managed to achieve defined head angle during leftward and rightward rotation at 30° in all three trials. None of the patients managed to achieve 0° angle and neutral head position during either leftward or rightward rotation, in contrast to control subjects who managed to achieve 0° angle as neutral angle.

We searched medical literature using Medline database and found only a few studies on the loss of proprioception after whiplash injury. One of the studies was conducted in 1995 at Medical Center, University of Kansas, Kansas City, and included 11 asymptomatic patients and 11 patients (age range 28-57 years) having sustained one or more whiplash injuries over a two-year period from the study onset. Proprioception deficiency was measured by means of CMS in repeat measurements of head positioning during maximal rotation and neutral head position. Results showed worse head positioning in whiplash injury patients, the difference being statistically significant[13-20]. This study included a rather small number of subjects, whereas in our study we examined 60 subjects with whiplash injury (age range 20-50 years), hospitalized at the Department during the year 2002. All patients had a history of only one whiplash injury sustained in car accident. The surgeon made the diagnosis of whiplash injury in the first 48 hours of the accident. All patients were categorized as injury degree II or III according to QTF protocol. They were properly treated according to the recommended management of whiplash injury: bed rest during acute phase, immobilization of cervical spine segment with soft neck collar for a mean of 14 days, and medicamentous therapy with analgesics. Three months after the treatment, all subjects underwent measurement of head positioning by use of CMS. Our results are consistent with those reported from the study conducted at Medical Center, University of Kansas, Kansas City, supporting the hypothesis that subjects with whiplash injury have a proprioceptive deficit and inability of reproducing subjective neutral head position, thus disabling correct determination of the head position in space.

Our study results might also suggest a different treatment and rehabilitation option for whiplash injury. In addition to improving muscle strength and cervical spine movements, physiotherapy should also include proprioceptive restoration therapy that may help patients relearn their motor skills[2,22].

Future investigations may be directed to the evaluation of pain and lesion severity according to QTF protocol as compared with the level of error during defined head positioning. Glencross and Thornton have reported on a positive correlation between the severity of ankle lesion and degree of error in trying to accomplish previous position[23]. This study as well as the observations from our study suggests that future investigations of proprioceptive evaluation might be needed.

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Sažetak

PROCJENA PROPRIOCEPCIJE STANDARDNIM INSTRUMENTOM ZA MJERENJE POKRETA VRATNE KRALJEŽNICE – SUSTAVA ZA VRATNO MJERENJE

M. Uremović, M. Bošnjak-Pašić, K. Sekelj-Kauzlarić, M. Lisak i V. Demarin

Trzajna ozljeda je među najčešćim ozljedama u prometnim nesrećama. Bolesnici s trzajnom ozljedom mogu imati iščašenje ili djelomično puknuće vratnih mišića, iščašenje jednjaka i grkljana, oštećenje temporomandibularnih zglobova ili ozljedu propriocepcijskih receptora smještenih u vratu. Cilj ispitivanja bio je utvrditi osjećaju li osobe koje su zadobile trzajnu ozljedu gubitak propriocepcije koja je definirana kao sposobnost opetovanog zauzimanja prethodno utvrđenog položaja glave. U studiju je bilo uključeno 60 bolesnika (raspon dobi 20-50 godina) s trzajnom ozljedom i 60 asimptomatskih ispitanika jednake dobi i spola. Sposobnost ispitanika da zauzmu definirani položaj glave tijekom rotacije vratne kralježnice za 30° udesno i ulijevo ispitivana je ponovljenim mjerenjima pomoću sustava za vratna mjerenja tri mjeseca nakon liječenja. Ispitivanje je pokazalo kako bolesnici koji su zadobili trzajnu ozljedu imaju statistički značajno lošije rezultate u usporedbi s kontrolnim ispitanicima ($p>0,001$). Rezultati ove studije govore u prilog pretpostavci da osobe s trzajnom ozljedom imaju lošiju percepciju položaja glave, što može predstavljati problem u njihovim svakodnevnim radnjama.

Ključne riječi: *Ozljede vratne kralježnice; Bolovi u vratu – fiziopatologija; Položaj tijela; Trzajne ozljede – fiziopatologija; Trzajne ozljede – mjerenje; Nesreće; Promet*