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ORIGINAL ARTICLE

Usefulness of biomechanical assessment in determining post-traumatic neck pain sequelae☆,☆☆

María José Vivas Broseta[a,*], Clemente Pastor Tendero[a], Enrique de Francisco Enciso[b], Raquel Marzo Roselló[a], Ana María Errejón García[c], Matías Vicente Mendoza[b]

[a] *Instituto de Biomecánica de Valencia, Universitat Politècnica de València, Valencia, Spain*
[b] *Instituto de Medicina Legal y Ciencias Forenses de Valencia, Valencia, Spain*
[c] *Juzgados de Valdemoro de Madrid, Madrid, Spain*

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Forensic medicine;
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Pain assessment;
Posturography;
Dynamometry;
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Abstract
Introduction: Post-traumatic neck pain is important in the context of liability compensation. In addition, legislative changes in 2015 give greater relevance to investigations. The aim of this study is to evaluate the usefulness of biomechanical assessment tests in assessing post-traumatic neck pain due to traffic accident by medical examiners, and to analyse the influence of these tests in determining sequelae.
Materials and methods: A descriptive study was conducted with a sample of people with neck pain after a traffic accident who were undergoing forensic assessment. Each medical examiner participating in the study selected cases they believed would benefit from a more complete assessment, conducted a pre-assessment of sequelae, referred cases for biomechanical assessment and, after receiving the results, assessed sequelae and the usefulness of the test. The initial and final assessments of sequelae were compared, taking into account the outcome of the biomechanical testing. The usefulness of the test was also described.
Results: A total of 59 cases was included, 51 of which accepted the testing. Results showed normal overall functionality (61%), slightly altered functionality (19%), altered functionality (12%) and no collaboration (8%). There were differences between the pre-evaluation of sequelae and the final assessment, with differences being less in the cases of normal functionality, no collaboration and rejection of testing, and greater in the cases of impaired functionality. A total of 98% of the test were useful to the participating medical examiners.

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* Corresponding author.
E-mail address: mariajose.vivas@ibv.upv.es (M.J. Vivas Broseta).

Conclusions: Biomechanical assessment test were useful to medical examiners in assessing post-traumatic neck pain sequelae secondary to a traffic accident and helped to rate the magnitude of the sequelae.

PALABRAS CLAVE
Medicina Forense;
Cervicalgia;
Accidente de tráfico;
Biomecánica;
Valoración del dolor;
Posturografía;
Dinamometría;
Fotogrametría

Utilidad de la valoración biomecánica en la determinación de secuelas por cervicalgia postraumática

Resumen
Introducción: La cervicalgia postraumática es importante en el contexto de las indemnizaciones por responsabilidad civil. Además, los cambios legislativos de 2015 dan mayor relevancia a las pruebas complementarias. El objetivo de este estudio es evaluar la utilidad de las pruebas de valoración biomecánica en la valoración de la cervicalgia postraumática por accidente de circulación por parte del médico forense y analizar su influencia en la determinación de secuelas.
Material y método: Se realizó un estudio descriptivo con una muestra de personas con cervicalgia por accidente de circulación en proceso de valoración en el Servicio de Clínica Médico-Forense. Cada médico forense participante en la investigación seleccionó casos que se beneficiarían de un mayor estudio, realizó una preevaluación de secuelas, los remitió para valoración biomecánica y, tras conocer los resultados, valoró las secuelas y la utilidad de la prueba. Se comparó la valoración inicial y final de secuelas en función del resultado de las pruebas biomecánicas y se describió su utilidad.
Resultados: Se incluyeron 59 casos, 51 de los cuales accedieron a realizarse las pruebas. Mostraron: funcionalidad global normal (61%), levemente alterada (19%), alterada (12%) y no colaboración (8%). Hubo diferencias entre la preevaluación de secuelas y la valoración final, reduciéndose en los casos de funcionalidad normal, no colaboración y rechazo de prueba, y aumentando en los casos de funcionalidad alterada. El 98% de las pruebas resultaron útiles para los médicos participantes.
Conclusiones: Las pruebas de valoración biomecánica fueron útiles para los médicos forenses en la valoración de secuelas de la cervicalgia postraumática por accidente de circulación y ayudaron a graduar la magnitud de las secuelas.

Introduction

Minor cervical injuries in traffic accidents are extremely important due to their frequency and their economic importance in the context of civil liability claims, both in the legislative framework up to 2015[1] and in the one that came into force as of January 2016.[2] According to a study by the MAPFRE Foundation[3] in Spain, this pathology is responsible for 50% of personal injuries caused by traffic accidents. According to Garamendi and Landa (data from Medical-Forensic Clinical Services)[4] it is involved in up to 50% of the assessments requested for crimes or misdemeanours and approximately 70% in the context of a traffic accident. In the references, there are very high percentages of sequelae in the injuries derived from whiplash (above 64%), and these are fundamentally subjective (75%) and with wide variability depending on the medical expert who performs the assessment.[5] The estimated incidence of exaggeration of critical symptoms in the cervical spine could be around 60% in cervical sprains and about 50% in chronic cervicalgia.[6]

The assessment of post-traumatic cervicalgia is complex at the diagnostic level due to the lack of specific complementary tests that allow the injury or its functional repercussion to be objectified. Its evolutionary course is often torpid with a tendency to be chronic and even depends on psychosocial factors such as initial anxiety,[7] fear of pain[8] or cultural environment.[9] Lastly, the opportunity for secondary gain linked to compensation could be an additional handicap for the assessment of bodily harm in the field of forensic and legal medicine. Although it should also be noted that, according to the systematic review by Spearing and Conelly from 2011,[10] there is no evidence of an association between injury compensation and poor health outcomes in people with whiplash.

In any case, any tool or method that improves the accuracy in the evaluation of this pathology and/or its sequelae would have a great professional, socio-economic and even

legal impact. In addition, there are two facts that confer greater relevance to the complementary tests at present. The first is the entry into force of the new Law,[2] where the sequela resulting from minor trauma to the cervical spine is compensated only if a conclusive medical report confirms its existence after the period of temporary injury. The second is the new role of the medical examiner in extrajudicial procedures (*Organic Law of the Judiciary*).[11,12] Both circumstances give greater importance to the complementary tests that may be part of a medical–forensic assessment protocol and are useful in the assessment of bodily harm. Specifically, the complementary tests that provide objective data that are imposed on the subjectivity of the symptoms characteristic of post-traumatic cervical syndrome.

Functional assessment using biomechanical techniques consists of the instrumental evaluation of functions. These tools allow an evaluation of the functional impact of an injury from a complementary point of view to the diagnosis, as opposed to most of the ''classic'' complementary examinations, in which the patient or subject is eminently passive. Some examples of valid methodologies applicable to the assessment of the functional repercussion of traffic accidents involving the cervical spine are: the kinematic assessment of cervical movement,[13] the evaluation of balance by posturography[14] or the dynamometric assessment of strength in the hand.[15] The treatment of the results allows the comparison of the data obtained with the reference population of the person assessed, the analysis of coherence in performing gestures, the congruence with other data of the person evaluated or the repeatability of the records.[16] The functional assessment using biomechanical techniques is widely implemented in Spain in areas such as physical medicine and rehabilitation or occupational medicine, but its development is still incipient in the field of forensic and legal medicine. Although it presents good prospects as to its use for the establishment of the health of the injuries, its interest for the medical examiner and its influence in the assessment of sequelae have not yet been studied.

The aim of this study is to evaluate the usefulness of biomechanical assessment tests by the medical examiner in the evaluation of minor cervical trauma due to traffic accidents and to analyse their influence in the determination of sequelae.

Materials and methods

Type of study and inclusion criteria of the sample

A cross-sectional, descriptive study was carried out by non-probabilistic sampling of consecutive cases in the city of Valencia, during the period between June 2013 and May 2014. The participants were people with post-traumatic cervicalgia secondary to a traffic accident in the process of forensic medical evaluation by one of the four medical examiners of the Institute of Legal Medicine and Forensic Sciences of Valencia who participated in the study. The inclusion criteria for selecting the sample were: age between 18 and 65 years, more than 3 years and less than 18 months since the accident, and no injuries of greater severity as a consequence of the accident. Biomechanical tests were prescribed for those injured who, following the stabilisation of cervical injuries, the medical examiner considered would benefit from obtaining complementary information through biomechanical tests. These were cases in which there were alterations in neck motility after the exploration or residual subjective symptoms or there were inconsistencies between the exploratory findings and the symptoms put forward or there were doubts about the existence of real residual symptoms.

Assessment protocol

Pre-evaluation of sequelae

In a first consultation, all those injured were assessed by their medical examiner through the study of their clinical record, medical history, physical examination and classification by the Quebec Task Force scale.[17] The Quebec scale assesses the severity of the whiplash syndrome in five grades. Data collection included socio-demographic factors, data regarding the accident, clinical diagnostic and therapeutic data, evolution, current subjective status and physical examination. In this first consultation, the medical examiners made their assessment of sequelae according to the Royal Legislative Decree[1] in force at the time of the study and recorded on the pre-evaluation form, which was kept by a researcher of the study until the data analysis phase. Participating medical examiners, who had been trained in the correct prescription and interpretation of biomechanical tests through two two-hour sessions of face-to-face training, prescribed the tests and those injured were referred for evaluation to the Institute of Biomechanics of Valencia (IBV in Spanish). The testing was voluntary. All participants were informed by their medical examiner and expressed their written consent prior to the assessment.

Biomechanical functional assessment

The biomechanical functional evaluation consisted of kinematic assessment of cervical movement, dynamometric assessment of hand strength and/or assessment of balance by posturography as indicated by the medical examiner. The kinematic assessment of cervical movement was performed using the NedCervical/IBV application, based on 3D photogrammetry.[13] Hand strength was assessed using the NedMano/IBV application, based on a non-deformable dynamometer.[18,19] The balance assessment was performed with the NedSVE/IBV application, which records the displacement of the pressure centre using a dynamometer platform[20,21] (Fig. 1). In all three cases, the results are compared to reference databases segmented by the disturbing variables of each type of assessment, such as sex, age or height. The three evaluation methodologies have been previously used in forensic medical assessment.[15,22] The results of each assessment were presented in a technical report to the medical examiner according to the technical standard UNE 50135:1996[23] prepared by a medical expert in biomechanical evaluation. The conclusions of the report always referred to the function assessed (which could be normal, slightly altered or altered), the limitation in the ranges of movement (if any) and whether or not the person had cooperated during the test; in other words, if they made an effort compatible with their possibilities to perform the gestures requested by the evaluator and, therefore, the

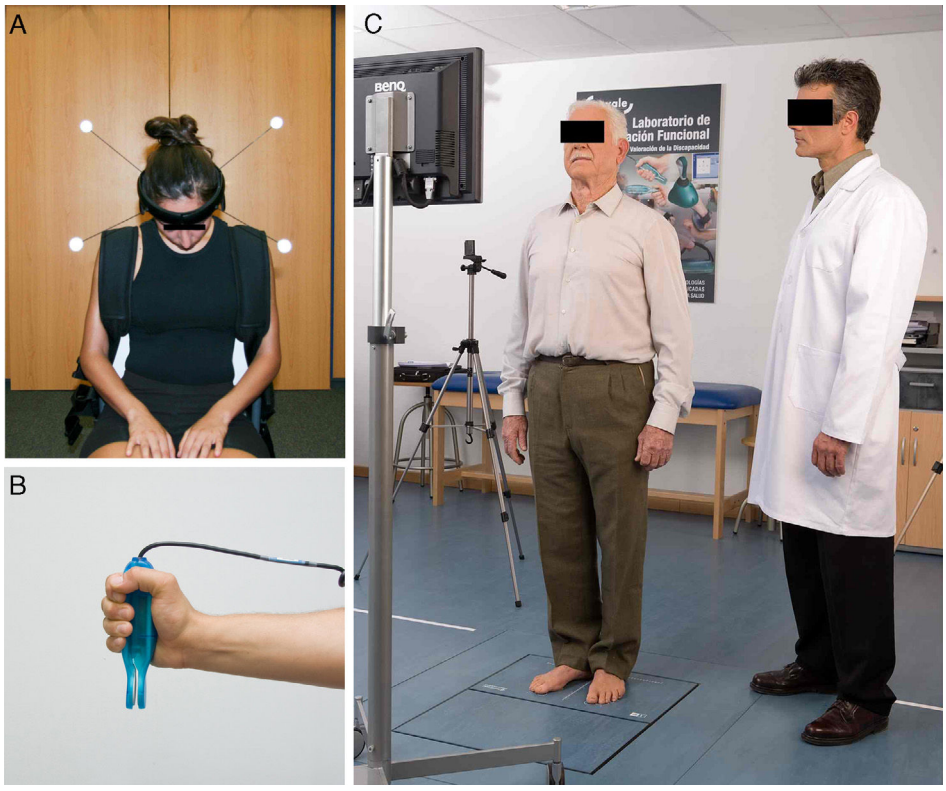

Figure 1 Images corresponding to the biomechanical assessment protocol with the NedCervical/IBV (A), NedMano/IBV (B) and NedSVE/IBV (C) systems, respectively.

results showed their real functional state. This conclusion is reached from the analysis of the consistency of results, study of repeatability of registers and/or comparison with patterns of simulated forms.

Final evaluation of sequelae and usefulness assessment of biomechanical tests

Once the biomechanical assessment report was received, the medical examiner completed the final evaluation form indicating the assessment of sequelae contained in the definitive Medical Forensic Health Report. In addition, their opinion was gathered about the usefulness of the biomechanical assessment report in decision-making and based on which criteria: (1) to show or confirm recovery, (2) show or confirm active symptoms and (3) show or confirm simulation.

Variables analysed

The variables analysed in this study are:

- Sequela score: numeric variable corresponding to sequential points awarded by each medical examiner participating in the study in the pre-evaluation and final evaluation according to the scale in force.[1]
- Type of sequela: description of the type of sequela granted in each case according to the scale in force.[1]
- Usefulness: dichotomous variable (yes/no) corresponding to the usefulness of the biomechanical assessment report perceived by the medical examiner.
- Type of biomechanical outcome: a description of the result obtained in the biomechanical assessment tests, which could be one of four types: ''normal functionality'', ''slightly altered functionality'', ''altered functionality'' or ''non-cooperative'' in the event of a lack of collaboration during the tests. The lack of collaboration during the tests means that the person assessed does not make an adequate effort to the best of their abilities to perform the gestures requested by the evaluator.

Data analysis

Data analysis was performed using the Microsoft Excel computer application and SPSS statistical software. It consisted of a descriptive analysis of the characteristics of the sample and the variables of this study. Furthermore, a multivariate statistical analysis was performed to compare the *sequela score* in the pre-evaluation and in the final assessment using the ANOVA technique for the set of cases corresponding to each type of biomechanical result.

Results

Description of the sample

During the recruitment period of the sample, 208 injured people met the established criteria, of which 64 (30.8%) were selected for biomechanical assessment and comprised the sample for this study. Of the 64 injured people who were

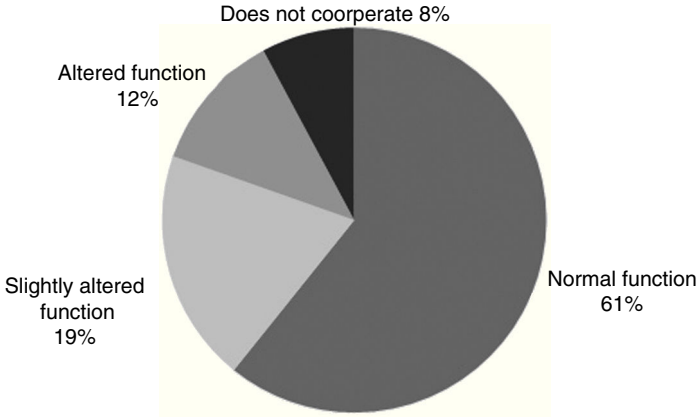

Figure 2 Distribution of biomechanically assessed cases by type of test result obtained.

submitted to the biomechanical study, 51 (79.7%) consented to the test, 8 (12.5%) refused to undergo biomechanical assessment and 5 (7.8%) were excluded from the study due to methodological problems in data collection.

The sample of people assessed consisted of 65% women and 35% men. The mean age was 36 years in women (standard deviation = 9.9) and 35 years in men (standard deviation = 10). 82% of the accidents were from behind and 253 days after the accident occurred (at least 107 days and a maximum of 398 days) at the time of assessment. According to the physical examination by the medical examiner, 57% of the sample presented grade I injury following the Quebec classification and 43% grade II. Both grades refer to pain, sensation of stiffness and cervical discomfort, in grade II with musculoskeletal signs (decreased joint movement and painful points) and in grade I with no signs. 100% of the sample referred cervical pain as initial symptoms and, to a lesser extent, other symptoms such as stiffness, dizziness, headache, paresthesia, nausea, vertigo or vomiting.

Results of the biomechanical tests

There were 47 kinematic assessments of cervical movement (92.2% of patients), fifteen assessments of hand strength (29.4%) and eight balance assessments (15.7%). The following were obtained: 31 cases (61%) with normal functionality, 10 (19%) with slightly altered functionality, 6 cases (12%) with altered functionality and 4 cases (8%) of non-cooperation during the biomechanical tests. The percentage of cases corresponding to each type of biomechanical result is presented in Fig. 2.

Comparison between pre-evaluation of sequelae and final assessment

The percentage of cases with and without sequelae in the pre-evaluation of medical examiners and in the final evaluation is presented in Fig. 3.

Table 1 shows, for each type of sequela granted, the number of cases with sequela, both in the pre-evaluation and in the final evaluation. In addition, the mean score of sequelae for each type of sequela is presented. The total number of cases with sequelae varies between the pre-evaluation and the final evaluation due to the change of medical examiner's criteria.

By comparing sequelae according to the type of biomechanical result, differences are observed between the medical examiner assessment of sequelae prior to the biomechanical assessment and the final assessment, as shown in Fig. 4. The difference in the assessment of sequelae between the pre-evaluation and the final assessment was statistically significant ($p < 0.05$) according to the ANOVA test for the set of cases with normal functionality. These differences were not statistically significant in the rest of the groups, whose sample size was much lower.

Medical assessments' opinion on the usefulness of biomechanical assessment tests

Data were collected from 49 of the 51 assessed cases and in 98% of cases (all but one) the medical examiner considered biomechanical assessment to be ''useful''. The criteria used to indicate the usefulness of the tests were: ''confirm or show recovery'' in 26 cases, ''confirm or show active

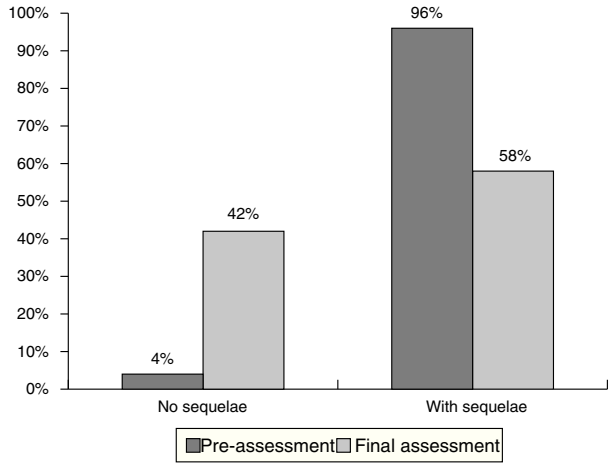

Figure 3 Percentage of cases with and without sequelae in the pre-evaluation and final evaluation of medical examiners (before and after knowing the results of the biomechanical tests).

Table 1 Summary of the number of cases with sequelae and their mean score in the pre-evaluation and final evaluation of the medical examiner after knowing the results of the biomechanical tests.

Type of sequela	No. of cases with sequela		Mean score of the sequela	
	Pre-evaluation	Final evaluation	Pre-evaluation	Final evaluation
Aggravation of prior arthrosis	3	2	2.67	3
Post-traumatic cervical injuries without spinal involvement	13	10	1.08	1.3
Post-traumatic cervical injuries with spinal involvement	7	1	1.71	5
Clinical picture derived from cervical hernia	4	5	4.5	2.4
Post-traumatic cervical syndrome	17	1	2.4	7
Mobility limitation of the cervical spine	0	10	0	2.8
Total	44	29	–	–

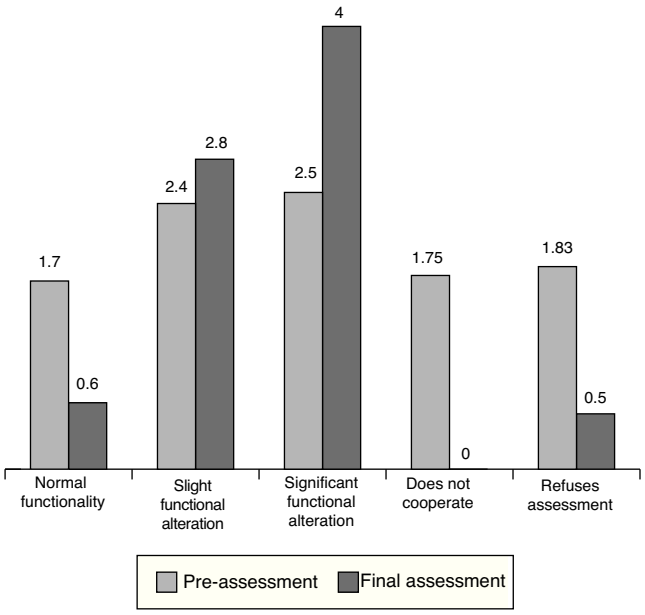

Figure 4 Mean score of the sequela for each type of biomechanical result in the pre-evaluation and final assessment of medical examiners (before and after knowing the results of the biomechanical tests).

symptom'' in 21 cases and ''confirm or show simulation'' in 2 cases.

Discussion

The characteristics of the sample of this study (65% women and mean age of 36 years in women and 35 in men) are similar to those of other studies on post-traumatic cervicalgia due to traffic accidents in a medical-legal context in Spain,[24,25] which strengthens the representativeness of our study sample. In the series from Pera Bajo et al.,[24] of 406 cases, the percentage of women was 59.6% and the average age of about thirty-six. In the sample from Rodríguez-Díaz et al.,[25] with 307 cases, female predominance was also found with 61.9% and a mean age of 35.3 years.

It is notable that the number of rejections to perform the test was a minority. Due to this it can be considered that the information protocol was effective, as it led to the injured people agreeing to perform the assessment. With the legislative change brought about by Law 35/2015,[2] the tests performed at the request of the assessing doctor would be part of the complementary examinations to which the patient may undergo to receive compensation; therefore, the rejection of the assessment could have influence on its attainment. Even so, it is interesting to note that most people in the assessment process voluntarily accept the biomechanical tests indicated by the medical examiner.

According to the indication criteria of the medical examiners, the most applicable biomechanical test was the kinematic assessment of cervical movement, which was performed in most cases. The dynamometric evaluation tests for hand strength and balance assessment were used on a smaller number of occasions and in this order. Bearing in mind that moderate/severe levels of persistent pain and disability continue to exhibit loss of active movement several years after injury,[26] it is logical that the assessment of cervical mobility is of interest in the assessment of sequelae. Thus, it would be interesting to contrast if this order represents the real interest of medical examiners by the different biomechanical assessment tests in the assessment of post-traumatic cervicalgia due to a traffic accident in future studies.

The most common result obtained in the biomechanical tests was *normal overall functionality*, which means that most of the cases whose assessment generated doubts had functionality within normality. It should be clarified that, in the case of the assessment of function related to cervical mobility and according to the biomechanical assessment reports themselves, normal overall functionality is not exempt from any type of alteration. In fact, in some cases, normal overall functionality can be accompanied by a limitation of movement in some of the planes, so it is not exempt from sequelae compensation due to mobility limitations. The cases with an *altered or slightly altered functionality* type of biomechanical result accounted for only a third of the sample. The proportion of cases that *do not cooperate* with the biomechanical assessment tests obtained in this study is clearly lower than the 50% simulation prevalence reported by some authors.[6] This result may be indicative of a lower real prevalence of simulation in the target population, or of the fact that those injured

people with an impression of simulation or exaggeration in the clinical consultation cooperate when dealing with an objective test. The sensitivity of the biomechanical assessment tests to detect non-cooperative behaviour has been previously demonstrated in the case of the methodology used for the kinematic assessment of the cervical spine[13] and is widely accepted in the case of posturography.

Taking into consideration the comparison between pre-evaluation and final assessment of the sequelae according to the traffic scale in force at the time of the study,[1] it can be seen that the medical examiner modifies their criterion after knowing the results of the biomechanical tests. They do so by following a trend: they assign a similar sequelae score among the entire sample of injured people in the pre-evaluation and, after knowing the results of the biomechanical tests, they change the score according to the test results. Hence, in the cases of normal overall functionality, with a lack of cooperation and rejections of biomechanical assessment, the sequelae score clearly decreases; it discretely increases in the case of slight alteration; and it increases considerably in the event of functional impairment. The lack of statistical significance in these results could be caused by the limited sample size in one of the groups.

Regarding the *type of sequela* granted, the most striking differences attributable to the fact that the medical examiner has the results of the biomechanical assessment are given in two cases. The first case is given in the sequelae due to *post-traumatic cervical lesions with spinal involvement* and in the *clinical picture resulting from spinal disc herniation*. In this case, there is a considerable reduction in the number of injured people that are given sequelae in the final assessment, although in those in which the sequelae persist, the average score increases. This seems to be related to the fact that most of the people evaluated have normal functionality and finally do not receive compensation for this type of sequelae; however, those who do receive it receive more because there is a real functional impact. The second case corresponds to the *limitation of motion of the cervical spine* and clearly increases in cases and score, since in the pre-evaluation there were no sequelae of this type. This may be justified by the fact that normal overall functionality that has been obtained in most of the sample may be accompanied by discrete movement limitations that may be the object of compensation for sequelae. From this information, it appears that there is a tendency to distribute the sequela points based on the objectification of the existence of functional alterations and their severity.

Regarding the determination of sequelae in other studies, there is great disparity and the percentages in which sequelae are reported range from 92% to 44%.[27] It seems reasonable that in the pre-evaluation of this study, a higher percentage (96%) was obtained since the cases of greater complexity were referred. However, it is striking that, after functional assessment, the percentage of patients with definite sequela is at an intermediate point (58%). It could be thought that the observed differences between the different studies may be due to a disparity of interobserver criteria and that the biomechanical assessment allows this possible bias to be limited, moving away from the extreme positions. However, this extreme should be studied in depth in the future to establish a definitive conclusion.

In relation to the main objective of the project, the result of the experimental phase indicates that the biomechanical assessment tests were useful for the medical examiners in the assessment of the people with cervicalgia from a traffic accident and in real conditions of application. This is consistent with previous experience regarding the application of these tests in this field.[15,22] In addition, it was observed that the participating physicians modified their criteria in different senses, both towards the increase and towards the decrease of sequelae. For this reason, we could consider that they have increased the accuracy of their opinions putting both recovery and the existence of pathology in objective terms.

However, there are a number of methodological limitations that could influence the generalisation of the results of this study and they should be noted. The first is that it has been carried out with the participation of only four medical examiners, who have participated voluntarily in this study and who have been deliberately trained for it in the context of this research project. The second has to do with the criteria for the prescription of biomechanical tests, which admitted a certain subjectivity. It would be interesting to find out whether equivalent results would be obtained with a sample derived from the application of other remission criteria of injured people for evaluation. Finally, it should be noted that the legislative context in which this study was carried out is no longer the current one. Thus, although preliminary, the results of this study are encouraging to validate the usefulness of biomechanical assessment in medical examiner assessment protocols.

The conclusions reached are:

1. The biomechanical assessment tests proved useful in the assessment of people with minor cervical trauma due to traffic accidents by medical examiners and under real application conditions.
2. Medical examiners evaluated the sequelae considering in the final decision making the results obtained in the biomechanical tests.

All these results, although preliminary, suggest that biomechanical tests in the assessment of people with post-traumatic cervicalgia due to a traffic accident could have a significant social repercussion. In addition, the possibility of providing medical examiners with complementary medical tests for objective assessment of the functional impact of injuries would contribute to providing better justice. Future research should be aimed at validating the results of this study with greater participation of medical examiners in the context of the new Traffic Law[2] and their new role in the extrajudicial procedures covered by the new *Organic Law of the Judiciary*.[11,12]

Conflicts of interest

The development of the methodology for carrying out this study and the corresponding preliminary study were performed with the help of the MAFPRE Foundation in its 2013 Research Grants Programme. This article was developed thanks to the collaboration of Centro Zaragoza and the support of the members of its Committee on Bodily Injuries, who

agreed to finance the biomechanical tests requested by the medical examiners participating in this study corresponding to the claims of those insured. The members of the Committee on Bodily Injuries are: Generali España, S.A. de Seguros y Reaseguros; Axa Seguros Generales, S.A. de Seguros y Reaseguros; Caja de Seguros Reunidos, Compañía de Seguros y Reaseguros, S.A. (CASER); MGS Seguros y Reaseguros, S.A.D.; Reale Seguros Generales S.A. and Zurich Insurance, PLC Office in Spain.

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Annex. Congresses and Conferences

Part of the content of this article has been previously presented:

- Camacho R, Pastor C, Marzo R, Mayans J, Giner J, Garcés L, San Martín CI. Medical-legal usefulness of biomechanical tests in cervicalgias following a traffic accident. XII Catalan Conference of Updates in Forensic Medicine, XVIII Conference of the National Association of Medical Examiners, XI Symposium on Medical-Practical Aspects in the Assessment of Bodily Injury; 21 Nov 2013; Barcelona.
- Pastor C, Errejón A, Vicente M, De Francisco E, Peydro F, Vivas MJ, Garrido D. Research project: Biomechanical functional assessment in traffic accidents. Cervical spine protocol. XII Catalan Conference of Updates in Forensic Medicine XVIII Conference of the National Association of Medical Examiners, XII Symposium on Medical-Practical Aspects in the Assessment of Bodily Injury, XI Symposium on medical-practical aspects in the Assessment of Bodily Injury; 21 Nov 2013; Barcelona.
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