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CAR SEATS ERGONOMIC EVALUATION

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ABSTRACT: *The purpose of this paper is to observe the ergonomic advantages of different car seats and how the driver is constrained to them during the drive. The study was conducted by taking in to consideration the dynamical characteristics of a standard vehicle and subjecting the human body model provided by the AnyBody Modelling System, to inertia and centrifugal forces, in three different driving posture cases. The simulation using the AnyBody Modelling System, is validated with the results of a real case thermographical experiment. The model proved to be viable and offered an image of different car seats advantages from ergonomic point of view.*
KEYWORDS: *human body, ergonomics, vehicle dynamics, muscle activity, car seat*

INTRODUCTION

The influence of different forces and vibrations transmitted to the human body through the car seat during the drive shows a distinctive importance because they inflict a state of tiredness, especially to the driver who makes an additional effort in comparison the other passengers.

The main effort results from centrifugal and inertia forces creating a postural stress, the effort made during the operation of different commands and the steering wheel, effort made for maintaining the balance in the seat while driving on uphill or downhill or following the road where the vehicle is driven.

Vehicle designers all around the world are trying to create functional seats that provide adequate physiological driving conditions. The creation of ideal driving condition implies a determination of the drivers efforts, their measuring and the response of the human body to each of these efforts, their comparison to normal physiological limits and as a result of this, the interventions on the driver's seat for setting the driver's demand to his physiological possibilities [3, 4, 5, 6].

Due to the presence of soft tissues, of bones, of internal organs and also because of the configurationally particularities, the human body is a complex mechanical system. External forces can be transmitted to the human body in vertical, horizontal, sitting positions or through the hands while driving. The ways of transmitting these forces (Figure 1) through the human body and the influence that they have on internal organs and tissues are of particular importance [1, 7, 8].

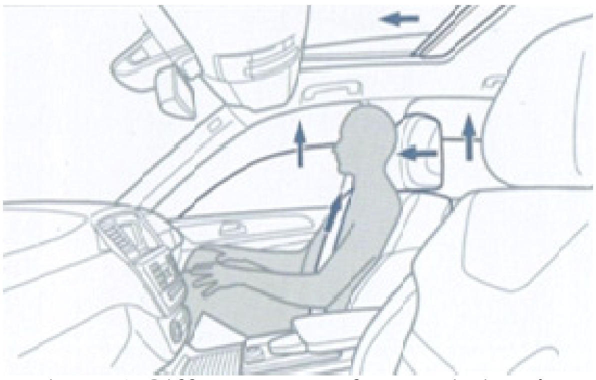

Figure 1. Different ways of transmitting the external forces to and trough the human body

THE VEHICLE DYNAMICS AND TRACK CHARACTERISTICS

To determine the forces that act on the driver or on the passengers, during the drive, it is necessary first to determine the vehicle dynamic characteristics. Therefore in this study it is considered a passenger car with the next characteristics, extracted from the vehicle's technical book.

The cylinder capacity	$V_c = 1995\ [cm^3]$
Maximum power	$P_{max} = 105\ [kW]$
Maximum torque	$M_{max} = 190\ [Nm]$
Revolutions at maximum power	$n_P = 6000\ [rev/min]$
Revolutions at maximum torque	$n_M = 4250\ [rev/min]$
Gearbox type	5 speed manual
Central transmission ratio	$i_0 = 4.5$
Transmission ratios of the gearbox	$i_1 = 4.32;\ i_2 = 2.46;\ i_3 = 1.66;\ i_4 = 1.03;\ i_5 = 0.85$

Gauge dimensions	*L = 4.25 [m]; B = 2.013 [m]; H = 1.421[m]*
Wheelbase	*Am = 2.76 [m]*
Axle track	*Ec = 1.5 [m]*
Tire type	*255/55 R16 H*
Own mass	*Ga = 1435 [kg]*
Maximum speed	Va_{max} *= 210 [km/h]*
Payload	Q_u*=475 [kg]*
Average consumption	C_{med} *= 5.9 [l/100km]*

Using these characteristics combined in the formulas from [2], the vehicle's engine external characteristics, traction forces [Figure 2], speed and acceleration [Figure 3] were determined for each speed gear.

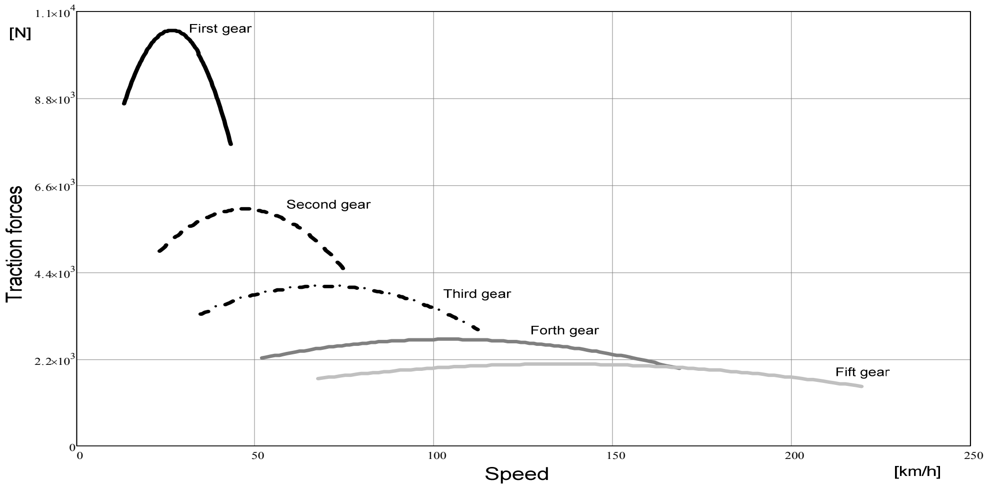

Figure 2. The traction forces for each gear depending on the vehicle speed.

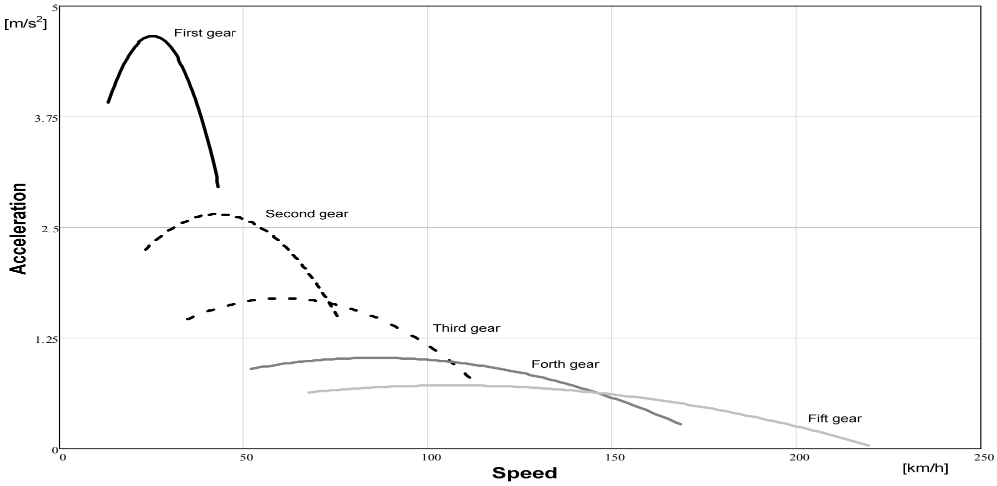

Figure 3. The acceleration for each gear depending on the vehicle speed

The next step in this study was to determine the inertia and centrifugal forces that act on the driver. Therefore it is considered a human model with its own mass of 80 [kg]. Because the influence of these external forces is more pronounced on the upper part of the body, in the driving position, the study is focused on the reactions of this upper body. When a person's upper body stands upright, the mass of the trunk, head and arms presses vertically on the lower lumbar spine with a force of approximately 55% of bodyweight, which in this case is 44 [kg] [1, 7].

As resulted in Figure 2 and Figure 3, it is also well-known that the vehicle's traction forces and acceleration have higher values in the first gear, and they decrease as the gear number and vehicle's speed increases. Thereby the inertia forces that act

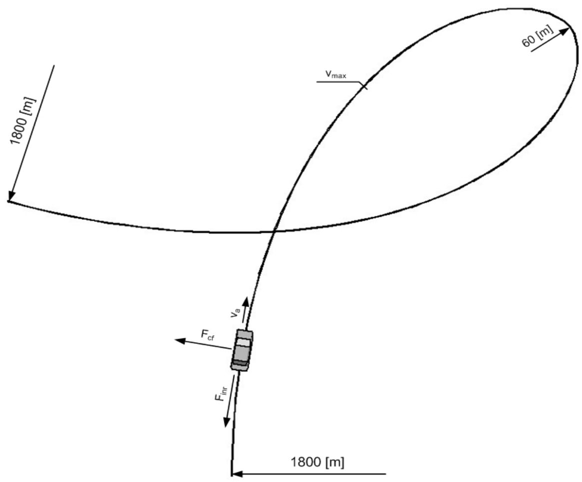

Figure 4. The curvilinear trajectory

on the upper body have a range of high values at the vehicle start off, and they decrease as the speed gear number and vehicle's speed increases until the speed is constant. In Figure 5 and 6 are represented the inertia force and the centrifugal force, that act on the upper body part of the human model while the vehicle is driven along a curvilinear trajectory (Figure 4) starting with a radius of 1800 [m], 60 [m] radius in the middle, and exiting the curve with a radius of 1920 [m].

Because in the second part of this study it is used the AnyBody Modelling System software to simulate the three cases of driving, is important to mention that the simulation of each body movements is based on time steps [8]. Therefore the drive along the curvilinear trajectory is divided in 100 time steps.

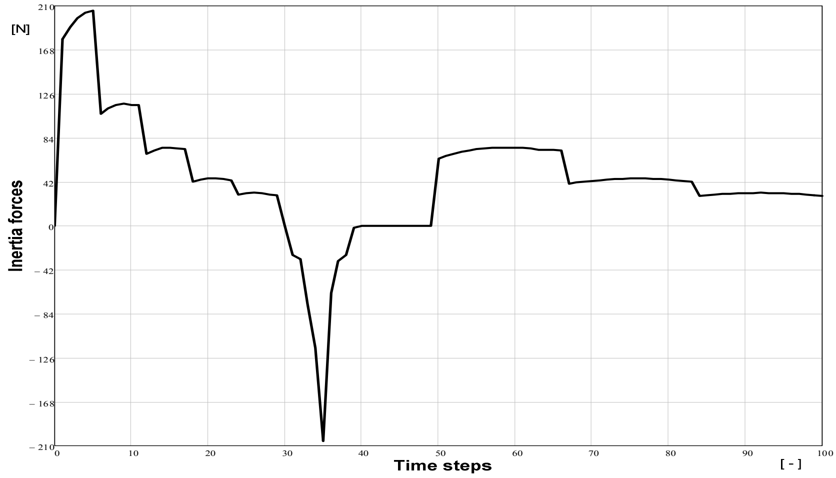

Figure 5. The inertia force that act on the upper body part

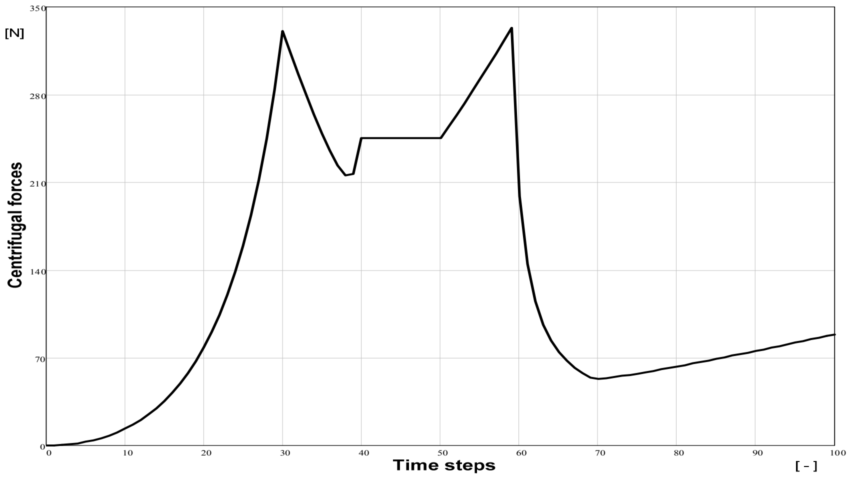

Figure 6. The centrifugal force that act on the upper body part

SIMULATION USING ANYBODY MODELING SYSTEM SOFTWARE

The AnyBody Modelling System is a software system for simulating the mechanics of the live human body working in concert with its environment.

The body models are available in the standard demo package that can be used in conjunction with the AnyBody human body simulation software. Starting from a standing human model, using pre-defined muscles and bone attachments, and building the seated driving postures scenarios, have been developed.

For the seated position, the car seat was added virtually through a node that offers a stabile platform for the pelvis region. The angles for the legs were obtained from an ideal theoretical position for the purpose of minimizing their involvement in the general muscle activity of the body system.

All activities include certain tensions in the hands given by the steering wheel load. Because of this factor, the model has forces attached to the nodes belonging to each of the hands. This ensures that the data output is similar to that which would be obtained from a real life model and further adds to the accuracy of the model [8].

All movement patterns were carefully studied for muscle collision and kinematical correctitude; after all data was considered viable, the next phase of the study - using inverse dynamics, was conducted. The data was then extracted from the output of the program for the various muscle groups that were of interest (trunk muscles and abdominal muscle activity). The most relevant data *was considered the trunk muscle fatigue. Muscle fatigue (Activity) is defined by the AnyBoby solver as muscle force divided by strength.*

The simulation was made for three different cases each representing a car seat type and the way the human body is constrained to it.

The first case represents a standard car seat with the upper body of the human model poorly constrained to the backrest. On the upper body are acting the inertia force and the centrifugal force. Because the upper body it is poorly constrained to the backrest, results a movement on the resultant force direction, effort made to keep the balance in the car seat. The second case represents a car seat with lumbar support and the upper body constrained to the backrest. In this case the upper body moves only on the centrifugal force direction, with less effort made to keep the balance in the car seat. The third case represents a car seat with lateral trunk and lumbar supports. The upper body is constrained to the backrest and to the lateral trunk supports, and it is subjected to inertia and centrifugal forces. Because it is constrained on both force directions, results no movements and almost no effort made to maintain the balance in the car seat.

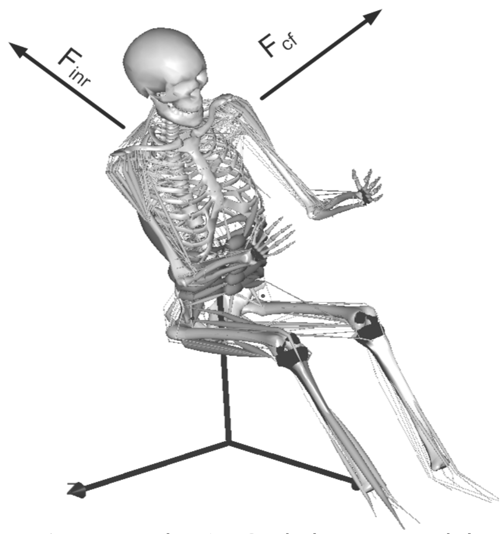

Figure 7. The AnyBody human model subjected to inertia and centrifugal forces during the drive

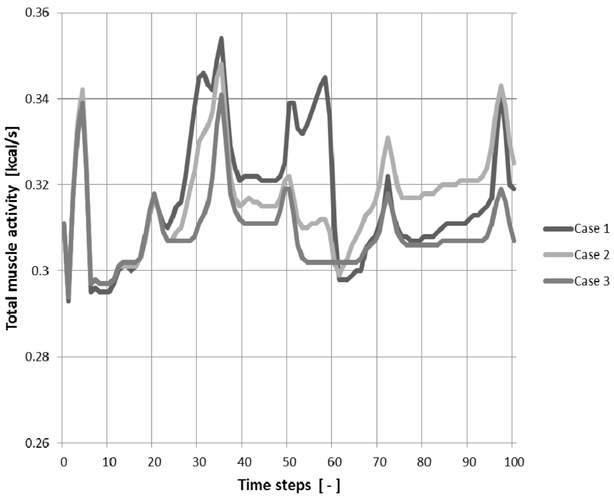

Figure 8. The total muscle activity for each case

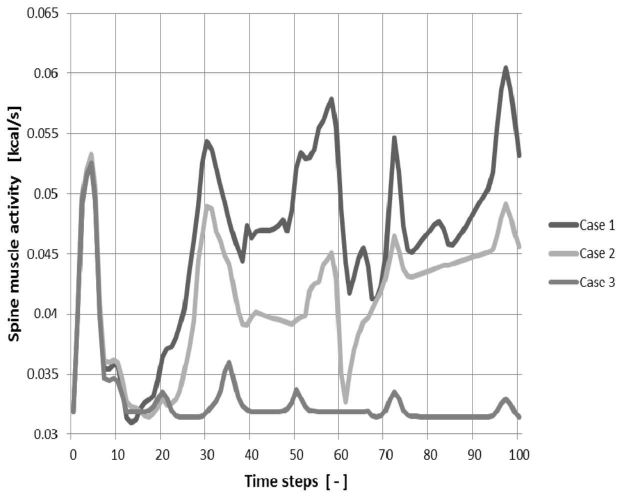

Figure 9. The spine muscles activity

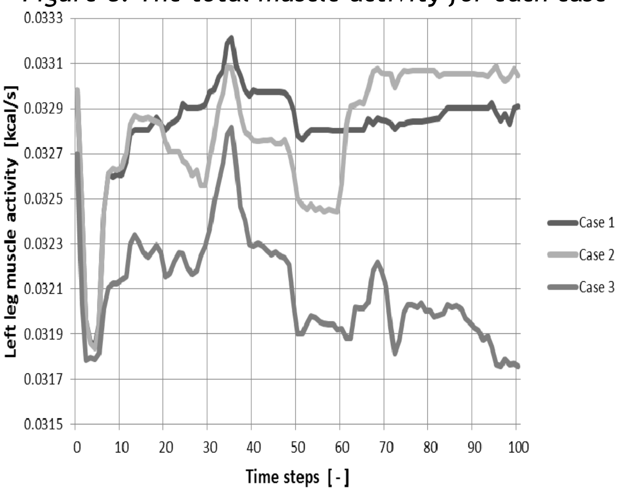

Figure 10. The left leg muscles activity

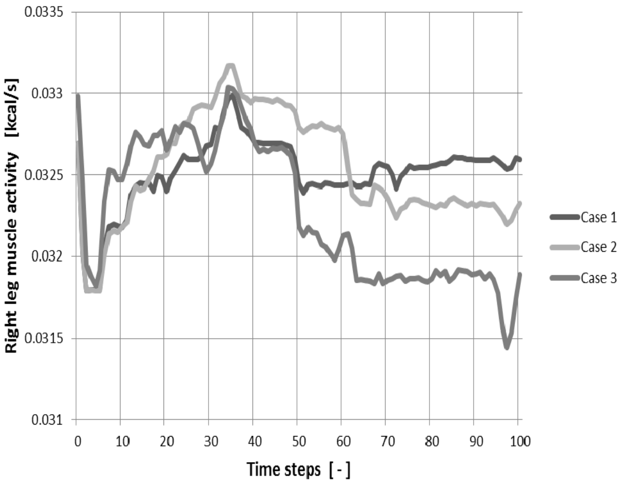

Figure 11. The right leg muscles activity

In Figure 8 is represented the total muscle activity, for each case of driving and car seat type. It is clearly reviled that overall in the first case that the energy consumption has higher values and that in the third case the effort made to keep the balance in the car seat is minimal.

In Figure 9 is represented the spine muscles activity, for each case of driving and car seat type, and in Figure 10 and Figure 11, the left and right legs muscles activity. It is clearly reviled that *overall in the first case that the energy consumption has higher values and that in the third case the effort made to keep the balance in the car seat is minimal.*

To highlight the importance of the lateral trunk and lumbar supports presence in the car seat design, in the driving simulation were added low frequency and high amplitude vibrations reproducing the passing over road irregularities. This type of vibrations amplify the effort made to maintain the balance in the car seat, and for a prolonged time they can cause severe musculoskeletal affections, especially to the lumbar spine were they can cause inter-vertebral disc side compactions leading to back pain.

THERMOGRAPHICAL EXPERIMENT

The temperature recorder (thermograph) is an important tool for medical diagnosis because science has managed to prove that all diseases cause temperature changes in a suffering organ. Some types of disorders lower the temperature in that particular organ, others raise it.

The infrared camera we used was FLIR B200 which is based on settings that sense and record on tape the cold and warm areas of the human body by detecting infrared radiations which react to blood flow [9].

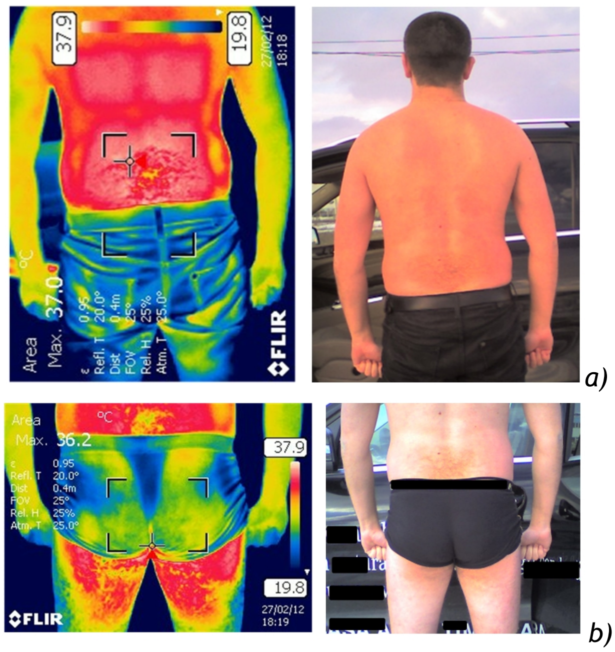

Figure 12. The first case scenario: a) the spine muscle contractions; b) the legs muscle contractions

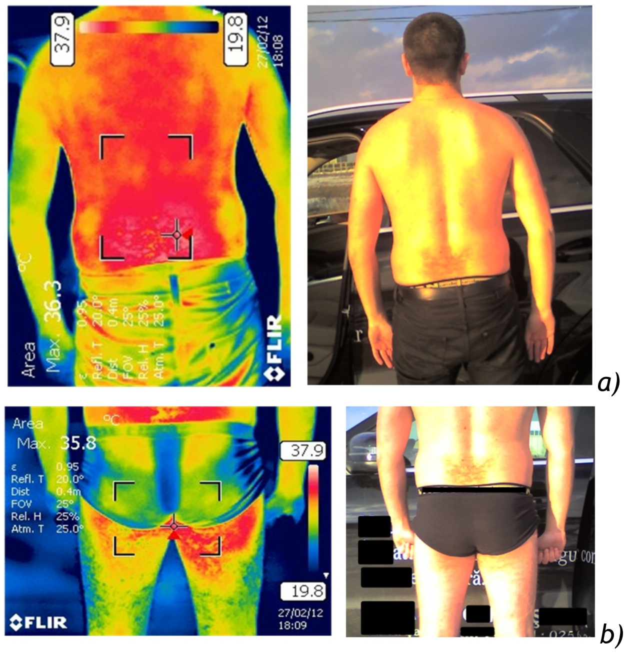

Figure 13. The second case scenario: a) the spine muscle contractions; b) the legs muscle contractions

With the help of the infrared camera there were taken a set of pictures which give the possibility to analyse the body temperature distribution and at the same time the increase of muscle contraction.

The conditions that had to be fulfilled to assure the accuracy of the study were the following:

- *low surrounding temperature, to avoid errors in measuring the real body temperature;*
- *the driver's position was maintained for a longer period of time;*
- *the driver posed shirtless so that the body temperature could be most accurate;*
- *the vehicle had the same dynamical characteristics with the one in the simulation;*
- *the car seat design included variable geometry offering the possibility to reproduce the three simulation cases.*

The study underwent by reproducing the driving on a similar track to the one used in the simulation.

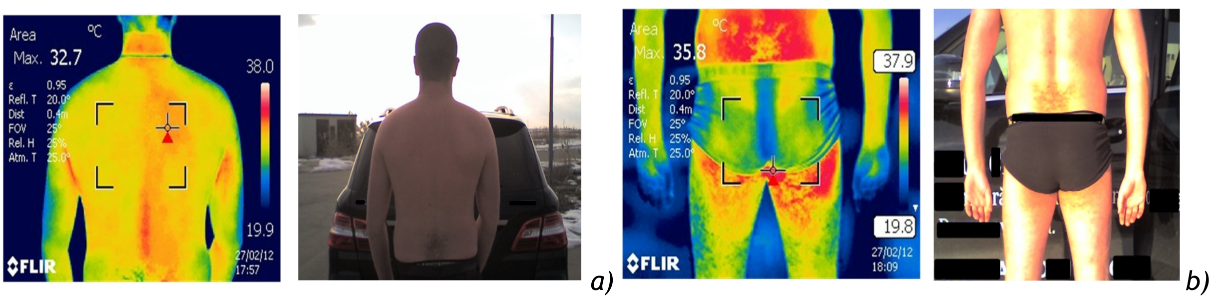

Figure 14. The third case scenario: a) the spine muscle contractions; b) the legs muscle contractions

CONCLUSIONS

Back pain is one particularly crucial problem that is in a driver's best interest to avoid. A good driving position and correct posture is vital for the efficient practice driving and to avoid chronic back pain. After a careful examination of the data and statistical analysis, a clear distinction between the energy consumption for the three driving postures became apparent. According to the results the ergonomic optimal posture is the 3th one representing a car seat with lateral trunk and lumbar supports. This result is validated also by the thermo graphic experiment by highlighting the temperature distribution. This shows that the posture with the smallest energy consumption and muscle activity is the 3th one.

These results are highlighting the importance of the car seat designed with trunk lateral and lumbar support that has to be comfortable; it should fit to lumbar curvature, and contact should be maintained with it while driving.

Another aspect of the study is the possibility of pointing out the individual muscle strain for the various trunk muscles.

This sort of data obtained from driving posture simulations and compared with thermo graphic results, is very useful in ergonomic design of the car seats, and also in improving the prevention of the musculoskeletal disorders by using ergonomics.

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