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On-track measurements of neck movements and muscle activity during motocross sessions with or without neck brace

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Abstract

This work analyse the movements and the muscular activity during motocross sessions and how a neck brace influence both. These movements are measured in terms of angles using two Biometrics® angular sensors (one for bi-planar flexion and one for torsion); the muscle activity is registered using four pairs of electrodes (muscle selected: Sterno-Cleido-Mastoid left and right, Trapezium left and right). From the results obtained, we can conclude that the pilot wants to focus the attention to the next jump or obstacle while accelerations of different nature are acting on the neck, therefore isometric contractions are predominant. The fact that the brace did not reduce the rotational range of motion is a positive result because the pilot field of view is not modified which is a safety requirement. According to the evidence of a fatigue effect, the brace is useful not only to protect the pilot during accidents but also as a supporting device during driving sessions.

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Keywords: Motocross, neck brace, muscle activity, neck movements, range of motion

1. Introduction

In the last two decades motocross became a popular sport among the young people and in many countries is the most practiced activity in the motorsport field. Protection devices have been designed since the nineteen seventies but only in the last few years a more rigorous approach has been used for their design. This work describes the technique used to measure the neck movements and the muscle activation pattern during motocross training sessions when the same track was driven with or without a

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specific neck brace under investigation, in order to understand the influence that it has on the behavior of the head-neck-shoulder system in riding conditions, as performed for other sports equipment [1, 2].

The tests were divided in two: laboratory session and on-track sessions, last ones were performed in three different circuits with difficulty levels and different pilots. Neck movements detected were: rotation (ROT), inclination (IN) and flexion (FLX). The considered muscles are the two couples of main neck muscles: sterno-cleido-mastoid (SCM) and trapezium. They both work together and synergistically to move the head. Also other muscles participate in the movements but their internal positions do not allow analyzing them with superficial myographic sensors.

Nomenclature

FLX	[°]	Flexional angle
IN	[°]	Inclinational angle
NB	[-]	No-Brace
ROM	[°]	Range of motion
ROT	[°]	Rotational angle
SCM	[-]	Sterno-Cleido-Mastoid (Muscle)
WB	[-]	With-Brace

2. Methods

2.1. Signal acquisition and sensor positioning

The angles and their ROM (range of motion) were measured using two Biometrics® angular sensors (one for bi-planar flexion and one for torsion); the muscle activity was registered using four pairs of electrodes (muscle selected: Sterno-Cleido-Mastoid left and right, Trapezium left and right). These sensors were connected to a BTS Pocket EMG® electromyographic data acquisition system. For every test session the rider stands in a rest position for 20 seconds then starts to ride and at the end of the session (2 minutes in the laboratory and 2 rounds of the circuit in the out-door sessions) stands again in the rest position for other 20 seconds. In this work the above described procedure is called “20-2-20”. The angular position of the neck is corrected by subtracting the value of the initial angle (measured as average of the values for two rest positions) from the acquired angle values. The angular sensors are placed at the bottom of the helmet for the moving part and attached on the brace’s frame supposed to be rigid respect to the body.

The myographic signal is first rectified, then digitally integrated (using finite sums with the steps of 200 ms) and finally filtered (low pass filter with the 5 Hz cut off). For the SCM the sensors are placed 40 mm under the inner third of the nuchal line and 20 mm away from the inner third of the clavicle bone. The neutral sensor is placed on the skin covering the extreme back side of *vertebra prominens* (C7). Then, the trapezium sensors are placed: one offset 60 mm from the sagittal plane in line with the neutral sensor, and the second one offset 40 mm from the sagittal plane and 40 mm higher in the head direction. Some individual adjustments have been done to match the main muscle fibre direction.

2.2. Laboratory session

The laboratory session had the aim to explore the possible ROM of the human neck with a motocross helmet on, with or without the neck brace. Firstly, a static test was made: the subject moved the head for 20 seconds in various directions with different velocities. Then a second test was made: the subject rode trough an off-road circuit following the 20-2-20 procedure. The ride was repeated for three times.

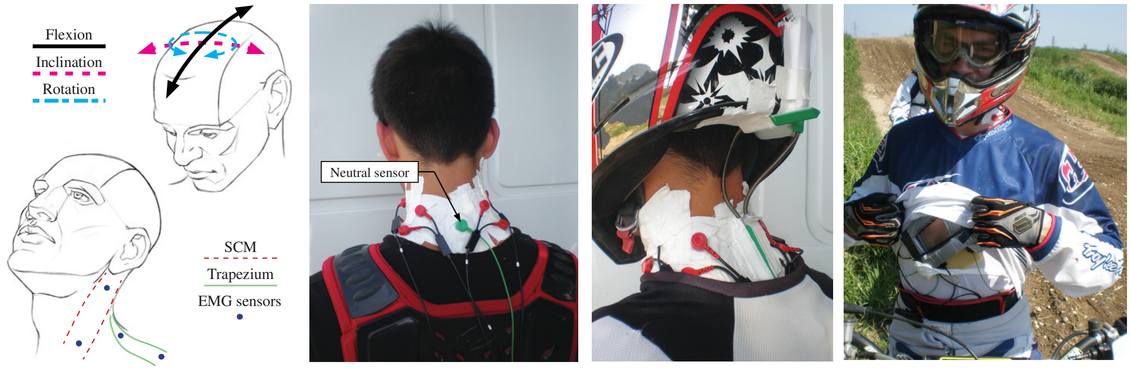

Fig. 1. (a) Sensors positioning; (b) Angular sensor positioning and BTS Pocket test subject

2.3. On-track sessions

The first on-track session was held in "*Ca del Bue*" national motocross circuit in Verona (Italy). The subjects were two semi-professional pilots. Every subject completed three times two sessions of 20-2-20 procedure, with and without the brace.

The second on-track session was held in "*Creek Canyon*" training circuit in Los Angeles (California, USA). The subjects were two professional pilots. These subjects completed the same amount of sessions as for the test in Italy. The fastest one was also required to make repeated sessions of just a jump. In this case the athlete was asked to ride 50 m before and after a jump, bell shaped, of approximately 3 m height for ten times. All the pilots involved in the project were healthy, non-smokers, not injured, carrying out specific weekly training for motorsport and aged between 18 and 24 years.

3. Results and discussion

3.1. Laboratory tests results

As summarized in Table 1 there is a great influence on ROMs due to the brace presence, except for the rotational ROM, which was not substantially modified. The significant reduction of the FLX ROM is quiet clear, the aim of the brace is to protect the pilot and prevent neck bone injuries (it usually occurs when the neck is stressed along the flexion direction, so the brace is designed to some extent restrict the neck flexion). The data in the table are averaged from the three tests mentioned in chapter 2.2.

3.2. On-track session results

As the field tests conditions are some variable, the data analysis is differing from the one performed for the laboratory tests. Hence, 20 events were chosen among the all the "potential events" present in the two circuits. The first 10 events belong to the first session in Verona and the events from 11 to 20 belong to the session carried out in Los Angeles. The events are: jumps (1,6,8,11,14 and 16), corners (3,4,5 and 10), woops (typical motocross asperities,18, 19 and 20) and others (2,7,9,12,13,15 and17) are selected for both the tracks. With the use of a chronometer and the analysis of the signal is possible to synchronize the signal paths and compare the ROMs for a single event. The results are summarized in Fig. 2, 3 and 4; every point is the average of three tests for two pilots. The results are shown in a non-sorted, event by event, or in sorted form, from the biggest to the smallest.

Table 1. Laboratory results, range of motion

Range of motion* (ROM)				
Condition	Angle	FLX	IN	ROT
Free to move [°]	Initial angle	49,547	-13,802	-3,334
	Ant/Left	82,372	40,924	55,009
	Post/Right	-38,615	72,763	67,448
	ROM	120,986	72,763	67,448
With brace [°]	Initial angle	45,660	-12,810	1,035
	Ant/Left	54,253	40,637	45,520
	Post/Right	-12,613	-19,980	-22,787
	ROM	66,866	57,617	68,317
Reduction	Absolute [°]	54,120	15,146	-0,869
	Relative [%]	44,7	20,8	-1,3

In Fig. 2 the reduction of the ROMs is clearly showed. Nevertheless, in Fig. 3 the reader can note that the inclination ROM with the brace, while sorted, is generally bigger then the respective ROM without the brace. However, in the not sorted data is possible to note that the inclination ROM while the brace is used never exceeds a threshold that can be fixed around 100°. The fact that in general the inclination is grater while the brace is used can be due to the fact that the flexion movement is constrained and the pilot tends to force the inclinational movements to have the same view angle as without brace. In Fig. 4 the negligible effect of the brace on the ROT ROM is shown.

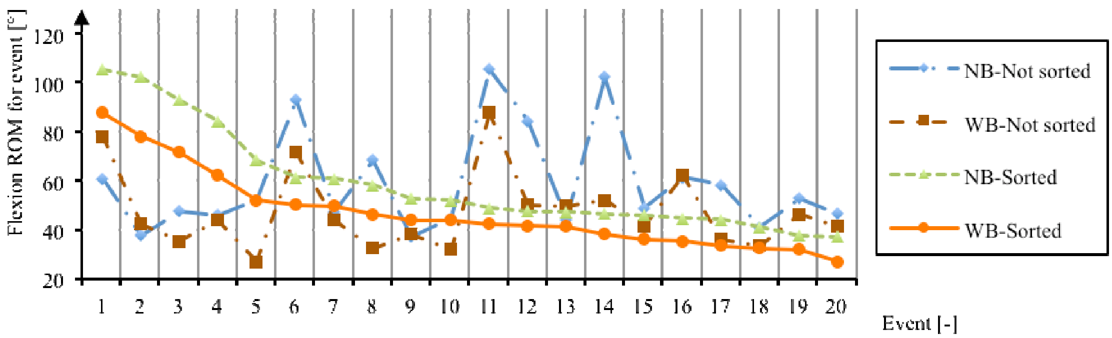

Fig. 2. Flexion ROM for every event

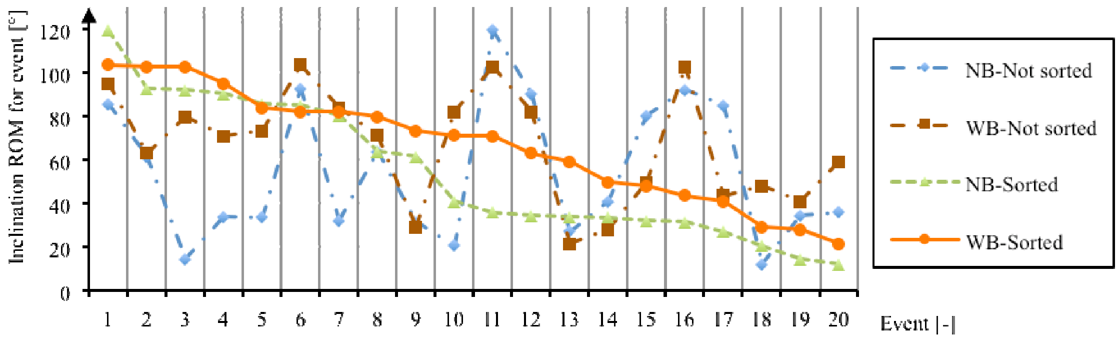

Fig. 3. Inclination ROM for every event

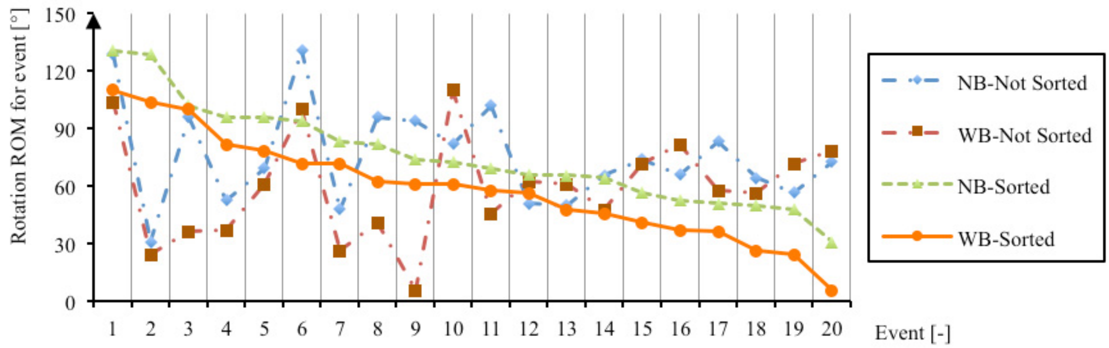

Fig. 4. Rotation ROM for every event

3.3. Electromyographic results

In order to better visualise the electromyographic data the authors selected two significant events from the on-track sessions namely to illustrate the reduction of the muscular activation during an event. The data are analysed to show the effect of the brace on different pilots. The activation data represent the average value of the tests for that pilot in that event. The fatigue phenomena was avoided with repeated resting periods during with the elctormiographyc's probes were not remouved. Fig. 5.a showes the reduction due to the brace in a right side bend where just a muscle is exited to react to the centrifugal acceleration. In Fig. 5.b is interesting to note that the trapezium is storngly cativated to mantain the head in the correct position, nevertheless the brace act on both the couple of muscles reducing the trapezium activation and nullifing the activation of the SCMs.

4. Conclusions

The results of the overall research carried out are:

- The muscular activity is not dominated by active movements but mostly by isometric stresses due to the continuous reactions to external accelerations.
- The neck brace limits the flexion ROM and the inclination ROM but does not affect the rotational

ROM. The average reduction of the flexion ROM, caused by the neck brace wearing, is 45% and the average reduction of the inclination movements is 28%.

- Dilettantish pilots and professionals have different driving styles hence different neck braces are needed.

Repeated tests show that when the muscular fatigue is becoming extreme, the pilots tend to use the brace as a support. From the results obtained, we can conclude that the pilot wants to focus the attention to the next jump or obstacle while accelerations of different nature are acting on the neck, therefore isometric contractions are predominant. The fact that the brace did not reduce the rotational range of motion is a positive result because the pilot view range is not modified (safety requirement). A simple marketing investigation showed that amateur riders tend to use products coming from the professional world: due to the different riding styles, the braces should have to be different only in the material used, e.g. the flexibility of the plastic parts. According to the evidence of a fatigue effect, the brace is useful not only to protect the pilot during accidents but also as an active aid during driving sessions.

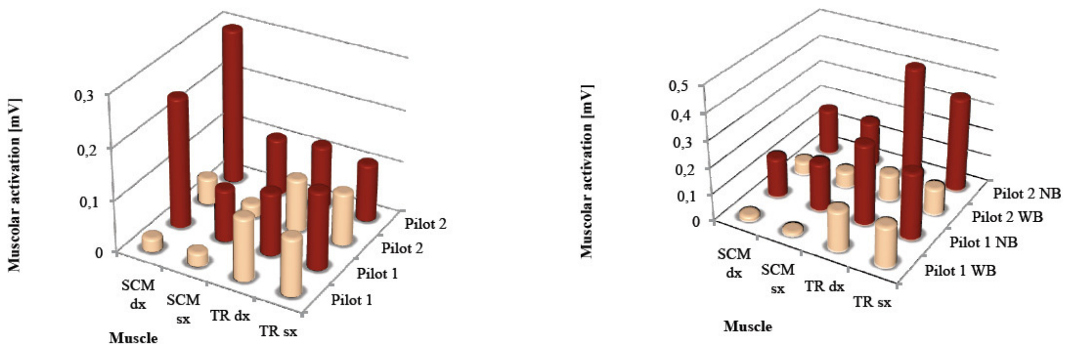

Fig. 5. (a) Muscular activation in a corner (Event 3); (b) Muscular activation in a jump (Event 16)

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