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Neck braces in motocross: different designs and their effects on muscular activity of the neck

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Abstract

Neck braces are designed to prevent traumatic injuries of the cervical spine by transferring the forces occurring at the head and spine to adjacent body structures, mainly the torso. Gorasso and Petrone (2013) showed that neck braces can influence the muscular activity of the neck during motocross riding, but their results only refer to one analysed neck brace system. Based on their results, this work analyses the effect of different neck brace designs on muscular activity of the neck during specific events in motocross riding. During on-track-measurements the muscular activity of m. sternocleidomastoideus and the upper part of m. trapezius were recorded in three different conditions: driving without neck brace (C1); driving with neck brace system A (C2); driving with neck brace system B (C2). For all the conditions mentioned the following riding events were examined: (a) turn, (b) bumps and (c) jump. Based on the results, it can be concluded that wearing a neck brace during motocross riding has various effects on the muscular activity of the neck. Depending on the neck brace design, the effects can be an increased or a decreased activity of the involved muscles and a change in the distribution of muscular activity in the neck. According to the recent results and with additional research, an improved neck brace system with optimized design can be developed, which not only serves protective purposes, but also can help to relieve the riders neck muscles during riding.

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Keywords: motocross, neck brace, sEMG, muscular activity, protective equipment

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1. Introduction

Motocross is a high speed motorsport, containing off-road racing, jumping over artificial obstacles with several meters of jump height, riding along high speed sections and busy race tracks. Thus, motocross often involves a wide range of injuries, reaching from fractures and bruises to permanent traumata. Neck injuries are among the most severe causing irreversible damage to the spinal cord, which may lead to different forms of paraplegia. These injuries are mostly caused by hyperflexion, hyperextension, hypertranslation or axial loading of the cervical spine in events of a crash.

In 2004, Dr. Chris Leatt developed and introduced the first neck brace system designed to prevent the aforementioned injuries. By limiting extreme neck movements and distributing external impacts and loads to the torso, neck braces aim to prevent and avoid traumatic damages of the cervical spine. The non-permanent connection to the rider and an easy handling, quickly made neck braces popular among a wide range of two-wheeled sports. After the first mass-produced neck brace was released in 2006, their use were rapidly established in various bike sports, especially in motocross riding, enduro and rally sports and downhill mountain biking.

In addition to their injury-preventive purpose, neck braces can also influence the riders performance by limiting his/her range of motion (ROM) in the neck. Gorasso and Petrone [1] published a work about neck braces influence on the muscular activity of the neck and ROM of the head during motocross riding. They showed that wearing a neck brace during motocross riding take influence on specific muscles of the neck. A fatigue effect in several ways was observed, but also a supporting effect due to neck braces, especially during long distance races was proven. Additionally, a restricted ROM in flexion, extension and lateral flexion of the head was found, whereas the rotational ROM of the head was not influenced by wearing a neck brace. Within their study, Gorasso and Petrone regarded only one neck brace system. Therefore no statement can be made how far specific brace designs take influence on the muscular activity of the neck during motocross riding.

To bridge this gap of knowledge regarding the effect of neck braces on riders this study describes the influence of different neck brace designs on muscular activity of the neck. It was expected that (1) selected muscles of the neck show less activation when a neck brace is worn than without neck brace, (2) that different neck brace designs lead to different amounts of muscle activation and (3) that during different events typical for motocross riding similar changes can be seen throughout all different conditions (no neck brace, neck brace design A or B).

2. Methods

A field test was conducted consisting of on-track measurements, during which neck muscle activity of one subject was recorded for riding with two different neck brace designs.

In the course of the field test, muscular activity of one subject was measured using a portable EMG system (developed and set up by the department of Biomedical Engineering, UAS Technikum Wien). Two muscles were identified to contribute most to the neck and head movement during riding: m. sternocleidomastoideus (scm) and the upper part of m. trapezius (trap). Both muscles work synergistically to move and stabilize the head during motocross riding.

The EMG system (Figure 1c) operates on a bipolar surface electrode configuration and is based on an ADS1298 (Texas Instruments, Dallas, USA) 8-channel and 24 bit analog-to-digital converter (ADC). It includes an analog low-pass filter (cut-off frequency 350Hz), an accelerometer and a micro-SD data logging device on which the information of one muscle per channel can be recorded with a frequency of 1000Hz. Embedded into a plastic and splash-proof case, the EMG system is suitable to be used in field testing under rough conditions. Two Ag-AgCl surface electrodes with a diameter of 20 mm (Ambu Blue Sensor N, Ambu A/S, Ballerup, DEN) per muscle, which were placed with an interelectrode distance of 20 mm along the length of the muscle-belly following the recommendations of [2], were used on both sides. The reference electrode was placed on the skin covered backside of vertebra prominens (C7). To avoid electrode and cable movement artifacts, additional adhesive medical tape was attached to give extra fixation of electrodes and cables (Figure 1a, Figure 1b). Due to terms of EMG data normalization, the subject performed three isolated MVC contractions for each muscle regarded. Furthermore to prevent damage in case of crashing, the EMG system was put into a waist pack that was worn by the subject during the measurements.

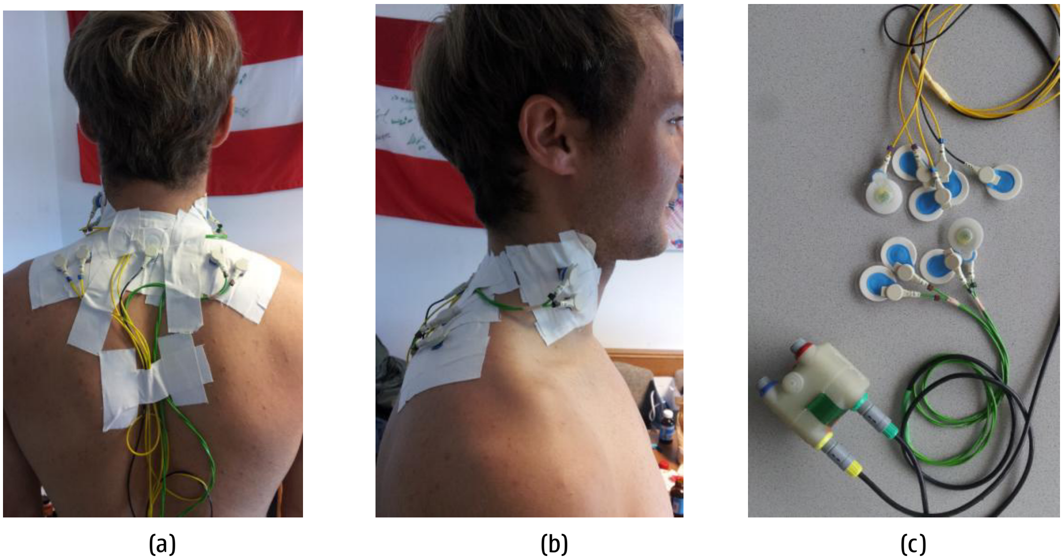

Fig. 1. EMG setup for the field tests (a) bilateral electrode placement, dorsal view and (b) sagittal view, (c) portable EMG datalogging device with cabling and electrodes.

Fig. 2. Neck braces viewed from the side. (a) neck brace model A with especially flat design; (b) neck brace model B.

Two different neck brace systems (A and B) with different design concepts were used in the measurement. Although providing the same functionality, system A (Figure 2a) offers a much flatter design than system B (Figure 2b), resulting in a less limited ROM of the head but also in a reduced preventive and supporting performance while riding.

The field test was conducted on a motocross track near Vienna (AUT). The track was approximately 1.4 kilometers long and included straights, jumps, left and right turns and a sequence of successive bumps. Due to its flat design with only small height differences, the track is mainly used for recreational riding and can be classified as less-demanding.

The subject, who was informed about the goals and methods of the study and gave his consent to participating, was a 23-year old, male and semi-professional motocross rider, who is used to riding with a neck brace. The subject was asked to perform several rides under three different conditions : condition 1 (C1) - riding without neck brace, condition 2 (C2) - riding with neck brace system A and condition 3 (C3) - riding with neck brace system B.

To support data evaluation, two GoPro Hero 3 cameras (GoPro Inc., San Mateo, USA) were placed on the drivers helmet and at the bikes handlebar, respectively. The camera at the handlebar was adjusted to get further information about the drivers head movement. Helmet cameras information was used to visually identify the start and ending times of three specific motocross riding events: (a) right turn, (b) bumps and (c) jump - events which will be further analysed in data evaluation. The GoPro cameras and the EMG system were synchronized by an acoustic and manual event before the start of every condition. During the field test, the subject wore a neck brace compatible motocross helmet Fox V4 (Fox Head Inc., Irvine, USA). After three laps completed within each scenario, the subject stopped and data were read out from the datalogging device.

Data were analyzed using Matlab 7.11.0 (MathWorksInc., Natick, USA) and Microsoft Office Excel 2007 (Microsoft Coorp., Redmond, USA). EMG data was high-pass filtered with a cut-off frequency of 10Hz and additionally smoothed by applying a root mean square (RMS) routine with a window size of 25ms [3, 4]. Additionally, EMG- signals were MVC and time-normalized for each event, using the aforementioned video information. For each muscle, event and condition the maximum EMG amplitude in each lap was detected and mean and standard deviation were calculated.

3. Results

EMG data show specific characteristics for the conditions observed. In Figure 3 it can be seen that muscular activity of m. sternocleidomastoideus and m. trapezius change for each condition. Whereas C1 (no neck brace) and C2 (neck brace A) show similar characteristics of muscle activity of m. sternocleido- mastoideus and m. trapezius for both body sides and for every event regarded, condition 3 (neck brace B), however, displays different results. Throughout C1 and C2, m. sternocleidomastoideus is clearly more activated than m. trapezius.

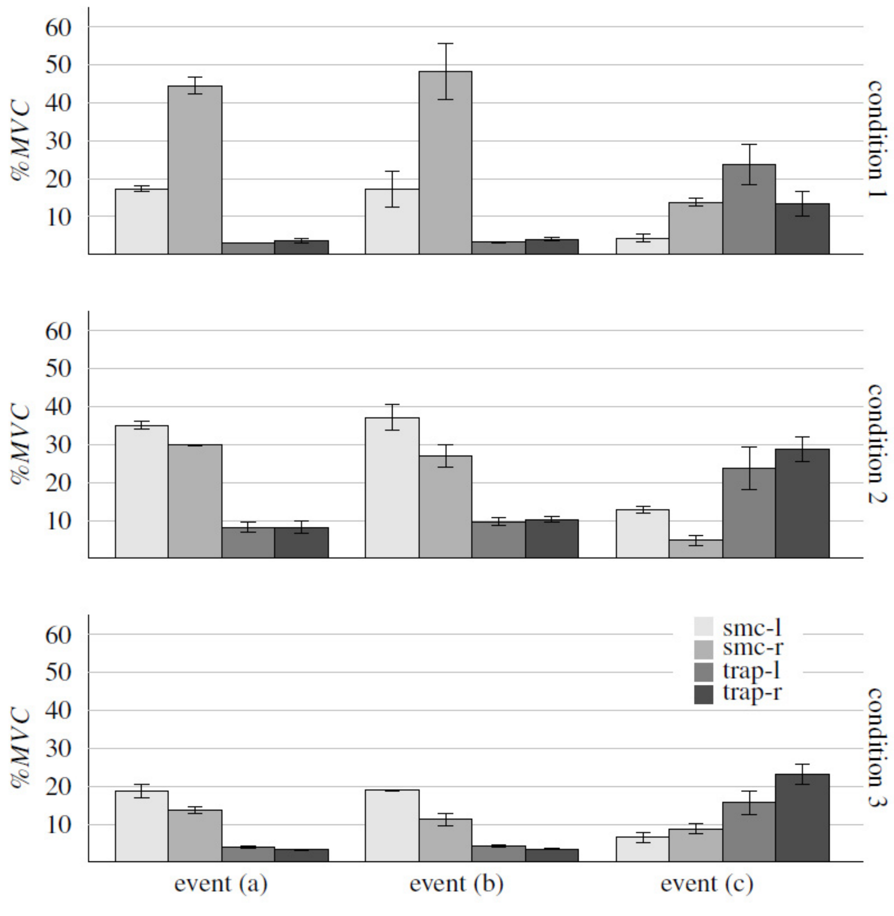

Fig. 3. Maximum mean muscular activity ± standard deviation for all conditions (top: C1 (no brace), middle: C2 (brace system A), bottom: C3 (brace system B)) of the measured muscles (m. sternocleidomastoideus (scm-l: light grey, scm-r: medium light grey) and m. trapezius (trap-l: medium dark grey, trap-r: dark grey),for all events (turn (a), bumps (b), jump (c) and all three scenarios (no brace (C1, light grey))).

While the right scm shows higher activity than left scm in event a (right turn) and event b (bumps), the opposite can be observed for event c (jump). During all events, m. trapezius activity is still less intense than m. sternocleidomastoideus activity which is nearly evenly distributed to both body sides. In opposite to characteristics of C1 and C2, a higher activity of m. trapezius and less activity of m. sternocleidomastoideus was detected within C3. Whilst activity of left and right scm is almost equal; the intensity of m. trapezius activity differs throughout the events. m. sternocleidomastoideus and m. trapezius show highest activity in event b, within all scenarios. Again, C1 and C2 share similar characteristics for m. sternocleidomastoideus and m. trapezius, whereas C3 displays the opposite, with a higher activity of m. trapezius compared to m. sternocleidomastoideus, throughout all events. In event a and event b, m. sternocleidomastoideus displayed a much higher amplitude than m. trapezius, while the right m. sternocleidomastoideus shows highest activity, for C1 and C3. In event c, the left m. sternocleidomastoideus is more activated than right one, for condition 1 and C3. Considering all events for C3, m. trapezius is still more active than m. sternocleidomastoideus. Only in event a, activity of the left m. trapezius is higher, compared to the right body side.

4. Discussion

From the results of the trials and the data obtained, it can be concluded, that neck braces take influence on neck muscle activity, while the effects on muscular activity are depending on the specific neck brace design.

Whereas neck brace system A offers a very flat design, the design of neck brace system B is higher and therefore more contact between helmet and brace can occur.

The similarities of muscle activity recorded for C1 and C2 can be related to the flat design of neck brace sys- tem A. Due to its low design, little contact occurs between helmet and neck brace, therefore EMG activity riding with neck brace system A (C2) is similar to riding without brace (C1). Similar to riding without neck brace, the rider cannot rest the helmet on the brace and therefore has to stabilize his head using muscular activity of m. sternocleidomastoideus.

Data obtained during C3 show that helmet and braces contact can result in higher muscular activity (m. trapezius), but can also have a supporting effect, yielding decreasing muscle activity of m. sternocleidomastoideus. As a result of frequent helmet and brace contact in the rear section and the rider trying to extend the neck, the rider pushes against the contact and hence higher muscular activity of m. trapezius can be observed. In contrast to the higher activity of m. trapezius in C3, less activity of m. sternocleidomastoideus can be explained by the riders attempt using the higher design of neck brace system B for resting the helmet onto the brace and therefore relaxing his neck muscles, respectively, left and right-sided m. sternocleidomastoideus, during specific track events (turn).

Less muscular activity in event c along all scenarios can be reasoned to external forces occurring. As a result of accelerations and bodys inertia while jumping, the head remains in abeyance, muscles are not required for head stabilization and hence yielding less activation of m. sternocleidomastoideus. For event b, the observed excessive muscle activity can be inferred from a highly demanding and intense character of riding along bumps which are often crossed within high-speed sections. While crossing bumps with high velocities, large external forces and big accelerations, respectively, are affecting the rider. Accordingly, the rider focuses on his head stabilization, resulting in higher activation of m. sternocleidomastoideus and m. trapezius.

Regarding neck brace design influences on muscular activity of the neck presented in this work, improved neck brace systems can be designed in the future taking specific requirements of different bike sports into consideration. While offering a supporting effect or less influence on ROM of the head, future neck braces should be designed regarding muscular activity. Thereby EMG data of on-track measurements can be used to adapt neck brace design to specific requirements.

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