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DRIVING ERGONOMY. NEW METHODOLOGY FOR THE ASSESSMENT OF STRESSES ON UPPER LIMBS

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ABSTRACT

The study has been carried out within a combined theoretical-experimental program. The objective is to demonstrate the possibility to weight the stress of the muscles related to an extended time in driving.
A very simple car simulator, properly arranged for reproducing a seat-steering system, has been installed at the laboratory of Rome University "La Sapienza", where an electromyographic equipment was already available.
The driving posture has been established according to the conclusion of a previous paper by te same Authors, as follows :
- back of the seat at 23 degrees behind the vertical :
- hands on the steering wheel at 10 :10 hours according to the standard convention.
Measurements by electromyographic tool have been taken on the tensions of main upper limb muscles involved while the driver is engaged with the steering.
Muscles taken under consideration are the brachial biceps, the deltoid, the trapezious and the neck long musclas.
Substantial differences have been noticed between stresses related to short and extended time in driving with a rate of growth up to 70%.
Even though tensions at the extended time have been noticed up to one hour of driving involvement, a further theoretical investigation has been carried out to understand better the serious consequences in the increase to stresses due to a more extended time.
The methodology can be applied also to other muscles involved in driving such as dorsal-lumbar muscles and lower limb muscles.
The knowledge of the stresses on the muscles will give the possibility to keep drivers aware by bringing their capabilities under control and consequently reducing accident probabilities.

INTRODUCTION

The aim of this study is to describe a way to determine kind and level of stress which interests that part of the neuromuscolar system more directly involved during driving. In order to test the conditions in the easiest way, even if this implies some approximations, we developed a model using a driving simulator

connected to an electromyographic apparatus able to detect the levels of muscular activity in different working conditions. These conditions include the movements done by the driver on the driving simulator as well as the postural muscular work. This study has been carried out thanks to an interdisciplinary approach where different specialists were involved in the various issues mentioned above.

MATERIALS AND METHODS

The driving simulator

In order to assure the reproducibility of the test, we decided not to use a moving car, but we developed a simple adjustable driving simulator reproducing the essential parts of a car (seat-steering systema), which could be used in our laboratory.

The simulator was made of:

- an adjustable seat, with the possibility of modifying height, angle and distance from the steer,
- an adjustable steer, with the possibility of modifying angle and height,
- a system able to reproduce the weights and moments which the driver has to oppose during the driving experience. This system was formed by a number of weights connected to the steer by cords and counterweights, adjustable according to different levels of activity.

The simulator is shown in fig. 1 which illustrates the system of weights and counterweights connected to the steer.

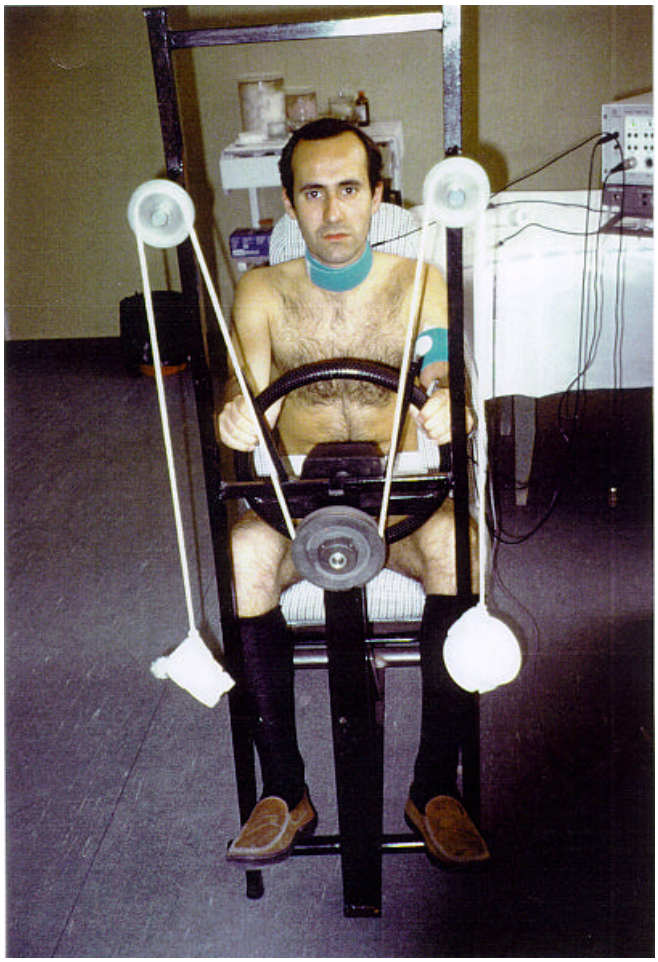
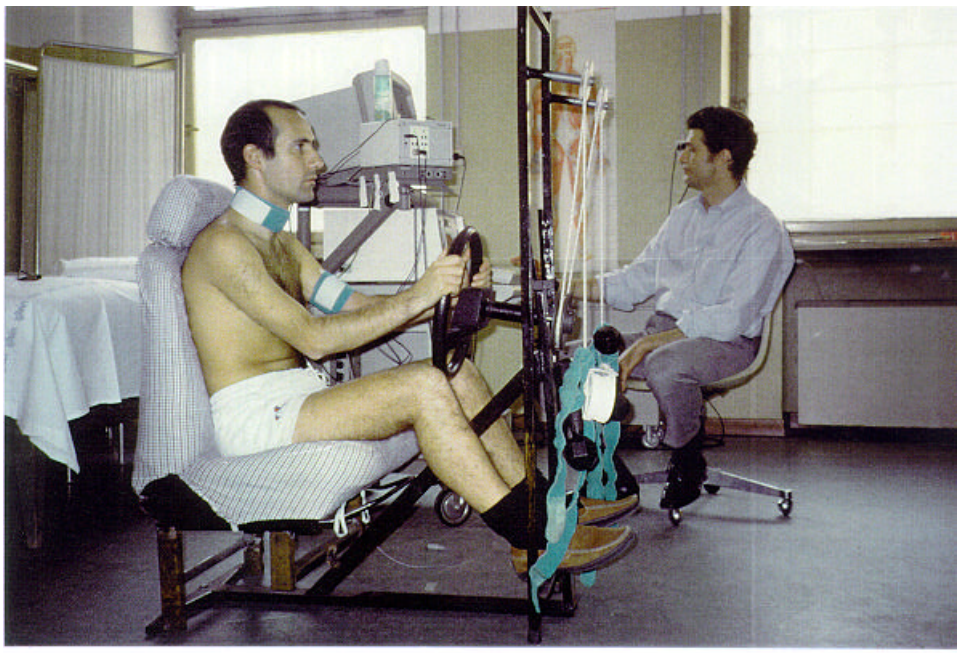


Fig. 1 The simulator which illustrates the system of weights and counterweights connected to the steer.



The correct position, with the back of the seat positioned at 25° behind the vertical axis and upper limbs flexed at the elbow in order to achieve a 90° angle between the arm axis and the steer plane.

The driver was carefully instructed before starting in order to avoid artifacts and unusual muscular movements during the test. Each test was performed in triplicate.

The electromyographic apparatus

In order to register the muscular activity during the driving test, we used a portable and compact elctromyographic (EMG) apparatus (Phasis), which is normally used in department for routine diagnostics. This instrument is supplied with a 14" high resolution color monitor and a speaker able to reproduce sounds from two different channels. The signals are then reproduced on paper by a printer. The registration of muscular activity was performed through superficial electrodes positioned on the different muscular surfaces under exam. The muscles examined were the brachial biceps, trapetious, deltoid neck long muscles, dorsal lumbar and lower limb muscles.

Experimental design

Preceded by a large pilot investigation to optimize the different conditions and registration procedures, this study was designed in order to :

- register the muscular activity during driving in correct position, and compare this with the activity under incorrect posture. Fig. 1 shows the suggested correct posture, with the back of the seat positioned at 25° behind the vertical axis and upper limbs flexed at the elbow in order to achieve a 90° angle between the arm axis and the steer plane. Fig. 2 and Fig. 3 show incorrect postures of the driver (too distant or too close) with parameters altered as compared to the ones shown in Fig. 1 ;
- register the muscular activity of the driver in different working conditions, referring in particular to different levels of energy during the steer turning activity. Fig. 4 shows a test taken during a right turn.

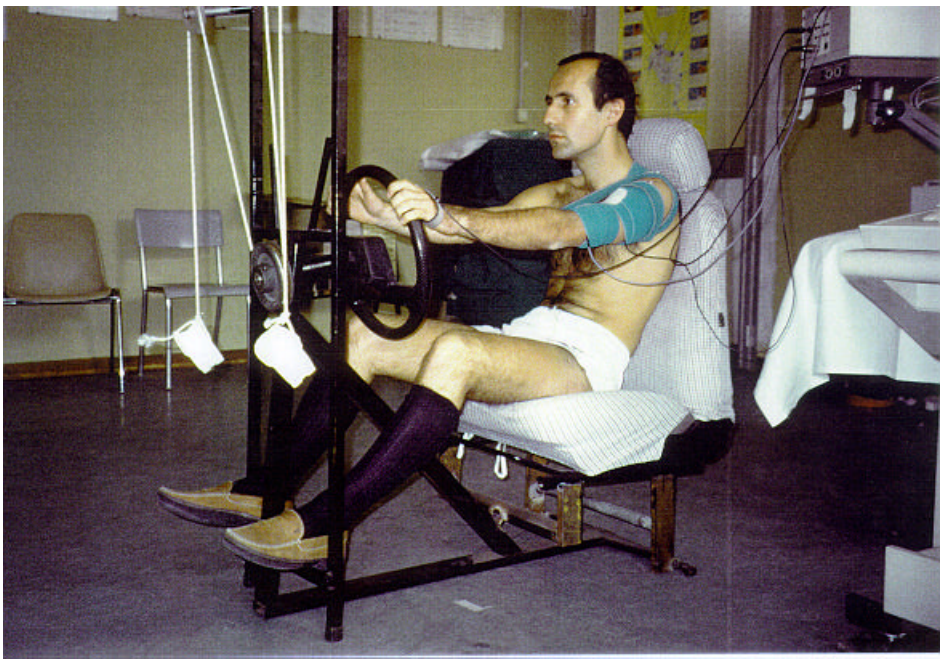


Fig. 2 Incorrect posture of the driver, too distant from the steer.

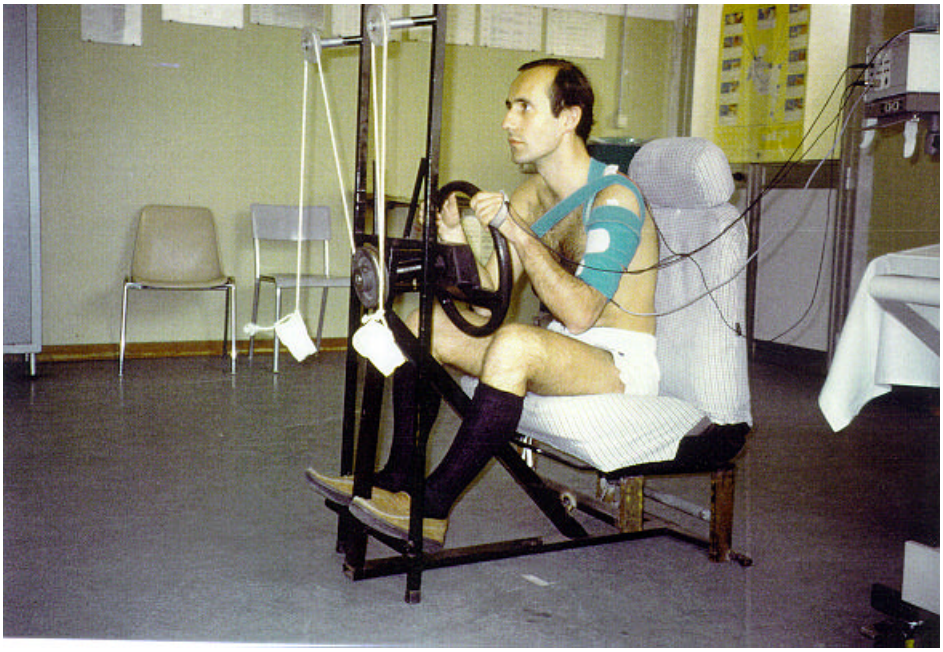


Fig. 3 Incorrect posture of the driver, too close to the steer.

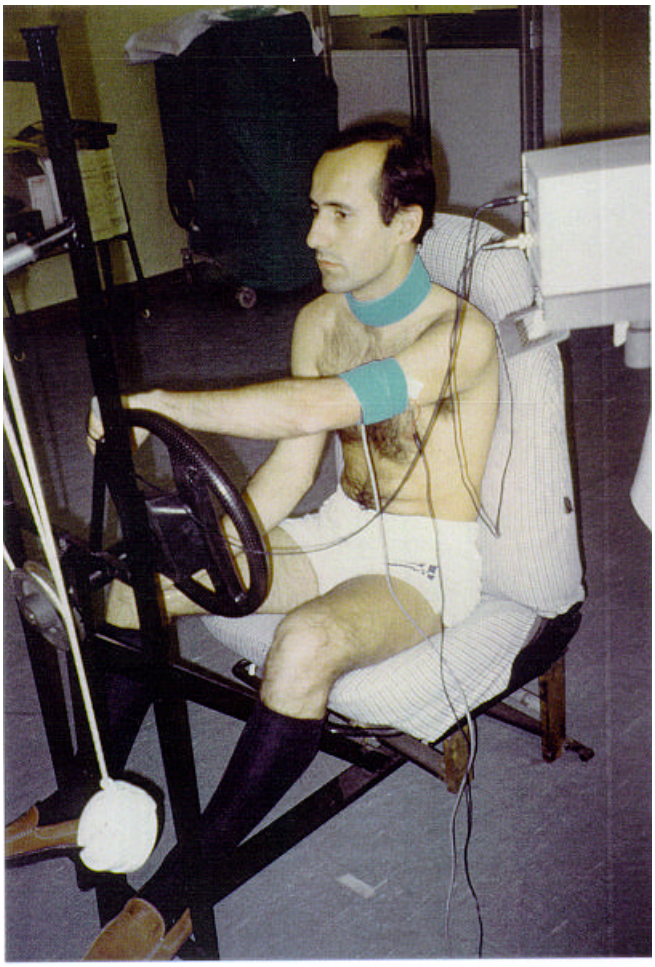


Fig. 4 Test taken during a right turn.

RESULTS

The EMG registration allowed a complete assessment of the muscular activity of muscular groups or single muscles. The superficial electrodes were able to collect the activity of several motor units during volontary movements. These units are activated sequentially during movements, therefore the electromiographic rate increases progressively. A good intensity activation is enough for the motor unit potentials to overlap, with disappearance of the hysoelectric line. The resulting EMG is called "interpherential EMG". We were able to collect three kinds of EMGs:

a) single-wave EMG, produced by weak contractions with involvement of a few motor units and therefore minimum muscolar activity ;

b) sub-interpherential EMG, characterized by a larger degree of muscular involvement;

c) interpherential EMG, produced by massive muscular involvement with activation of all the motor units.

Different kind of EMGs recorded during this study are represented in Fig. 5-19.

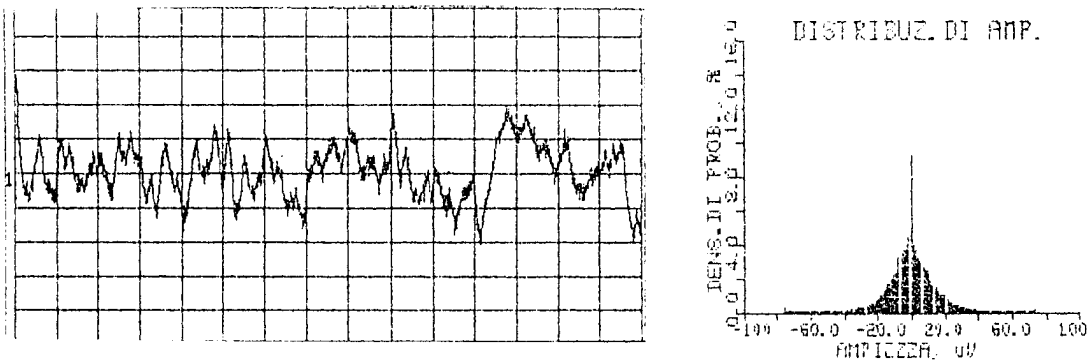


Fig. 5 Sub-interpherential EMG of the left brachial biceps, taken during driving in the incorrect posture (too far from the steer) showing a minor degree of muscular involvement.

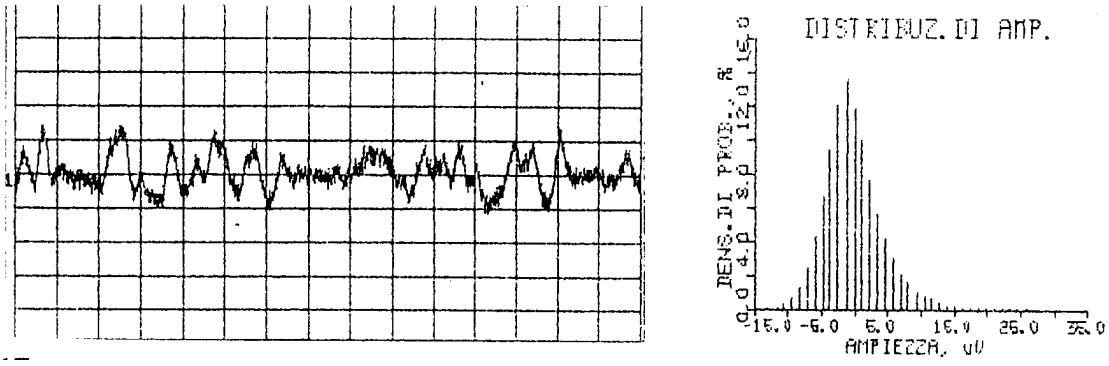


Fig. 6 Single-wave EMG of the left brachial biceps, taken during driving in the correct posture, showing minimum muscular activity.

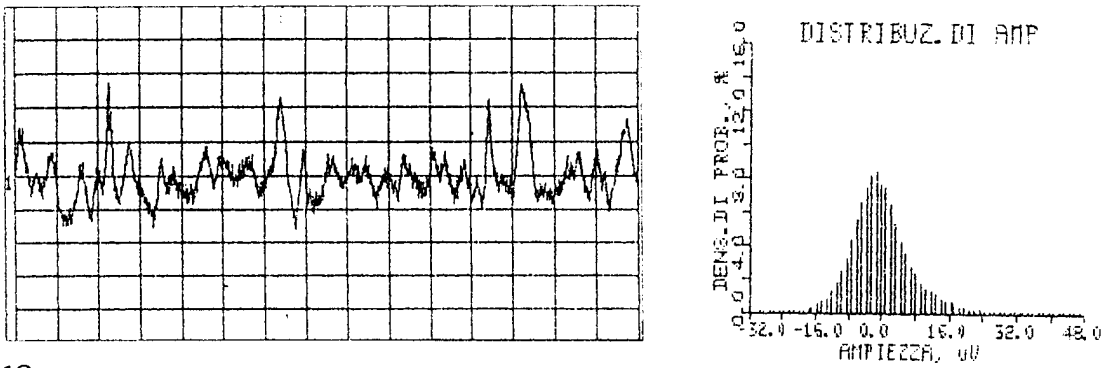


Fig. 7 Sub-interpherential EMG of the left brachial biceps, taken during driving in the incorrect posture (too close to the steer) showing a minor degree of muscular involvement.

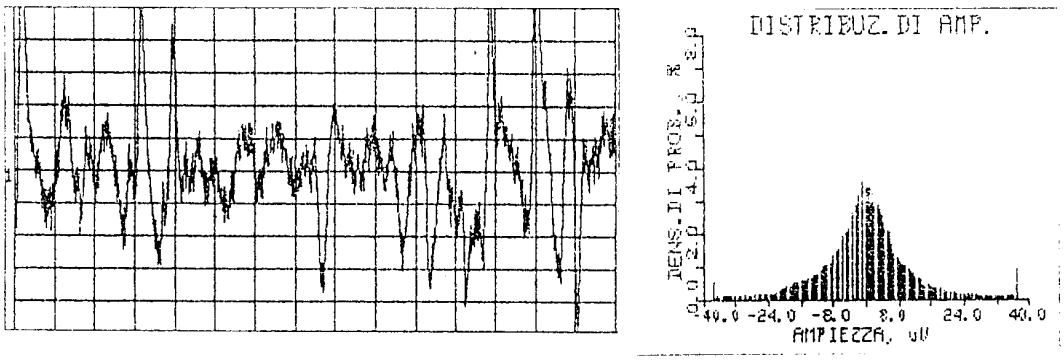


Fig.8 Interpherential EMG of the left brachial biceps, taken during a right turn driving in the incorrect posture (too far from the steer), showing massive muscular involvement with activation of all the motor units.

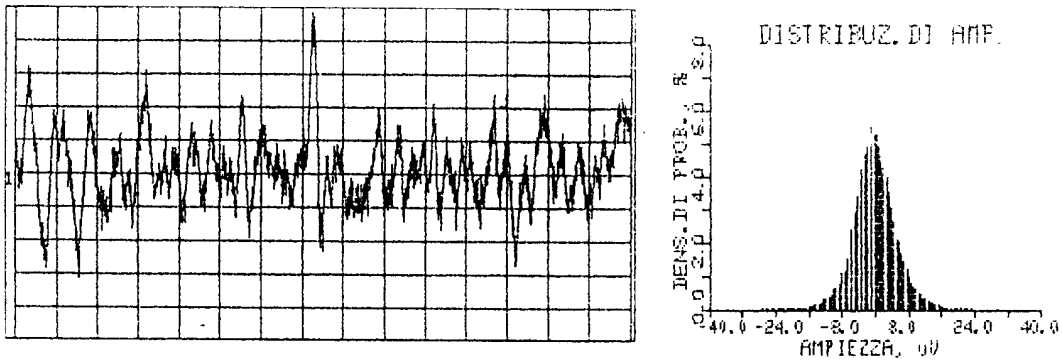


Fig. 9 Interpherential EMG of the left brachial biceps, taken during a left turn driving in the incorrect posture (too far from the steer), showing massive muscular involvement with activation of alla the motor units.

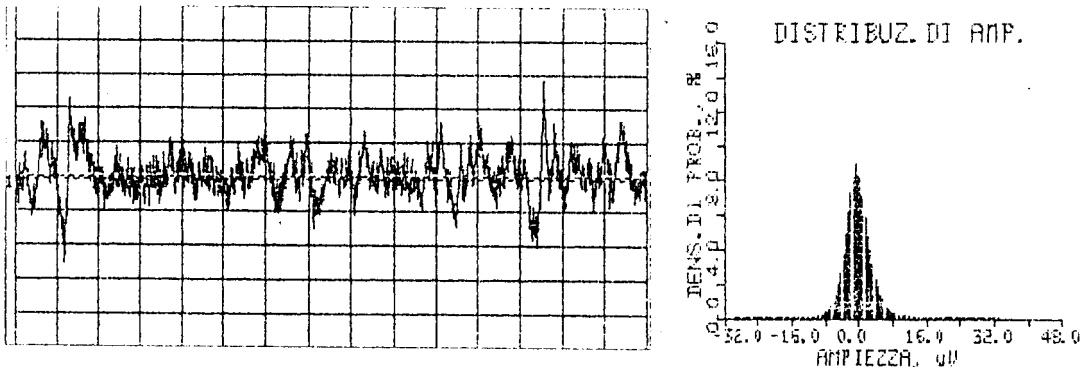


Fig. 10 Sub-interpherential EMG of the left brachial biceps, taken during a right turn driving in the correct posture showing minor muscular involvement.

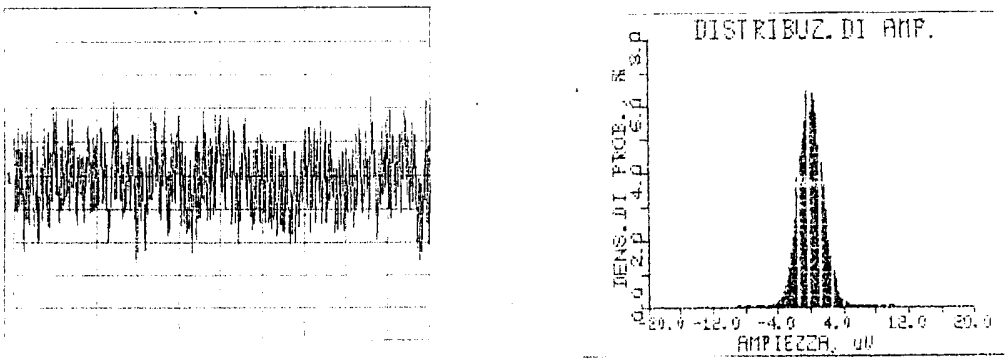


Fig. 11 Interpherential EMG of the neck long muscles, taken during driving in the incorrect posture (too far from the steer), showing massive muscular involvement.

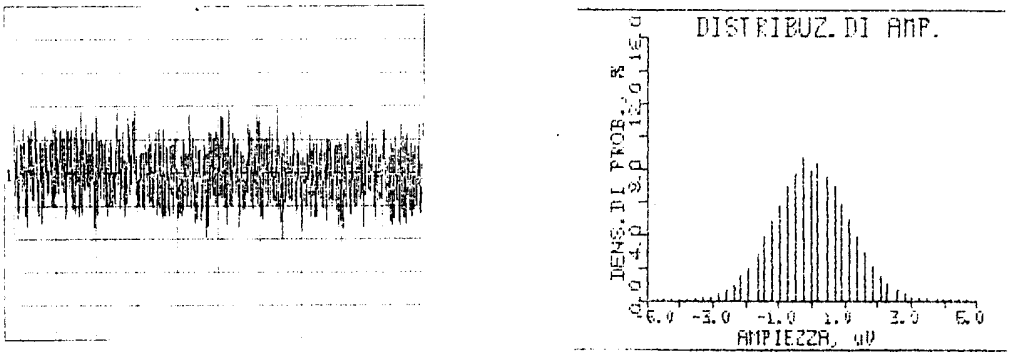


Fig. 12 Sub-interpherential EMG of the neck long muscles, taken during driving in the correct posture, showing minor muscular involvement.

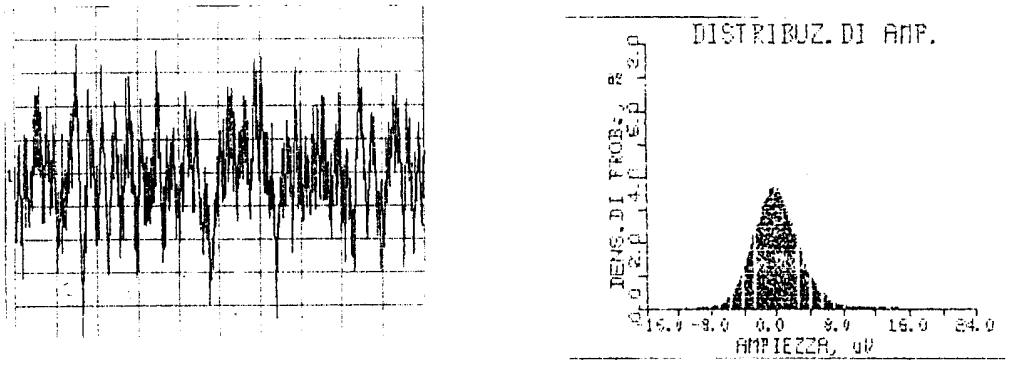


Fig. 13 Interpherential EMG of the neck long muscles, taken during driving in the incorrect posture (too close to the steer), showing massive muscular involvement.

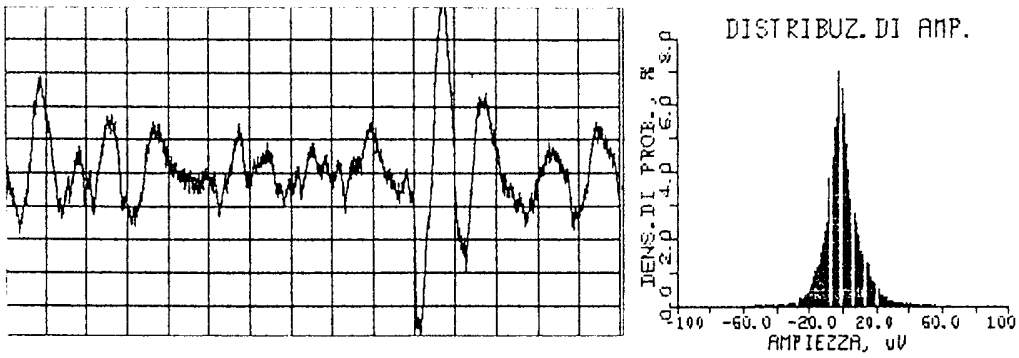


Fig. 14 Sub-interferenzial EMG of the dorsal lumbar muscles, during driving in the incorrect postures (too far from the steer), showing minor muscular involvement.

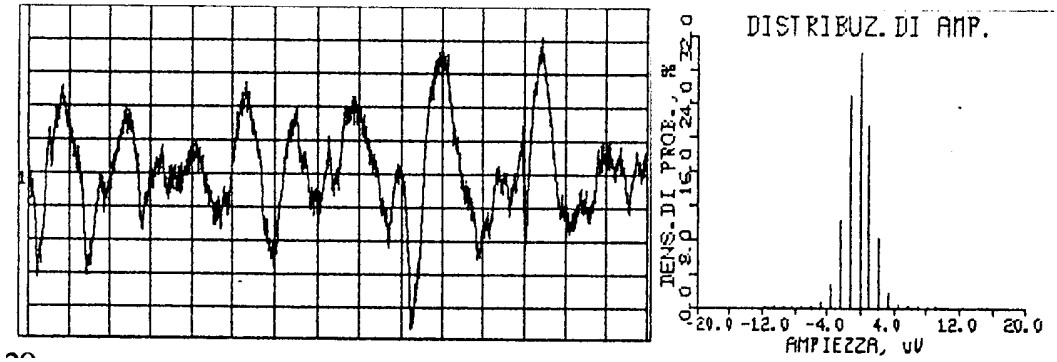


Fig. 15 Isoelectric EMG of the dorsal lumbar muscles, during driving in the correct posture, showing absence of muscular involvement.

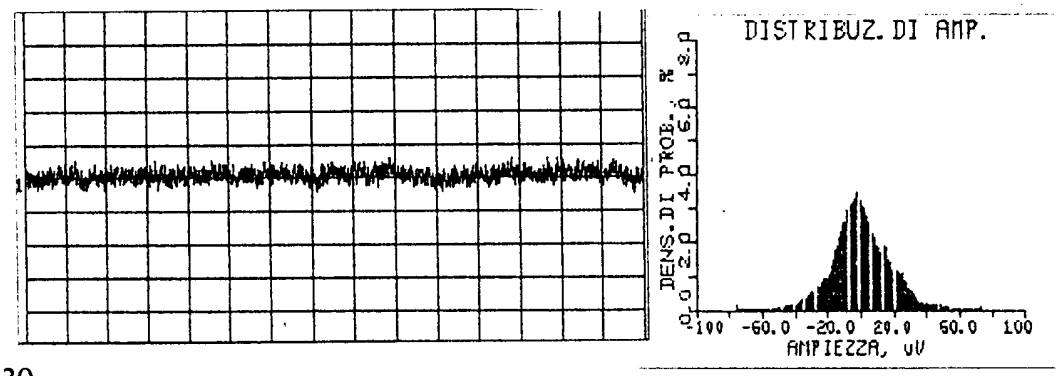


Fig. 16 Interpherential EMG of the dorsal lumbar muscles, during driving in the incorrect posture (too close to the steer), showing massive muscular involvement.

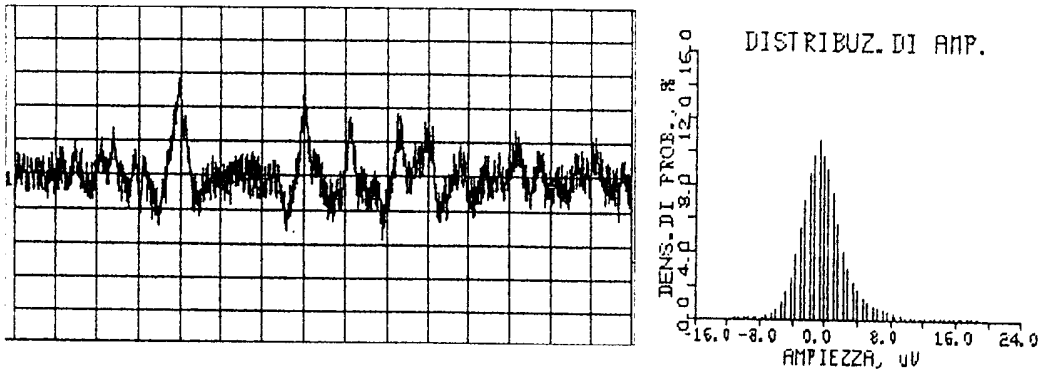


Fig. 17 Sub-interferenzial EMG of the lower limb muscles, during driving in the incorrect postures (too far from the steer), showing minor muscular involvement.

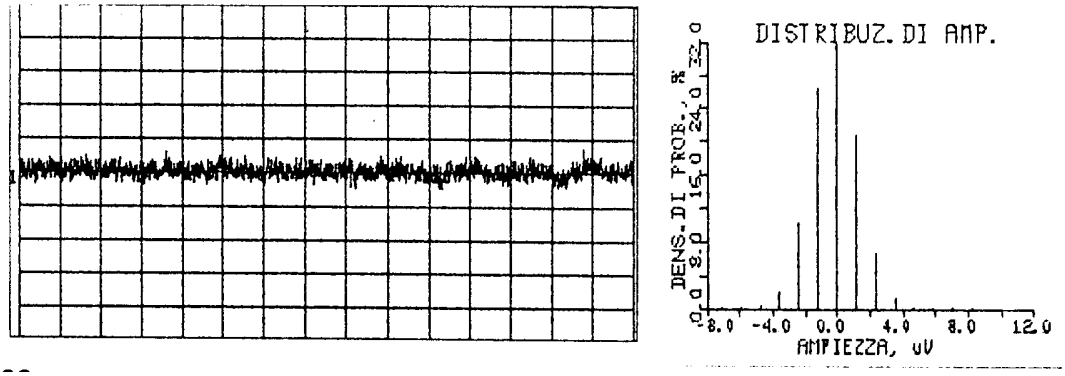


Fig. 18 Isoelectric EMG of the lower limb muscles, during driving in the correct posture, showing absence of muscular involvement.

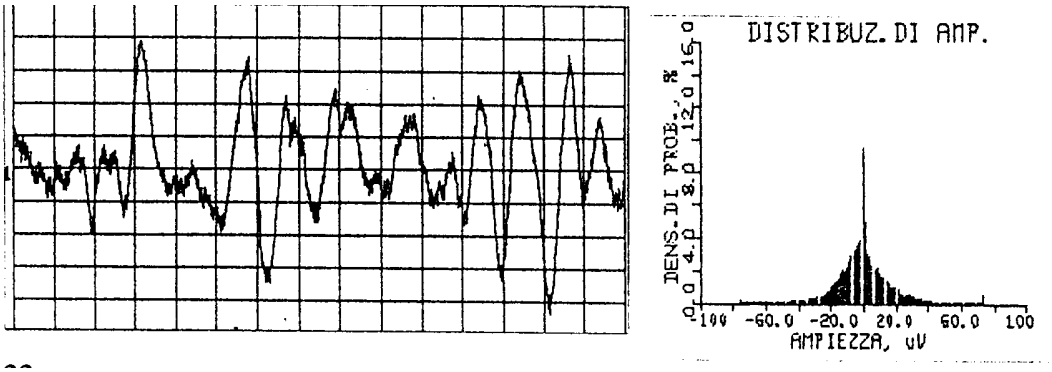


Fig. 19 Interpherential EMG of the lower limb muscles, during driving in the incorrect posture (too close to the steer), showing massive muscular involvement.

The examination of the EMGs recorded during the tests, referring to different muscular groups and different driving phases, showed clearly that the position connected with lower muscular involvement and therefore less fatigue, is the suggested correct posture showed in Fig. 1 (hands on the steering wheel at the hour 10 :10 , back of the seat positioned at 25° behind the vertical axis and upper limbs flexed at the elbow in order to achieve a 90° angle between the arm axis and the steer plane). The EMGs represented in Fig. 6 and 12 show the significant reduction in the upper limb and neck muscular activity during driving in the correct position. Fig. 15 and 18 clearly show the total electrical inactivity of the dorsal-lumbar and lower limb muscles during driving in the correct position. In contrast, these muscular groups, during driving in incorrect position (shown in Fig. 2 and 3) undergo significant postural stress, as shown by the EMGs cause of muscular pain and aches during driving. These symptoms could be related to discomfort and reduction of

the level of attention of the driver, with possible subsequent increase of accident rate during driving in the incorrect position.

CONCLUSIONS

This study demonstrate the feasibility of accurate detection of different levels of muscolar activity in various driving conditions. The relevant differences detected between correct and incorrect postures or different working conditions show that muscular fatigue can be substantially reduced or increased in different conditions. The main conclusion of this study is that it is possible to identify a standard of correct posture which allows the optimal conditions for stress reduction. Moreover, the muscular comfort and attention level of the driver could be an important in maintaining good conditions of safety during driving.

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