PREVENTION & REHABILITATION OF DIVERS' CERVICAL VERTEBRAE INJURIES FROM THE PERSPECTIVE OF BIOMECHANICAL BALANCE

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In this paper, the theory of biomechanical balance of the cervical vertebrae (CV) from medical studies was used to help explain the causes of CV injuries suffered by divers. By re-analysing the data of CV injuries of 312 divers, we concluded that CV injuries may be caused by damage of the biomechanical balance of the CV. Based on this theory, combined with some medical knowledge - suitable exercises and appropriate therapeutic intervention for coaches, therapists and trainers were suggested to treat and prevent CV injuries in sporting events.

KEY WORDS: biomechanical balance, cervical vertebra injuries, prevention, rehabilitation.

INTRODUCTION: Cervical vertebrae (CV) injuries are one of the most common injuries suffered by divers. Most research is done on the clinical investigation and prevention of it (He, 2005, Zhou, 2005), but seldom is conducted on the relationship between the biomechanical balance of the CV and its related injuries. Biomechanics of cv balance state that the CV are not in abnormal strain under physiological loads, and they have no excessive abnormal activities of functional spinal units. Medical research (Jiang et al. 2002, Ran, 2003) has shown that CV diseases were closely related to the biomechanical imbalance of the CV - not only from its etiology and pathology, but also from its treatment and prevention. Accordingly, some medical studies focus on treating CV diseases by restoring equilibrium to the biomechanical balance of the CV. It is both logical and intuitive to assume that this theory and its methods can be applied to CV injures. This paper studies the mechanism, prevention and rehabilitation of divers' CV injuries from the angle of biomechanical balance of the CV.

METHOD: Paying extra attention to the anatomical characteristics of the CV and the biomechanical balance principle from medical studies, we reanalysed data collected from this field in order to find out the causes of divers' CV injuries and their categories. Clinical checkups were conducted on a sample of 312 Chinese divers, which comprised of 165 male and 147 female divers whose ages are in the range 9 - 24 with 16 being the average. It found out the rate of cervical vertebra injuries and the main causes of them. At the same time, an image check was conducted on 173 randomly chosen divers. Through X-ray analyses, the conditions of cervical vertebrae and the categories of these injuries were clear. It also contained an analysis of the physical characteristics of diving - which may damage the biomechanical balance of the CV. Lastly, it outlines measures and methods that can be taken to prevent CV injuries in the perspective of biomechanical balance and by the analysis of principles of sports injury.

RESULTS: The conditions of biomechanical balance of CV: Ordinary people's CV balance and stability are maintained by two parts. First is endogenous balance: which includes centrum, accessories, intervertebral disk and connected ligament which forms static balance. Second is exogenous balance: this mainly concerns regulation and the control of muscles which form dynamic balance as the original source of energy. If any organ contained among these two systems does not work well with others, the normal biomechanical balance of the CV will be lost. As Jiang et al (2002) proposed - that at static balance in the CV, the inter-vertebral disk is the key part in the bearing system. The ligament helps maintain spinal stability, especially for the upper part of the CV (Weiss, 2002). From the neck muscle mechanical analysis (Zhang, 1986), it finds out $C_{4\text{-}5}$ muscles are weak and

have the worst stability in neck curved peak. The CV are often in dynamic balance during movement and its power-line movement will generate torque. So the divers need to keep their muscles moving in order to counteract this torque and maintain a balance. Enhancing the moving strength of the divers' neck muscles is very important for the dynamic balance of the CV.

The results of the checkups of the divers show that 95 out of 321 divers presented a history of neck injuries（30.45%), of which 42 divers' injuries are caused by a single reason, and the remaining 53 are caused by a variety of reasons, such as unskilled technique at the commencement of training, false entry work, wrong rip entry, incorrect angle entry and insufficient strength in cervix when entering water. The 173 X-rays show that only 85 cases are completely normal, 43 cases are of exercise-induced adaptive changes, and 45 cases are of CV injuries. The categories of the above injuries are listed as atlantoaxial joint dislocation, CV degenerative, anterior dislocation of atlas, congenital fusion of CV and cervical fatigued fractures (see table Ⅰ, Ⅱ).

Table Ⅰ Causes of Cervical Vertebra Injuries

Causes of CV Injuries	N (Total = 95)	%
Unskilled technique at the commencement of training	87	91.6%
Incorrect rip entry	84	88.4%
Incorrect angle of entery	61	64.2%
Lack of strength in neck	65	68.4%

Table Ⅱ Types of Cervical Vertebra Injuries

Type of CV Injuries	N (Total = 45)	%
Atlantoaxial joint dislocation ,	20	44.4%
Cervical degenerative changes	15	33.3%
Anterior dislocation of atlas	5	11.1%
Congenital vertebral fusion	4	8.9%
Cervical fatigued fractures	1	2.2%

DISCUSSION AND RECOMMENDATIONS: The survey finds that the rate of divers' CV injuries is as high as 35.45%. These 173 X-ray samples show that 45 divers have CV injuries in minor or medium degrees and a minority have severe injuries. These injuries are mainly caused by the water pressure formed during the entry process. The categories of these injuries are listed as atlantoaxial joint dislocation, cervical vertebra degenerative, anterior dislocation of atlas. The X-rays show that atlantoaxial joint dislocation and anterior dislocation of the atlas all belong to abnormal atlantoaxial dislocation, indicating the laxity of the atlantoaxial ligament and joint and the over-range of motion as well as the destruction of endogenous balance of cervical vertebrae. The reasons are related to the previous ones, particularly in the entering process. When divers perform head flexion and extension, it is easy for them to have joint instability and thus form atlantoaxial joint dislocation. In the survey, 15 cases are of cervical vertebra degenerative, in which there are varying degrees of vertebral body hyperosteogeny. The intervertebral space of $C_{4\text{-}5}$, $C_{5\text{-}6}$ is narrow and shows typical degenerative changes of cervical spondylosis. Because of the worst stability of cervical exogenous $C_{4\text{-}5}$ and the trauma or chronic soft tissue injuries, plus muscle cramps caused by imbalance, the CV injuries inevitably occur in the central point of $C_{4\text{-}5}$.

As we know, the head and upper limbs make contact the water firstly during diving. Even if the entry into the water is performed correctly, the largest enduring force is 16 to 25 times that of the body weight (Stevenson, 1985). According to the '*moment balance principle'*, if the angle into the water is not vertical and thus forms an acute angle between the CV curve and the horizontal axis i.e. the water, the pressure placed on the cervix will be greatly increased. When the atlas makes contact with the water, the resulting bend or extended state will add strain to atlanto-axial ligament, and cause avulsion or possibly a fracture. When the external

force makes the CV exceed its natural range, it will shift one side of the small joints too much and the other undergoes a similar shift in the opposite direction. Thus, it results in unilateral joint dislocation. The above cases are all caused by the instant imbalance between the muscle strength and the external force, so that the power balance of the CV is perturbed, resulting in acute traumatic CV injury. This catalyst accelerates the detrimental effect on intervertebrae discs, small joints, vertebral body and other parts of the body. Day by day, this impact will damage the endogenous balance of CV factors, and cause chronic damage to CV. Divers should rotate their necks in order to complete the aerial somersault and twist. This kind of rotating movement will easily cause injuries to the ligaments, muscles and joints of the neck.

Maintaining the biomechanical balance of CV includes two aspects. First, improve self-ability in maintaining CV balance (including muscle strength and joint-ligament flexibility). Second, reduce the outside force to the CV during diving (including the angle of entry, the technique of rip entry, movements of the neck and head during the diving process). So the specific preventative measures for CV injuries are summarised as follows:

● Those who have congenital CV malformations are likely to suffer from CV injuries due to their abnormal anatomical structure and defects in their endogenous stability. These individuals are not suitable candidates for diving exercises.

● Further study should be undertaken regarding the techniques of rip entry and eradicate the incorrect aspects of their water entry.

● Strengthen the neck ligaments and exercise muscle groups in order to overcome the pressure caused by the water to the neck and head. Two methods are listed below which are suggested to help with this.

Method one: Undertake static training for neck muscles. Assume the prone position, then extend your chest and remain balanced for one minute. Then turn your head slowly in a controlled manner from right to left with six repetitions for each set. In this type of exercise, sports joint capsule, ligaments and muscles around the joints are continuously stretched so as to improve muscle coordination.

Method two: Assume the prone position, then place your hands close to your thighs which are in a lateral position, with feet closed together and your head and legs raised as high as possible. Do this for 5 to 10 seconds each time, and repeat 5 to 8 times daily. This exercises the neck muscles and ligaments, which helps improve the stability of the CV, while also helps strengthen the neck and back muscles through weight-lifting exercises at the same time.

● Focus on the preventive cervical traction and relaxation and then undergo an acu-point massage after training. e.g. use two thumbs or a middle finger to press and smear Fengchi, Jianjing, Chien Wai Shu, Waikuan, Meeting Valley and the tender point. Through this massage, blood circulation is improved and the local flow of lymph is promoted so as to add nutrition to body tissues. It should be obvious that when these tissues become soft and flexible, their functions are improved.

● Perform regular inspection of the CV. Once CV injuries happen during competitive training, medical workers can use traction, physical therapy and other methods to improve the microcirculation status around the divers' neck.

Undertaking these methods will strengthen and promote the divers' nutrient metabolism and muscle, so as to help restore (and improve) the dynamic and static balance in the CV.

CONCLUSION:

Understanding the biomechanical balance conditions of the CV and the causes of this kind of imbalance will be helpful in the design and implementation of correct training methods that will help prevent CV injuries. Following the advice that this paper has mentioned, implementing the preventive methods and the performing the exercises which improve neck strength in daily training will be easier than recovery training and it's a good way to prevent injuries and save valuable training time. As the adage says - "Prevention is better than cure!"

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