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On-track measurements in motocross: The correlation of neck muscle activity and contact incidents of helmet and neck brace

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Abstract

Modern motocross racing is a very demanding and a highly injury rated sport. Within a wide range of injuries, cervical spine injuries are most feared and can even end up in different forms of paraplegia. Worn around the neck and with a non-permanent connection to rider, neck braces primarily offer a protective purpose to prevent cervical spine injuries. Beside the protective purpose, neck braces can have a supporting or a fatigue effect to the rider's neck muscles, where the effects depend on the specific neck brace design and the contact occurring between helmet and brace. Within a field test one subject was measured. During on-track measurements the contact incidents of neck brace and helmet were recorded utilizing a self-made sensor construction. The sensor construction was based on 12 electrical push-buttons and was mounted at the helmet's underside. Contact data was stored using two portable data-logging systems. Additionally muscular activity of m. sternocleidomastoideus (scm) and the upper part of m. trapezius (trap) were recorded while riding using a portable EMG-system. The acquired EMG data delivered information about a change of neck muscle activity while riding with the neck brace system. Activation levels and distribution of muscular activity of m. sternocleidomastoideus and m. trapezius show divergent activation levels and a changed distribution of muscular activity in response to wearing a neck brace. Related to the data of specific contact areas, it could be observed that almost one fifth of total riding time, contact between helmet and neck brace could be recorded. Low and high frequent contact areas of helmet and neck brace were calculated for total riding time, single laps and specific events, whereby a decreasing trend of contact incicdents by increasing riding time was observed. The EMG and contact data obtained delivered information about a connection of the changes of neck muscle activity and the frequent contact areas of helmet and brace. It can be concluded that driving with neck brace affects the activation levels and distribution of muscular activity of the muscles observed. According to the recent results, the correlation of contact and EMG data could be used for further neck brace design improvements and specific design adaptations to special requirements of several bike sports.

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Keywords: motocross, MX, sEMG, neck brace, protective equipment

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(a) (b)

Fig. 1. (a) overview of the sensor and data logging device setup for both sEMG and contact measurement; (b) sensors attached to the underside of a motocross helmet.

1. Introduction

”Fascinating”, ”sensational” or breathtaking” modern motocross racing is one of the most entertaining but also one of the most dangerous two-wheeled sports in the world. During the last two decades motocross riding experienced a constantly increasing popularity in recreational as well as professional riding. Despite the steady developments of bike-specific safety gear closely linked to the growing requirements of riding more powerful and lighter machines, motocross racing still involves the highest injury-rate of two-wheeled motorsports [1,2]. Within the wide range of motocross-involved injuries, permanent spine injuries are most feared. Fractures or dislocation of the spine can result in permanent trauma and especially neck injuries can end up in paralysis or even death [3].

Designed to prevent cervical spine injuries, the first neck brace system was developed and introduced by Dr. Chris Leatt in 2004. While crashing, neck braces aim to avoid cervical spine damages by limiting extreme neck movements and transferring loads from the neck to the torso [4]. Based on a non-permanent connection to the rider, an easy handling and high benefits at relative little costs, neck braces were rapidly established in various bike sports like mountain and downhill biking, enduro or rally sports and particularly - motocross riding.

Beside the preventive intentions, wearing a neck brace during motocross can affect the rider in various ways. [5] showed that riding with a neck brace takes influence on the rider’s range of motion (ROM) of the head, as a result of frequent contact between neck brace and helmet. Furthermore they observed that riding with a neck brace system can also lead to both a higher and lower neck muscle activity. The different activity levels of the neck muscles involved can be related to a supportive or fatigue effect, respectively.

In order to evaluate how frequent contact between helmet and neck brace correlates to different levels of neck muscle activity, in this work several measurements were conducted during a field test. For recording the contact incidents between helmet and neck brace during motocross riding, a new sensor setup was developed. The sensor setup allowed to gather data about frequency and location of the contact incidents between helmet and brace during on-track measurements. In addition to the contact measurements the muscular activity of the neck was recorded using portable EMG-system.

By gathering data about neck brace and helmet contact incidents and the influences on muscular activity of the neck, the aim of this study was to investigate the specific interaction of neck brace and rider during motocross riding, which can lead to design-optimization of future neck brace systems and enhanced rider performances while wearing a neck brace during motocross riding.

2. Methods and materials

The sensor setup was based on a low-cost, portable and easily interchangeable construction, which most importantly does not influence the rider’s performance, described in detail in [6]. The sensors were designed to withstand

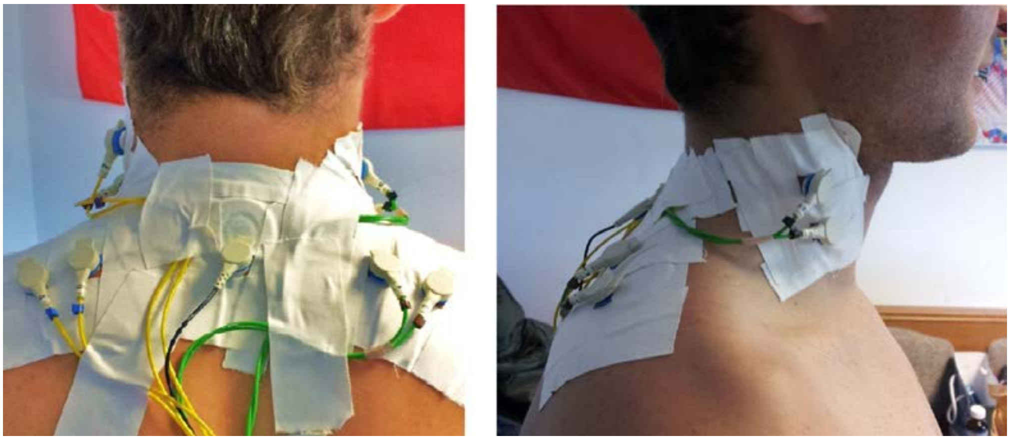


Fig. 2. EMG electrodes (bipolar and bilateral) attached to the subject and secured with tape.

the loads, stresses and vibrations of motocross riding while providing a stable signal during on-track measurements. For recording contact information of helmet and neck brace, twelve electrical micro push-buttons (Namae Electronics Inc., Incheon, RSK) were used. Regarding the aforementioned criteria, the chosen mirco push-buttons provided very small dimensions (6mm x 6mm x 5.1mm) and an operations force of 1.6N. The push-buttons were equally distributed (approx. 30 degrees) on the helmets underside (Figure 1). Every single push-button was mounted on a carrier-construction, which was based on a simple 90 degree angle joint. Furthermore, a small metal-lever was attached onto every single push-button, to ensure the correct recording of tangential contact incidents. The contact information was transformed into a simple voltage variation. The signal was recorded and A/D-converted with a frequency of 250 Hz and 10 bit resolution by using two Logomatic V2 data logging devices (SparkFun Electronics, Niwot, USA).

During the field test, the muscular activity of the subject was recorded using a portable EMG-datalogging system (developed and set up by the department of Biomedical Engineering, UAS Technikum Wien). The EMG system operates on a bipolar electrode configuration and is based on an ADS1298 (Texas Instruments, Dallas, USA) 8-channel and 24 bit analog-to-digital converter (ADC).

The muscle activity was recorded with a frequency of 1000 Hz. The system also includes an analog low-pass filter (cut-off frequency 350 Hz), an accelerometer and a micro-SD data logging. Within the study, the activity levels of m. sternocleidomastoideus (scm) and the upper part of m. trapezius (trap) were recorded for both body sides, following the SENIAM recommendations [7]. 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, whereas the reference electrode was placed on vertebra prominens (C7). Regarding the EMG data normalization process, three static and isolated MVC contractions were performed for each muscle. The field test was conducted on a private motocross track near Vienna (AUT). The on-track measurements were performed by a 23-year old, male and semi-professional motocross rider, who is experienced in riding with various neck brace systems. The off-road track was about 1.4km long, included jumps, turns and a sequence of bumps while running in a very flat and less-demanding course design.

To support data evaluation and time normalization, two GoPro Hero 3 cameras (GoPro Inc., San Mateo, USA) were placed on the driver's helmet and at the bike's handlebar. The separated EMG and contact data logging devices and the video cameras were post-hoc synchronized by a manual and acoustic event.

Contact and EMG data were analyzed using Matlab 7.11.0 (MathWorksInc., Natick, USA) and Microsoft Office Excel 2007 (Microsoft Coorp., Redmond, USA). EMG data was processed by applying a high-pass filter with a cut-off frequency of 10Hz and additionally smoothed by using a root mean square (RMS) routine with a window width of 25ms. For each muscle, event and condition the maximum EMG amplitude in each lap was detected and mean and standard deviation were calculated. Furthermore the data was normalized to maximum voluntary contraction (MVC) measurements conducted prior to the on-track tests.

Table 1. helmet and neck brace contact in % of total riding time for every sensor (t1 ... t12) grouped by contact sections.

front		right		rear		left		∑
t1	0.51	t4	0.09	t7	1.05	t10	2.16	
t2	0.04	t5	5.02	t8	0.78	t11	2.92	16.95
t3	0.20	t6	2.34	t9	1.04	t12	0.79	

3. Results

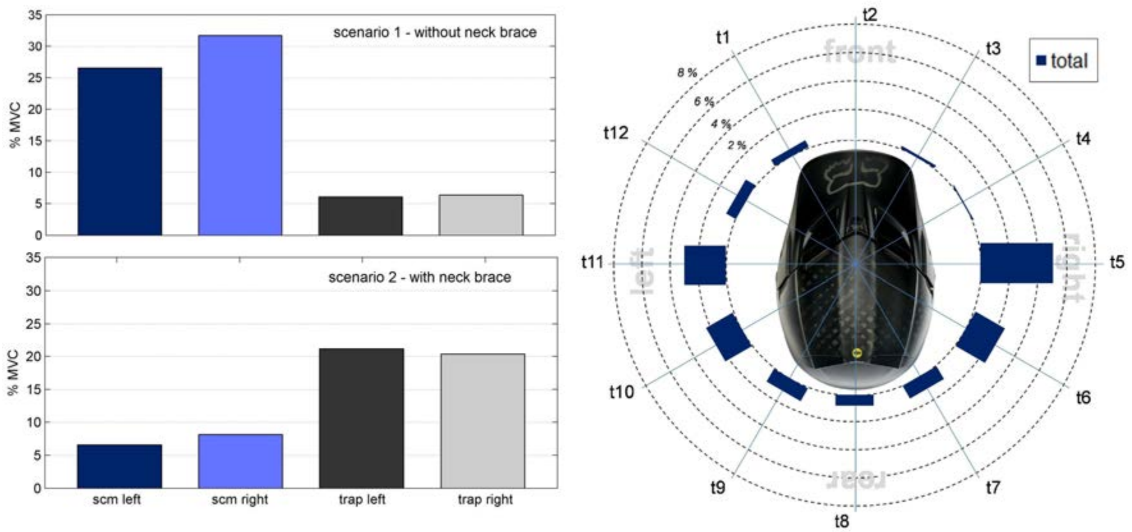
Processed EMG and contact data is plotted as bar graphs in Figure 3a, whereby activation levels of the muscles recorded are shown as percentage of MVC. In Figure 3b contact incidents between underside of the helmet and upper side of the neck brace are represented as percentage of total riding time for each sensor location (t1-t12). Referring to the contact information of the sensor setup, it can be observed that most of the contact incidents were recorded for left, right and rear section, whereas least contact times could be measured at the front section.

For the duration of almost one fifth (16.95%) of total riding time, contact between helmet and neck brace was recorded. Most contact was recorded by t5 (5.02%) and t11 (2.92%) at the left and right section, while almost no contact was recorded for the sensors t2, t3 and t4 (Table 1).

Regarding EMG data representation in Figure 3a, opposite characteristics of muscle activation levels of scm and trap can be observed for scenario 1 (without) and 2 (with neck brace). While for scenario 1 both left and right scm show maximum activity of up to about 30%, both trap muscles have lower activity (approx. 7%). For condition 2 both scm muscles are clearly less active (approx. 8%), whereas both trap muscles display increased activity (approx. 20%) (Table 2).

4. Discussion and conclusion

From the results of the trials and the data obtained, it can be concluded that frequent contact incidents of helmet and neck brace have certain impacts on neck muscle activity during motocross riding. Referring to contact sensors'



(a) (b)

Fig. 3. (a) Mean maximum activation of the measured muscles in % of MVC, above: scenario 1 (without neckbrace), below: scenario 2 (with neckbrace); (b) contact incidents between underside of the helmet and upper side of the neck brace aas percentage of total riding time for each sensor location (t1-t12).

Table 2. neck muscle activity in % of MVC, for both scenarios ((1),(2)) and both muscles m. sternocleidomastoideus (scm) and m. trapezius (trap).

scenario	scm (left)	scm (right)	trap (left)	trap (right)
(1) without nb	26.8	32.1	6.2	6.3
(2) with nb	6.9	8.1	21.7	20.1

information, for almost one fifth of total riding time contact between helmet and neck brace could be recorded, indicating that the interaction of rider and brace could be an influencing factor on muscular fatigue and hence rider's performance and should roughly be considered in future neck brace design developments.

Nevertheless, frequent contact between helmet and neck brace is also expressed in different activation patterns of neck muscle activity. Relating to presented EMG data (Figure 3a, Table 2), it can be seen that riding with a neck brace system can result in higher or lower activity levels of the neck muscles observed. On the one hand, frequent contact at the neck braces' side sections suggest that the rider tends to rest the helmet onto the brace and therefore uses the brace as support device for neck stabilization, which also is expressed in less activation of m. sternocleidomastoideus during scenario 2. On the other hand, the interaction between neck brace and helmet can affect the rider's performance in a negative way. Influenced by the frequent contact incidents at the rear section, the rider is forced to push his head against the contact and therefore m. trapezius is definitely more active comparing to riding without neck brace system. However, one of the most challenging tasks of future neck brace design developments will be to find the perfect combination of protective purposes and less restrictions on the rider's performance. With regard to future designs, neck braces should be adapted to neck muscle activation patterns depending on frequent contact areas of neck brace and helmet to find and overall optimization of the rider performances in every kind of bike sports involving neck brace.

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References

[1] A. Gobbi, B. Tuy, I. Panuncialman, The incidence of motocross injuries: a 12-year investigation, Knee Surgery, Sports Traumatology, Arthroscopy 12 (2004) 574–580.
[2] Y. Tomida, H. Hirata, A. Fukuda, M. Tsujii, K. Kato, K. Fujisawa, A. Uchida, Injuries in elite motorcycle racing in japan, British journal of sports medicine 39 (2005) 508–511.
[3] J. T. Grange, J. A. Bodnar, S. W. Corbett, Motocross medicine, Current sports medicine reports 8 (2009) 125–130.
[4] C. Leatt, C. de Jongh, P. A. Keevy, White paper: Research and development efforts towards the production of the leatt-brace moto gpx unrestrained torso neck brace, online, 2012. URL: `http://www.leatt-brace.com/images/uploads/library/LEATT_WHITE_PAPER_FINAL_rev1.pdf`, retrieved: 15/01/2013.
[5] L. Gorasso, N. Petrone, On-track measurements of neck movements and muscle activity during motocross sessions with or without neck brace, Procedia Engineering 60 (2013) 337 – 342. 6th Asia-Pacific Congress on Sports Technology (APCST).
[6] G. Thiele, P. Kafka, S. Litzenberger, A. Sabo, A sensor construction to measure contact between helmet and neck brace during motocross riding, Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology (2015). Online first published on July 3, 2015.
[7] H. J. Hermens, B. Freriks, R. Merletti, D. Stegeman, J. Blok, G. Rau, C. Disselhorst-Klug, G. Hägg, European recommendations for surface electromyography, Roessingh Research and Development 8 (1999) 13–54.