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Impairment of Proprioception After Whiplash Injury

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A B S T R A C T

Whiplash injury usually occurs in traffic accidents. Persons experienced this injury might have an impairment of proprioception clinically expressed as inability to determine the exact position of their heads. The aim of this study was to examine the loss of proprioception in people who had a whiplash injury. The study included 60 subjects with cervical spine injury, aged 20 to 50 years and 60 healthy volunteers matched by sex and age. The instrument used for cervical spine mobility assessment was the Cervical Measurement System (CMS), which determines the ability of subjects to return their head in the exact position as it was before they turned it 30 degrees left or right. Patients with cervical spine injury showed significant impairment of proprioception in comparison with healthy subjects ($P<0.001$). The results support the hypothesis that subject with recent cervical spine injury have incorrect perception of their head position. Therefore, their rehabilitation should include the correction of proprioception and head coordination.

Key words: *whiplash injury, proprioception, standard measurements of cervical spine mobility (CMS), rehabilitation of cervical spine injury*

Introduction

Cervical spine is frequently exposed to injury due to great mobility and head mass which is approximately 4.5 kg[1]. Cervical spine injuries often result from car accidents [(3)] and are usually complex in origin[2]. The distance between the driver's or passenger's head and the head restraint is between five and 25 cm. In a car accident, the head and the neck are abruptly thrust backwards, which can result in spinal injury[3]. Initial symptoms such as neck pain, headache and vertigo, are of low intensity. Later symptoms include pain spreading through the arms, vision disturbance and limited mobility of cervical spine[4–8]. Symptoms can last for months, even for years after the injury. The duration of rehabilitation depends on the patient's age, severity of injury and type of medical treatment[9]. The initial treatment includes neck immobilization, analgesy and physical therapy[10,11]. Standard rehabilitation includes cervical spine mobility and cervical muscle exercises[12].

Cervical spine injuries can result in the damage of sense receptors which surround and innervate cervical structures. These sensors are muscle spindles, situated in inter-vertebral and dorsal muscles, which transmit information about changes in muscle length to the central nervous system (CNS)[13,14]. There is evidence of inhibition of gamma motor neurons, due to the pain after injury, which results in incorrect information from muscle spindles to the CNS and in incorrect proprioceptive sense[15]. This is important in everyday activities, because moving to any object requires precise sense of the head and neck position[16].

Most published articles on whiplash injury have addressed its pathogenesis, mechanism and epidemiology. On the other side, only a few authors have investigated the damage of proprioceptive sense as a frequent cause of imbalance in patients with pull injuries[17,18].

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The aims of this study were:

1. to determine the damage of proprioception in patients who had a whiplash injury. Proprioception is here defined as ability to repeatedly return the head in the exact position as it was before turning the neck 30 degrees left or right.
2. to show that Cervical Measurement System (CMS), which is used to determine head movement to a defined position, is a reliable method for this purpose.

Subjects and Methods

The study included 60 subjects of both sexes (30 women and 30 men), aged 20 to 50 years, who were treated for whiplash injury at the Physical Medicine Unit and Neurology Unit of Clinical Hospital »Sestre Milosrdnice« in 2002. All patients experienced the whiplash injury in a traffic accident. They were examined by surgeon after injury (mean time after injury: 16.7 hours; range: 1–48 hours). Whiplash injury was diagnosed to all patients after clinical and x-ray examination, according to the criteria which are used in every-day clinical practice: radiologically cervical hyper- or hypolordosis, or even no radiological signs with limited neck mobility and spasm of paravertebral muscles. Classification was performed also by the surgeon, according to QTF protocol, which classifies patients into four grades according to their clinical symptoms and associated syndromes: Grade 0 – no pathological or clinical signs of injury; Grade 1 – Pathological signs: microscopic or multiple small lesions of soft tissue. Clinical signs: no muscular spasm; Grade 2 – Pathological signs: bleeding in soft tissue, including ligaments, tends and joint capsule. Clinical signs: neck stiffness, PVM (paravertebral muscles) spasm, Grade 3 – Pathological signs: grade 2 + neurological damages as a primary consequence of injury or secondary due to bleeding or inflammation. Clinical signs: neck stiffness + neurological signs, Grade 4 – serious neck injury with radiological signs of cervical spine instability or fracture[19]. Patients who were classified to be in the second or third degree of QTF Protocol were included in this investigation. The injuries were treated equally in all patients: resting and neck immobilization in mean duration of 10 days and analgesia. Functional X-rays of cervical spine were performed at the end of immobilization. Physical therapy lasted 15 days in average and consisted of strengthening neck muscles and application of low-energy, high-frequency pulsed electromagnetic therapy on pain sites.

The control group consisted of 60 subjects (30 women and 30 men), matched by sex and age, who were treated in the same hospital units in 2002, but never experienced a whiplash injury and had no abnormality found by cervical X-ray.

All subjects were taken medical history. Detailed data were collected about the accident, crash sites and patients' seat in the car.

Measurement of head motion to the defined position was performed three months after physical therapy using a CMS. It is a plastic device, which is positioned on the patient's head. Head movements in the frontal and sagital planes were measured with gravitation goniometer, while compass goniometer was used for movements in the transversal plane. Coefficient of variation for CMS was obtained by ten measurements of head movement in one healthy volunteer. The coefficient was 1.36%. A validity, and sensitivity of CMS in measuring neck motility has already been proved in several studies[20,21].

During the measurement, subjects were seated in a chair, with the head in the neutral position (0° of rotation). They fixed their eyes on a point on the wall, which was in the level of their eyes. The CMS was placed on the patient's head. At the beginning of the examination, the patients closed their eyes and let the investigator rotate their head for 30° to the right and then return it to the neutral position (0°). After that, the patient was asked to repeat the movements three times in 60 seconds. The whole procedure was repeated for the left turn. The CMS served to determine whether the head returned to the neutral position (0°).

Statistical analysis was performed using Statistica for Windows version 5. Data were presented as mean ± standard deviation. Comparison between measurements was performed by Mann-Whitney U-test. The P value of less than 0.05 was considered statistically significant.

Results

Most patients were injured in a rear-end collision, and then in head-on and sideswipe collisions (Table 1). There were no differences between the sexes by the type of collision. Most men were drivers, while most women were front and back-seat passengers (Table 2).

CMS measurements of the head movement back to the neutral position after a 30° rotation to the right and

TABLE 1
NUMBER OF SUBJECTS ACCORDING TO COLLISION TYPE

Type of collision	Men (N = 30)	Women (N = 30)
Front	5 (16.7 %)	9 (30.0 %)
Rear	22 (73.3 %)	17 (46.7 %)
Side	3 (10.0 %)	4 (13.3 %)
Total	30 (100.0 %)	30 (100.0 %)

TABLE 2
POSITION OF PATIENTS IN THE CAR DURING THE ACCIDENT

Position of patient	Men (N = 30)	Women (N = 30)
Driver	19 (63.3 %)	10 (33.3 %)
Front-seat passenger	5 (16.7 %)	11 (36.7 %)
Back-seat passenger	6 (20.0 %)	9 (30.0 %)
Total	30 (100.0 %)	30 (100.0 %)

TABLE 3A
CMS MEASUREMENT OF HEAD ROTATION TO THE RIGHT IN THREE ATTEMPTS

	Men (N=30) Median	Women (N=30) Median	Mann-Whitney U-test
First attempt	30° (28°–30°)	30° (27°–30°)	n. s.
Second attempt	28° (26°–29°)	28° (26°–30°)	n. s.
Third attempt	27° (25°–28°)	27° (26°–29°)	n. s.

CMS – standard measurements of cervical spine mobility

TABLE 3B
CMS MEASUREMENT OF HEAD ROTATION TO THE LEFT IN THREE ATTEMPTS

	Men (N=30) Median	Women (N=30) Median	Mann-Whitney U-test
First attempt	30° (28°–30°)	30° (28°–30°)	n. s.
Second attempt	28° (26°–30°)	29° (27°–30°)	$p<0.05$
Third attempt	27° (26°–29°)	27° (25°–29°)	n. s.

CMS – standard measurements of cervical spine mobility

left, showed that n the second attempt, women rotated their heads in significantly lower degree, comparing to men ($p<0.05$) (Table 3a and b). In the first attempt, 17 female and 22 male patients correctly turned their heads 30 degrees to the right. In the second attempt, only one female and no male patient were able to repeat the movement with the same precision, and in the third attempt none was able to do the same. In all attempts, there were no significant differences between men and women in turning their heads 30°. Turning their heads 30 degrees to the left, 23 female and 23 male patients did it correctly in the first attempt, five women and one man in the second attempt, and one woman and three men in the third attempt.

Patients rotated their heads in significantly lower degree than controls ($P<0.05$ in the first attempt; $P<0.0001$ in the second and third attempt) (Table 4a and b). No patient was able to turn her or his head for 30° in the third attempt.

Patient with neck injury were not able to return the head to the neutral position of 0° after 30° rotation, unlike 93.3% controls who were able to do it (Figure 1).

TABLE 4A
CMS MEASUREMENT OF HEAD ROTATION TO THE RIGHT IN THREE ATTEMPTS IN PATIENTS AND CONTROLS

	Patients (N=60) Median	Controls (N=60) Median	Mann-Whitney U-test
First attempt	29° (27°–30°)	30° (29°–30°)	$P<0.05$
Second attempt	28° (26°–30°)	30° (29°–30°)	$P<0.0001$
Third attempt	27° (25°–29°)	30° (29°–30°)	$P<0.0001$

CMS – standard measurements of cervical spine mobility

TABLE 4B
CMS MEASUREMENT OF HEAD ROTATION TO THE LEFT IN THREE ATTEMPTS IN PATIENTS AND CONTROLS

	Patients (N=60) Median	Controls (N=60) Median	Mann-Whitney U-test
First attempt	29° (27°–30°)	30° (29°–30°)	$P<0.05$
Second attempt	28° (26°–30°)	30° (29°–31°)	$P<0.0001$
Third attempt	27° (25°–29°)	30° (29°–31°)	$P<0.0001$

CMS – standard measurements of cervical spine mobility

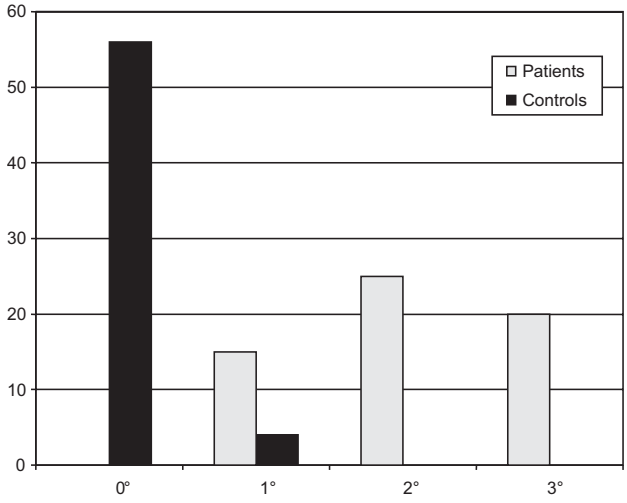

Fig. 1. Percent of patients and controls who returned the head to a neutral position of 0°and to other degrees of head rotation (1º, 2º and 3º).

Discussion

This investigation shows that a CMS system for measuring cervical spine mobility can reliably assess the loss of proprioception in patients with cervical spine injury. There have been several studies on the loss of proprioception after back, knee, hip and ankle injuries[22–24]. Grigg and colleagues found that patients with total hip endoprothesis had different joint-position sense than healthy people[25]. In an investigation of equilibrium disorders, Bly and Sinnot found that patients with back injury had more frequent difficulties in standing on one leg or in holding the upright position, than controls[26]. Furthermore, the ability of repetitive body positioning was found to be worse in patients with back injury[27].

There are a number of investigations addressing disturbed proprioception after whiplash injury[28–31], there is only one investigation from the University of Kansas Medical Center which refers to the loss of prorpioception in patients with neck injury measured using CMS[18]. Eleven patients aged 28 to 57 years with neck injury showed worse results than 11 controls. Our investigation included a larger number of younger subjects, which minimizes the risk of finding degenerative changes on the cervical spine. They all underwent the same study protocol. Our results showed that most patients failed to precisely rotate their heads left or right for 30° and that the results worsened in repeated attempts. This suggests that proprioceptive abilities in these patients deteriorated with time.

Apart from incorrect head rotation, these patients demonstrated incorrect movement of the head to the neutral position. The majority missed the neutral position by one or two degrees to the left or right.

The results from our study coincide with the University of Kansas Medical Center investigation, proving the hypothesis that people with whiplash injury have proprioceptive loss. The rehabilitation of these patients should include exercises for strengthening neck muscles and improving neck mobility and proprioception. The patients would learn to use motor skills based on a new, probably abnormal sensor input. This was evidenced by Freeman and col. who showed that kinesthetic sense could be improved with exercises in co-ordination and proprioception[32].

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POREMEĆAJ PROPRIOCEPCIJE NAKON WHIPLASH OZLJEDE

S A Ž E T A K

Whiplash ozljede se obično javljaju u saobraćajnim nezgodama. Osobe koje su zadobile takvu ozljedu mogu imati poremećaj propriocepcije koji se ispoljava kao nemogućnost točnog određivanja položaja glave. Cilj ovog istraživanja je bio analizirati poremećaj propriocepcije u osoba s whiplash ozljedom. Sudjelovalo je 60 ispitanika s ozljedom vratne kralježnice, u dobi od 20 do 50 godina. Kontrolna skupina se sastojala od 60 zdravih osoba stratificarnih po dobi i spolu. Za procjenu pokretljivosti vratne kralježnice korišten je »Cervical Measurement System« (CMS), kojim se određuje sposobnost pojedinca da, nakon rotacije glave od 30^{o} na desnu ili lijevu stranu, vrati glavu u početni položaj. Bolesnici s ozljedom vratne kralježnice su imali značajan poremećaj propriocepcije u odnosu na zdrave ispitanike ($p<0,001$). Rezultati podupiru hipotezu prema kojoj osobe s nedavnom ozljedom vratne kralježnice imaju nepravilnu percepciju položaja glave. Zbog toga njihova rehabilitacija treba uključivati korekciju propriocepcije i koordinacije glave.