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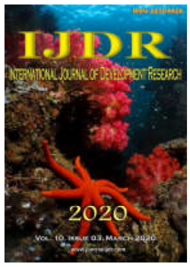

RESEARCH ARTICLE OPEN ACCESS

BIOMECHANICAL FACTORS INVOLVED IN CERVICAL FRACTURES TRAUMA, INJURY MECHANISM, INFLUENCE OF MUSCULATURE ON INJURY AND IMPACT AREA

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ABSTRACT

The trauma mechanisms that lead to a cervical fracture are complex and not well understood, since mechanisms of the same nature may culminate in different injury patterns. This study aimed to review the current literature about the biomechanical factors that contribute to cervical fractures trauma. The search was conducted in databases PubMed, LILACS, SciELO and Cochrane Library platforms. We used the descriptors "Biomechanical Phenomena", "Cervical Vertebrae" and "Fractures, Bone". Found 185 articles, of which 183 were from the Pubmed platform and two from Cochrane Library platforms, in the other search platforms studies were not found. The inclusion criteria were: studies published in the last 5 years that were fully available on the web. After using these filters, 16 studies were found, all from the Pubmed platform only. Exclusion of 11 studies. Selected 5 articles to compose the review sample. They were divided into 3 categories to be discussed more closely, namely: injury mechanism, musculature influence to the injury and impact site as fracture determinants. Cervical fractures traumas occurs through indirect mechanisms where the most common mechanisms are flexion, extension, compression and dissociation. Moreover, it is observed that the cervical muscles behave as a protective factor for cervical fractures trauma.

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INTRODUCTION

Cervical trauma represents 2% -15% of injuries and can cause important sequelae that negatively impact some prognoses, especially in cases involving traumatic spinal cord injuries, which correspond to alarming 45-60% and per year are recorded 179,312 new cases, which cause important neurological limitations. The incidence rate varies from 15 to 40 patients per 1 million inhabitants, being more prevalent in urban areas, a number that grows with each decade (Santos EAS *et al.,* 2009; Young AJ *et al.,* 2015; Chan CWL *et al.,* 2016). The main causes of cervical and vertebral spine trauma are falls from their own height (63%), followed by car accidents (25%), compressive impacts, high energy trauma, impacts during sports activities and, less frequently, injuries by firearm (7%), shallow water dives (3%) and assaults (2%) (Young AJ *et al.,* 2015; Ricart PA *et al.,*2017; Campos MF *et al.,* 2008; Dowdell J *et al.,*2018; Whiting WC, 2015). The trauma mechanisms that lead to a cervical fracture are complex and not well understood, since mechanisms of the same nature may culminate in different injury patterns. There are factors that may be influencing agents in different types of trauma, such as the magnitude and the direction of the forces causing the injury, the spine orientation at the trauma moment, as well as predisposed structures (Nightingale RW *et al.,* 1996). Another factor that can influence the type of trauma is age. It is known that skeletal muscle strength depends on bone mineral content, therefore, considering that the relationship between age and bone quality is inversely proportional, it is suggested that age is a data of significant importance and may be correlated with the type of fracture, such as compression injuries (Yoganandan N *et al.,* 2018). Therefore, this study aimed to review the current literature about the biomechanical factors that contribute to cervical fractures trauma.

MATERIALS AND METHODS

Study Design: This is an integrative review, whose guiding question designed to start the search was: What are the main factors that influence the kinematics of cervical fractures trauma?

Data Collection: The search was conducted in June 2019 on the PubMed, LILACS (Latin American and Caribbean Health Sciences Literature), SciELO (Scientific Electronic Library Online) and Cochrane Library platforms. We used the descriptors "Biomechanical Phenomena", "Cervical Vertebrae" and "Fractures, Bone".

Data Analysis: After using the descriptors we found 185 articles, of which 183 were from the Pubmed platform and two from Cochrane, in the other search platforms studies were not found. Inclusion criteria were: studies published in the last five years that were fully available on the web. After using these filters, 16 studies were found, all from the Pubmed platform only. Then there was the analytical reading of the title and the summary of 16 articles available on the platform, allowing the exclusion of 11 studies. Regarding the excluded studies, five were due to address only the post operative kinematics; one study addressed only the context of patients undergoing orotracheal intubation; another dealt with complications of surgical procedures; another concerned chronic degenerative diseases and three did not address the issue in any aspect. Thus, being selected five articles to compose the review sample (Table 1). In addition, studies that dealt with literature or editorial reviews were not considered for the sample of this study.

Table 1. Articles Summary found in databases PubMed, Cochrane Library, LILACS; SciELO

Platform	Found	Selected	Sample
PubMed	183	16	5
Cochrane Library	2	0	0
LILACS; SciELO	0	0	0

RESULTS

The selected articles were organized in a table so that the topics considered pertinent of each study were exposed, such as: author, type of study, study subjects, objectives, main results and conclusion (Table 2). There were three articles from 2014 and the most recent was from 2017 and one from 2016, thus complying with the inclusion criteria, which allow the inclusion of articles published in the last 5 years, however, no articles from 2015, 2018 and 2019 were found. In the studies that made up the sample, most (4/5) used synthetic models for the analysis, while the other study used human cadavers. All studies were published in English. Thus, based on the articles reading, they were divided into 3 categories to be discussed more closely, namely: Injury Mechanism, musculature influence to the injury and impact site as fracture determinants.

DISCUSSION

Injury Mechanism: Cervical trauma occurs through indirect mechanisms, where the force applied to the skull is dissipated to the spine Defino HL (2002) associated with various variations of trauma kinematics along with the individual's initial position, cervical region, age and use of the affected region muscles Yoganandan N *et al*. (2018) However, flexion trauma is the most common type of cervical trauma Marchetto A *et al*. (2002), where this type of injury can lead to fracture of the vertebral body (Yoganandan N *et al.,* 2018; Marchetto A *et al.,*2002). Such facts corroborate the findings of the study. Analyzing the present study results, the positioning in vitro studies consisted of different arrangements to select areas of the skull primary impact Ivancic PC (1976) and exploring the directions of forces capable of influencing trauma to the cervical region of the compressing spine, shear, flexion and extension (Cusick JF *et al*. 2002). There are several types of injuries caused by flexion mechanism, such as anterior atlantoaxial subluxation, rare injury when there is no pre-existing injury, and may also occur in the context of football during the Tackle movement - Impact between players to prevent the play progression (Dowdell J *et al.,* 2018 ; Whiting WC, 2015). Another injury resulting from this mechanism is the odontoid process fracture, where there is anterior displacement of C1 in relation to C2 (Dowdell J *et al.,*2018; Boughton OR *et al.,*2015), being the most common cervical spine fractures (Boughton OR *et al.,* 2015).

In the case of extended trauma, traumatic spondylolisthesis may occur, in which the C2 pars interarticularis fracture occurs, being known as hangman's fracture, since it can occur in hanging attempts, but the major cause today is car accidents (Dowdell J *et al.,* 2018). In addition to Teardrop fracture at C2 fracture, fracture that occurs by avulsion of the anterior longitudinal ligament during hyperextension. In addition, fractures of the odontoid process may also occur due to anterior sliding of C1 relative to C2 (Dowdell J *et al.,* 2018). An example of compression injuries is a C1 fracture, which can have various patterns, including atlanto-occipital dislocation, also called internal decapitation, and Jefferson's blast, which usually presents as four fractures in the arches from atlas. The contexts in which C1 fractures are most easily encountered are shallow water dives and vehicle collisions (Mead LB *et al.,* 2016). Concerning the dissociation mechanism, occipatocervical dissociation is mentioned, a lesion in which there is total or partial rupture of the ligaments between the occiput and the first cervical vertebrae. The most common contexts in which these injuries occur are high-speed motor vehicle accidents and pedestrian trampling (Kasliwal MK *et al.,* 2016). Correlating results (Yoganandan N *et al.,* 2018; Nightingale RW *et al.,* 2016) present in the study, it is possible to understand that the positioning for forces of greater influence, such as compressive, consists in cervical spine rectification. Characterized by a cervical spine slight flexion, we can mainly associate the joint between C1-C2 due to vertebral movement in flexion. The atlas may extend due to the biconvex nature of the lateral joints and a compressive posterior force to the C1-C2 joint contact point (Bogduk N *et al.,* 2000). This is a mechanism that could possibly explain the compression fractures present in the results Ivancic PC (2014a) , however the specimens tested took as their initial position the human cervical natural lordotic curvature showing different types of fractures, but predominantly these being of axis body.

Table 2. Synthesis of the articles selected for the literature review according to the author, type of study, subject, objectives, main results and conclusion

Author	Type of Study	Subject	Objectives	MainResults	Conclusion
Yoganandan N et al.,2018	Quantitative experimental	Two groups withdifferent ages.In group Awas appliedacompressionby contactin the head inupright positionincomplexeshead-neckinhumans .In group B were performed inverted tests with simulated back, within thatgroup wereperformed twotest typesonesimulating themuscle actionandother not.	Analyze theinjuries andforces inmany differentmechanismsof cervical traumaregardingage.	In group A themechanismsof traumawere:compression(60%),flexion (30%)and extension(10%).Themost ofinjuries werefractures of thevertebrabody(13/20)and theage wasanimportantvariantto theinjuries,the older you are, the greater the risk of injury.In group B the tests withoutmuscularactivityhad themostof injuriesdue to the extension mechanismsandthe age wasan important variant,butinverselyproportionalto the risk oflesion.On the other hand, in the testswithmuscular activitythemainmechanismsof injury washyperextensionand the agewas not an importantvariantfor the riskof injury.	The testsperformedstandinghad moreinjuries in thevertebra bodybecause of thecompression mechanisms,on the other hand, the test ofupside downwere more related to theextension mechanismsandinjury of softfabrics.That said, thefractures of thevertebraebodyaremorerelatedWith the agethan the injuriesof softfabrics.
Nightingale RW et al.,2016	Quantitative experimental	It was used a head andneck model to the fall of the headscomputer Simulations.	The goalof the study wasuse a computermodel of thehypothesesaboutthecompressiveimpact of thecervicalcolumn :01.Activecervicalsmusclesdo notaffectthe columncompressionbecause they don'treact tocompression.02.Restrictionsof the back movementdo notaffect thecompressionin columnbecause the injuryoccurs beforethat theback canchange thedirection of the backmovement.	The compressionforceat articulation depends on the level of vertebrae restricted back and from the muscle condition. The back restriction hada minor effect on compression, shear and momemt, only one small increase. To the pre-flexion angles close to 30° the compression force increased until 700N.It was noticedthat the muscles had effect on magnitude and inthe peak load time regarding the cervical, by having larger loadpeaksandshear,besides keep the hihg levelsof strength bymore time.It was notnoticed important effect at the time.	Pre-flexion, for leaving the cervical more straight, made it possible a high orderbucklingand largerloads ofcompression,being able tochange the typeof trauma.The back restrictionhad little effectat the peak ofstrength and intimeregarding the cervical becausethe back position and attitudevariesminimally duringthe first10ms which isthe time requiredtoreachthe peak of strength,do notgiving the requiredtimeto change the movement direction. The muscles presenceincreased the buckling, one possibleexplanation isthat due toa biggerst ability provided by the muscle, the neckstay longer up right increasing the strength ofcompression, and, due to this was noticed that themusclesdo notreducetrauma,butas a matter of factmayincrease them.
Ivancic PC, 2014a	Studybiomechanical in vitro	13 columnspreservedfrom cervical high, occipitoto C3, with average o age 83.1 years.	Investigate the fractures mechanisms of the axis (C2) due to the simulated head impacts.	5 speciespresentedthe fracture, with impacts on higher front region on medium line (1); in the front region laterally upper (3); in the region side top (1) at speed in velocity 3.4m/s.	Impacts caused in frontal and side region of the human head are risk factors to C2 fracture.
IvancicPC,1976	Studybiomechanical in vitro	13 columnspreservedfrom cervical high, occipitoto C3, with average o age 83.1 years.	Investigate mechanisms of odontoides fractures due to head simulated impacts.	4 specimens presented the fracture,with impact in the higher front region on medium line in velocity 2.6m / s.	Impact caused in frontal region is a factor of risk to fracture of odontoid process in C2.
IvancicPC,2014b	Studybiomechanical in vitro	13 columnspreservedfrom cervical high, occipitoto C3, with average o age 83.1 years.	Investigate mechanisms of fractures like *plough* due to impacts simulated head	Only one specimens presented thefracture with impact on higher front region on medium line in velocity 2.7 m / s.	The types of impacts studied could not in a clear way reproduce the biomechanics required to emergence of the fracture in more than one specimen.

Thus, it is not possible to report positioning biomechanical linearity involved in cervical trauma.

Musculature on injury influence: It is important to highlight that in all studies found trauma to the cervical region occurred at some point, where its degree of injury is possibly related to body position during the impact on which a cevical pre-flexed and the use of musculature delayed the onset of the injury lesion, but increased its degree at the end of the event (Nightingale RW *et al.,* 2016). Similar findings from Brolin K. show that muscle activation protects the upper cervical spine in frontal impacts, reducing the risk of spinal ligament injury and lateral impacts. Protecting ligaments and reducing tension at all levels of the spine [Brolin K *et al*. (2005)]. The studies included in the review (Ivancic PC, 1976; Yoganandan N *et al.,* 2018; Nightingale RW *et al.,* 2016; Ivancic PC, 2014a; Ivancic PC, 2014b) that simulated cervical musculature underscore the importance of researches carried out in *in vitro* studies that took care with the mounting method of the test specimen. Preliminary results from Saari A suggest that load simulation that may be similar to muscle forces in vitro provides significantly different in vitro impact results from the cranio-cervical complex than similar biomechanical tests in which the musculature is not simulated (Saari A *et al.,* 2013).

Impact site as fracture determinants: One of the risk factors for cervical vertebrae fracture is the impact on the frontal region, with emphasis on the odontoid process of C2 (Bogduk N *et al.,* 2000). Representing 7% to 15% of cervical spine fractures, however, these fractures have very different characteristics according to the patient's age (Child, Young Adult, Elderly) such as incidence, epidemiology and trauma mechanism Defino HL (2002). Studies that specifically address the relationship of impact sites with a specific type of fracture have not been seen in the literature; however, there is an association between cervical trauma and craniomaxillofacial trauma, as well as approached by (Elahi MM *et al.,* 2008), who highlighted the relationship between craniomaxillofacial trauma and cervical fractures, since in 3.69% of patients with fractures in these regions also had associated cervical spine fractures, an example would be the relationship between base fractures of the skull and occipital condyle with lesions in the frontal and supraorbital bones. Babcock L *et al.,* (2018) found that the impacts that are most related to fractures in cervical vertebrae are those that occur in the upper third of the face, as well as in (Lalani Z *et al.,* 1997) who showed in his studies that injuries of the spine upper portions (C1-4) is more related to lesions on the lower third of the face, with the most prevalent being jaw injuries, while injuries to the lower segments of the cervical spine (C5-7) are more related to lesions on the middle third of the face. face. A study by Richard C SCULTZ (1667) studied 400 patients who had facial trauma, and found a relevant association with head and cervical spine injuries, since about 54% of patients would have these injuries concomitantly.

Conclusion

Therefore, the biomechanical factors knowledge involved in trauma is important, considering that the injury, flexion, extension, compression and dissociation mechanism are the most common, which can cause several fractures, which may be associated with both car accidents and injuries resulting from sports practice. Moreover, it is observed that the cervical muscles behave as a protective factor for cervical fractures trauma in this topography and that the trauma impact site may suggest the clinical topography of the injury.

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