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COMPARATIVE ANALYSIS OF CORE MUSCLE BEHAVIOR ON INGRESSION AND EGRESSION IN DRIVING POSITION

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Abstract: *The aim of this study is to assessment the muscle behavior from lumbar side, during ingression and egression in driving position on medium class car. Using VICON system and BoB (Biomechanics of bodies) software we make an analysis of torque torsion of the lumbar spine and also an analysis of muscle imbalance left/right, during two types of ingression and egression. The torques seem to be more closely for both types of movements. The gap of numeric values of torques between types 1 and 2 is 8-10% , in favor of ingression 1 and muscle imbalance is high for Erector spinae muscle.*
Key words: *Biomechanics, ingression and egression, muscle imbalance.*

1. INTRODUCTION

1.1 Problem description

Ingression and egression on the car is a complex activity and could involve an overuse for the driver due to important control and coordinate mechanism that are involved for obtain stability and comfort which has to be keeped during the driving process. This is also a challenge for the designers.

This could be obtain based on sensorial informations and also motor control.

The knowledge of the physiologic mechanism by the designers and manufacturer could have important ergonomic impact that allows to improvement the models which satisfy the custom requires [1].

Until this moment the researchers speak about the patterns of ingression and egression in according with car geometry and comfort.

This analysis has been made after the researchers have defined the ingression and egression phase, follow up 5 strategies for ingression: lateral sliding, backward motion, forward motion, trunk forward, trunk backward and 3 strategies for egression i.e., head forward, parallel, and two foot.

Much more, the kinematic studies showed that are some tendencies of ingression and egression for each person if we refree to older and younger people or healthy versus disabilities people suffered of spine column pathology.

In present in automotive controls the attention is focused on seat adjust for comfort, but don't forget that this means to have a proper resistance and tilt design, for reduce the possibility of muscle fatigue development.

1.2 Application field

The results and conclusions of this study could give informations in field of ergonomy and offers details about specific action in ingression/egression if we speak about the muscle activity. This muscle behavior could be understand by the driver and much more the algorithm of analysis the muscle activity from the lumbar region for increase the understanding of how the designers could apply the informations for reduce the risk of spine overuse especially for professional drivers.

1.3 Research stages - state of the art in biomechanic assessment

Many studies are in ergonomy referee to different age population or people with disabilities, but are not so many studies that referee to these two movements ingression/egression [2].

Some studies speak about the Digital Human Models (DHM) for analysis the specific movements in ingression/egression in the car, but this requires a in-depth analysis for create some models for various population groups.
The question for the designers is increasingly using digital mock-ups of the built environment in concert with DHMs as a means to reduce costs and speed-up the "time-to-market" of products [3] .
The aim of many studies is to improve the ergonomy of the car by DHMs simulation, in this sens researches from Santos Human (University of Iowa) and HumoSim (University of Michigan), analysis the body posture, eyes, coordination etc. In the project 'Handiman' (University de Lyon, France) a digitized the egress motion of older adults and create a real model, which is in according with physical abilities of the users based on biomechanic evaluation of the specific movements during ingression/egression.
However in this moment dosent exist studies about the specific patterns of ingression/egression.
Shippen et al. [4] analyse the biomechanic factors that could affect the skills of ingression/egression, like knee torque [5], horizontal and vertical momentum, balance, which influence the motor strategies of the trunk and members [6]. These evaluations are made using the magneto-inertial Xsens MVN Awinda system. In actual context development of digital human models for ergonomic assessment of vehicle design, needs a biomechanic evaluation of dynamic movements and also the forces developed in relation with the discomfort. This aspect has been presented by Pannetier [7] in the context of study how clutch pedal could influence the dynamic and comfort.
From this point of view have been studied 2 situations, one for imposed configuration and one with less imposed conditions.
Identify the biomechanic parameters could explain a lot of indicators that define the discomfort and help to design the clutch pedal. Relationship between posture and force developed has been studied by analysis the force excert under the clutch pedal. The conclusions of the study were that the direction of force excerted is closely with the posture alignament based on the principle of minimize of joint torques that means a minimize of muscle activity which is a whish.
Simulation of ingression/egression has been made many times, using the models from capture library. By this way many simulations use the manikin (from capture library), with different anthropometric parameters and different cars. Have beed analysed joints markers trajectories [8].
In ergonomy are a lot of guidelines and strategies for assure the comfort of the users. One of the factor that could involve discomfort is interaction between ambient car environment and muscle constraints [9]. Some of these constraints are joints angles and muscle forces [10, 11].
Video method proposes the analyse of these aspects and we find in the Loczi et al. study [12] discussion about movements evaluation, calculate the loading of the spine and the conclusion is that the loading is small.
Muscle forces have beed analysed by reporting to neutral position [13] and the authors found that the muscle stretching is a phenomen during ingression. This analysis has been made using OpenSIM™ software, start from VICON system informations [14].
However the discomfort aspect in relation with ingression/egression seems to be not enough for the designers and need kinematic approach [15]. The conclusion is about how easy is to use the car and what about discomfort [16, 17], that means is need to study the biomechanic behavior of each segment for give suplimentary informations.

1.4 The aim of the study

The aim of the study is to evaluate the trunk muscles behavior during ingression/egression. We studied the muscle imbalance forces for two different types of ingression and egression in driving position:

- Ingression type 1-classic ingression – the driver use the right lower limb in the same time with left lower limb like support. In the second phase of the ingression the driver is sitting and the end of the movement is to introduce inside the left lower limb. The egression from the car is the first egression and the left lower limb is on the ground follow by trunk lifting on the seat;

- Second ingression, type 2 is not usually and the driver sits on the car chair and then introduce the legs inside of the car. The egression for the type 2 consists on rotation the trunk follow by put the legs on the gorund.

In the same time we evaluate the muscle imbalance of paravertebral muscle and try to contribute to define the muscle patterns during ingression and egression.

2.METHODS

2.1 Equipments and softwares

The study has been made on a male, age 35yrs, high 1.65m, weight 64kg.
We used VICON system and the experiment has been made in laboratory on the experimental stand that was build by using a part of the car, the driving position of the car. (Figure 1).

Fig.1. Experimental stand used for analys the ingression and egression

The biomechanical analysis of the specific movement of entry and exit from the driving position was performed with a complex system of capture and image processing type VICON [18], which is part of the equipment of the Laboratory of Techniques and Innovative Processes in Bioengineering from the Research Infrastructure in Applied Sciences INCESA of the University of Craiova (http://www. incesa.ro) and allows determining the trajectories of marked points on the studied biomechanical system, by recording motion, using 14 ultrafast video cameras (Figure 2).

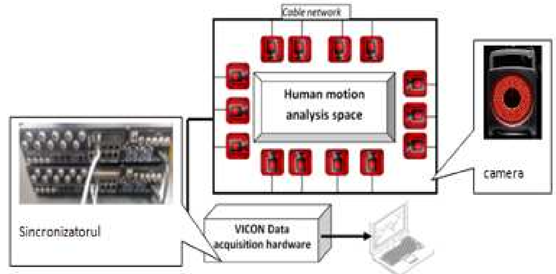


Fig.2. Schematic diagram of the Vicon [18] system with the 14 ultra-fast T / series camcorders

VICON system has 14 cameras, 250 Hz. The system uses 39 points on the body and NEXUS software allows to process the dates and give files like *.c3d. These files gives data for BoB software BoB (Biomechanics of bodies [19]). This help us to simulate the muscle behavior.

2.2 Data collection

Using BoB we recorded the images from figures 3 and 4, that represent type of ingression/egression 1.

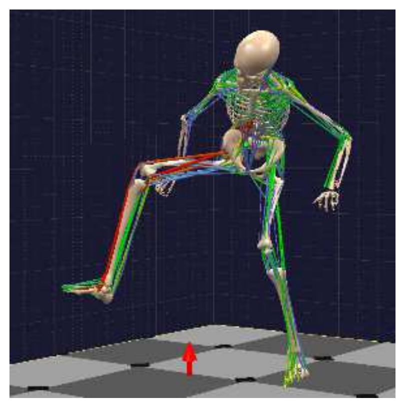


Fig.3. Ingression 1-body position

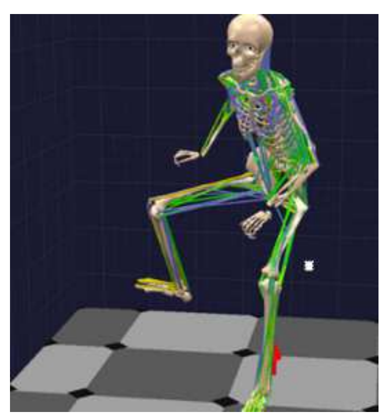


Fig.4. Egression type 1-body position

Figures 5 and 6 referee to ingression/egression type 2.

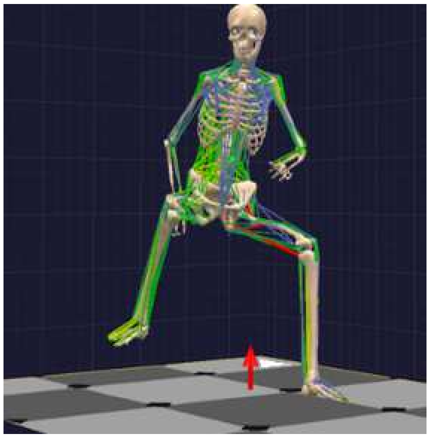


Fig.5. Ingression type 2-body position

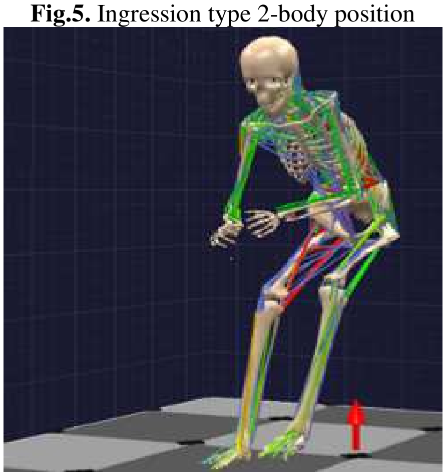


Fig.6. Egression type 2-body position

In the experiment we analysed the muscle parameter like muscle force for muscle groups: *Erector spinae* (Figure 7), *Quadratus lumborul* (Figure 8) and *Latissimus dorsi* (Figure 9).

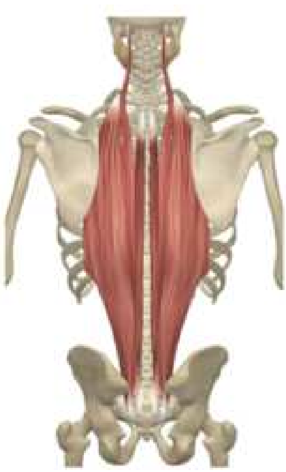


Fig.7. *Erector spinae* [20]

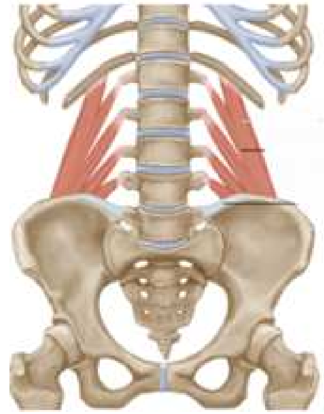


Fig.8. *Quadratus lumborul* [21]

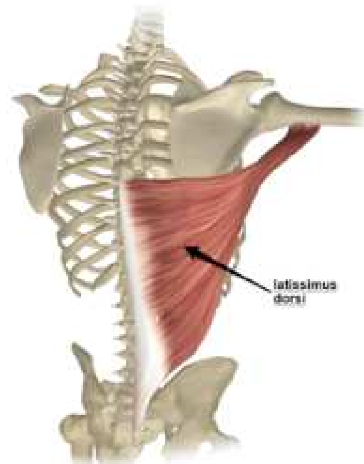


Fig.9. *Latissimus dorsi* [22]

3. RESULTS

For each movement ingression/egression in driving position, using the BoB software, we selected the torques variations of the lumbar vertebraes l1-l2, l2-l3, l3-l4 si l4-l5 (Table 1). The maximal variation means the maximal rotation of the vertebraes. Analyse the muscle imbalance has been quantify by forces values [N] form right and left side during the maximal torques variations (Table 1).

Table 1

Intervals for maximal torque for each movement

Movement type	Start of maximal torque [s]	End of maximal torque [s]
Ingression 1	6	8
Ingression 2	3	5
Egression 1	4	4,5
Egression 2	5.5	6

Muscle imbalance has been evaluated also from qualitative point of view using the colours diagrams from software BoB, green for minimal muscle contraction (lower muscle force) and red colour for important muscle contraction (high muscle force). For ingression type 1, on driving position, the variation of the intervertebral torque is presented in figure 10. We observe that maxim torque is on lower back side L4-L5.

For ingression 2 is the same maximal torque at lower back L5-L5 and it is presented in figure 11. If we analyse both situation we can see that in ingression 2 the torques has some fluctuations of the values that means a tendency to restore the segmentar balance by muscle action like protection mechanism.

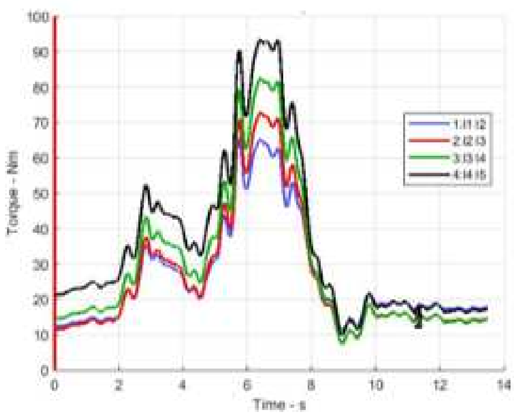


Fig.10. Variation of spine torque level l1-l2, l2-l3, l3-l4 and l4-l5, ingression 1

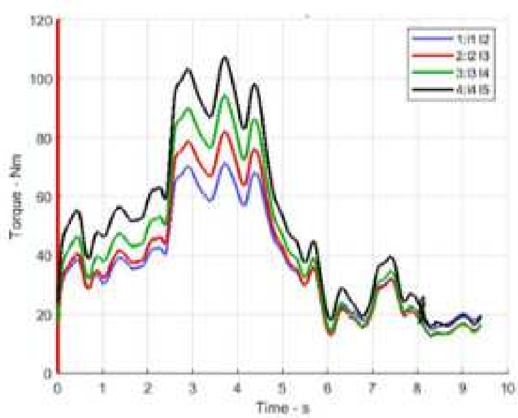


Fig.11. Variation of spine torque level l1-l2, l2-l3, l3-l4 and l4-l5, ingression 2

The muscle imbalance is assess using the qualitative way of BoB software and are presented in figures 12 for ingression 1. We can see a high imbalance left right, in ingression1, left side is less loading then right side.

For ingression 2 the qualitative aspect of imbalance is presented in figure 13, and we can see the imbalance is less then in ingression 1, the spine loading is on median side of the spine, due to intervation of intrinsec muscles of the spine.

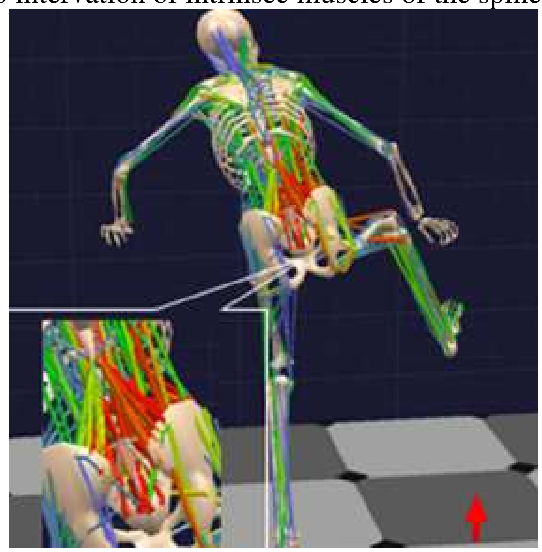


Fig.12. Muscle imbalance ingression 1 (right side loading-red colour) moment t=6s

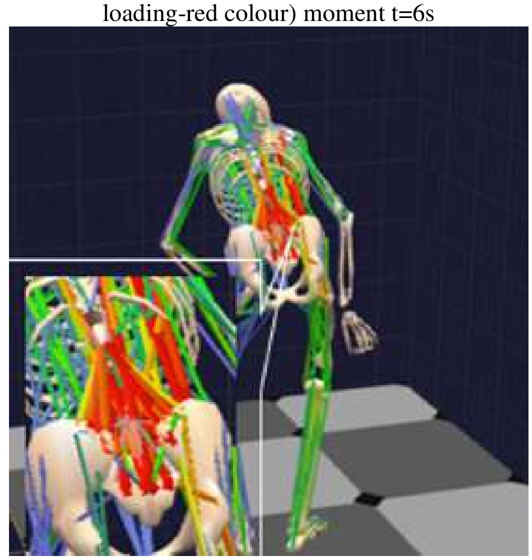


Fig.13. Muscle imbalance ingression 2 (less the ingression1) moment t=3.5s

The difference between muscle force between left and right side is evaluated by BoB software also, and are presented in figures 14,15,16, for each muscle group, in both situations.

Legend 1

ingression 1

ingression 2

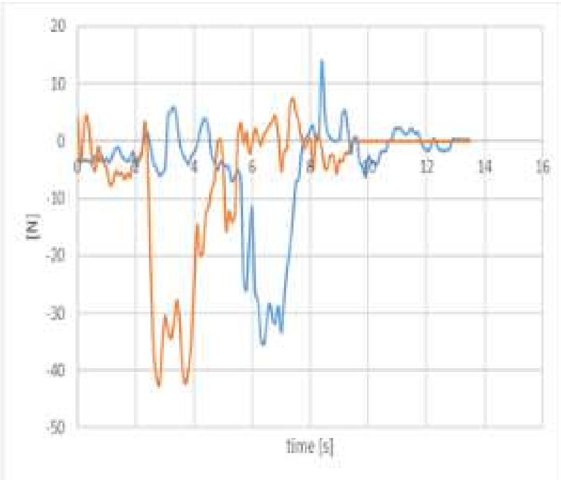


Fig.14. Comaparative anaylse of muscle imbalance (muscle force) between ingression 1 and 2, for *Erector spinae*

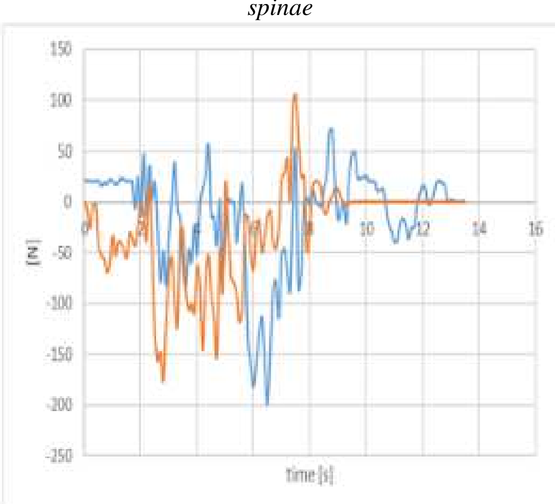


Fig.15. Comaparative anaylse of muscle imbalance (muscle force) between ingression 1 and 2, for *Quadratus lumborul*

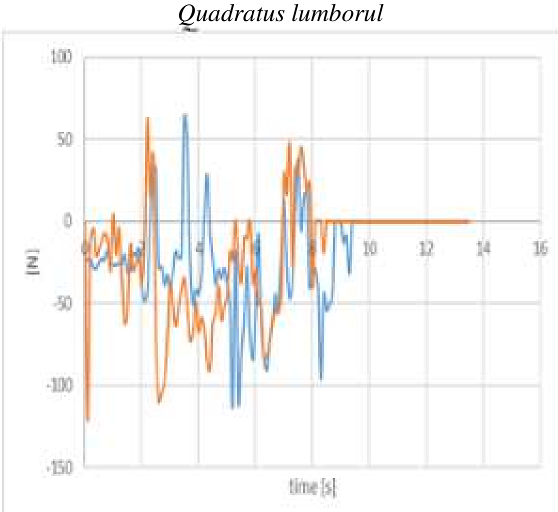


Fig.16. Comaparative anaylse of muscle imbalance (muscle force) between ingression 1 and 2, for *Latissimus dorsi*

We made also the evaluation of torques for egression 1 and 2, and the results are presented in figures 17 and 18.

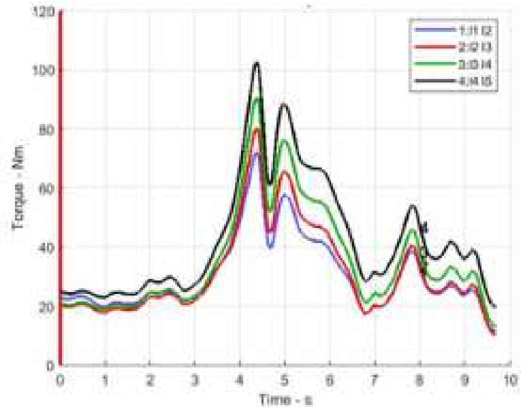


Fig.17. Variation of torque spine egression 1 l1-l2, l2-l3, l3-l4 si l4-l5

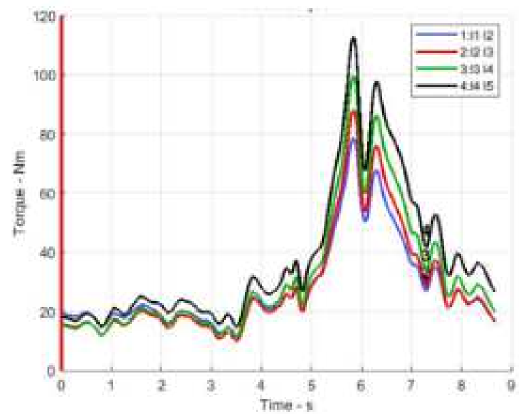


Fig.18. Variation of torque spine egression 2 l1-l2, l2-l3, l3-l4 si l4-l5

Muscle imbalance like qualitative representation, is presented in figures 19 and 20, and quantitative difference, like muscle force, is presented in figures 21, 22, 23.

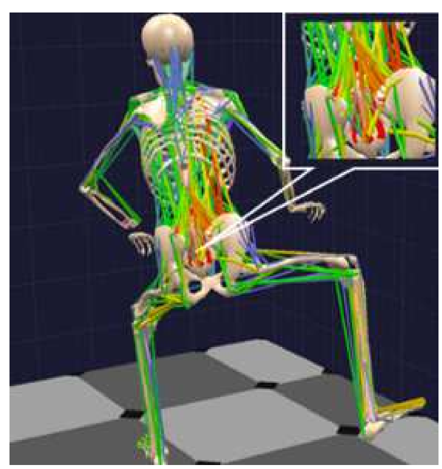


Fig.19. Qualitative difference of muscle imbalance egression 2 moment t=4.6s

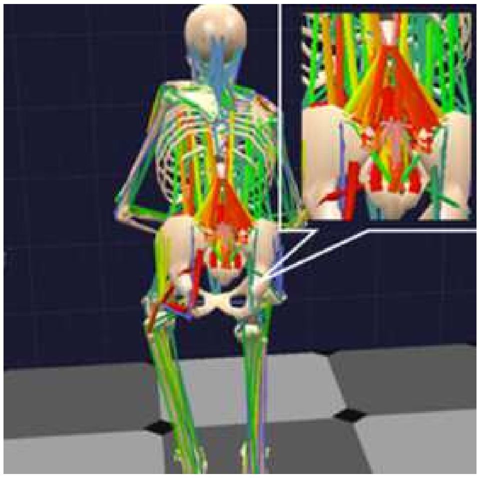
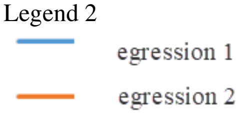


Fig.20. Qualitative difference of muscle imbalance egression 2 moment t=5.8s

Legend 2



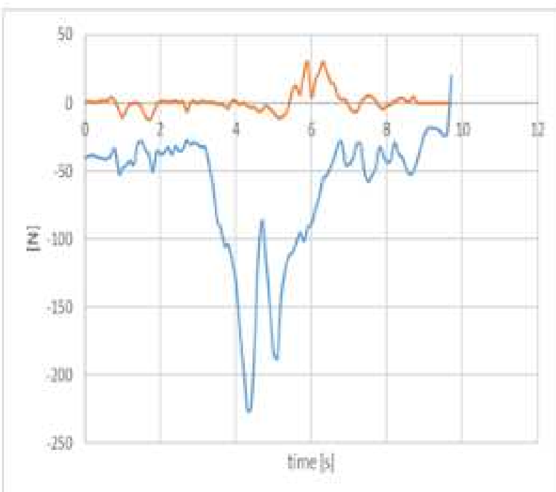


Fig.21. Comparative muscle force imbalance left/right for *Erector spinae*

Analyse the results in figures 14,15,16, show us that the bigger gap of muscle imbalance is for muscle *Erector spinae,* which is the muscle most involved in intervertebral movements. Such, at this group the muscle imbalance is higher in egression 1 then egression 2 and for muscles *Quadratus lumborul* and *Latissimus dorsi,* the muscle imbalance has not significantly difference between egression 1 and 2, this means that is possible to exist a compensatory muscle mechanism for decrease the torque and torsion of the spine.

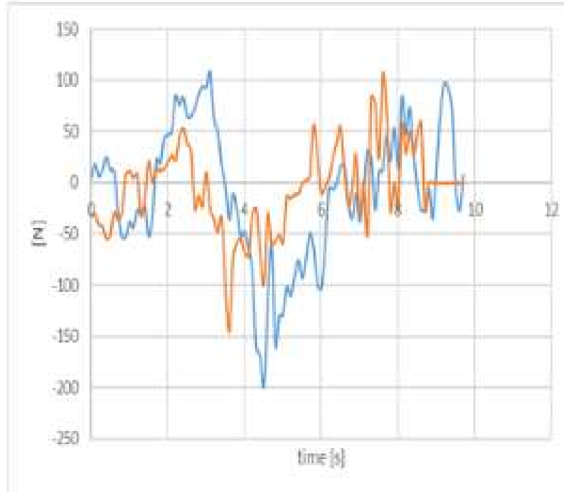


Fig.22. Comparative muscle force imbalance left/right for *Quadratus lumborul*

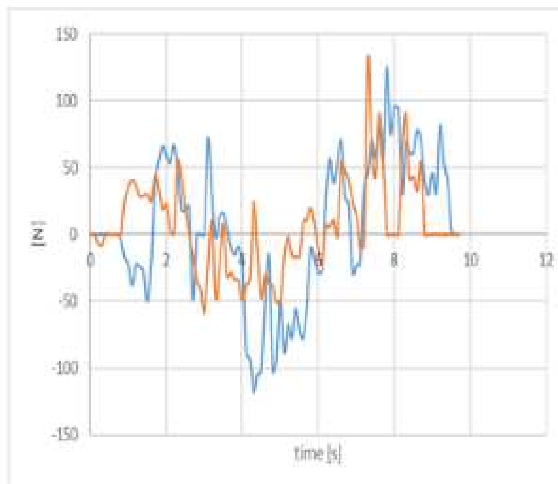


Fig.23. Comparative muscle force imbalance left/right for *Latissimus dorsi*

Analyse of torques torsion show us that in both egressions the maximal torsion is in lower back side L4-L5, and this could be explain because the start position is the same in both situations. From the qualitative point of view muscle imbalance is higher in egression 1 then 2 and also is a higher loading of *Quadratus lumborum*. Not the same imbalance is in egression 2. Regarding muscle force, difference between both egressions, are presented in figures 21, 22, 23 and we observe that for *Erector spinae* is an important gap between egression 1 and 2, but a reduced inbalance for other muscles group, even if in egression 1 is a little bit more difference.

Experimental results could be find in many researches, many of the authors consider that need to be more evaluation of posture and how the the body posture mechanisms work in different situations and how is the loading of muscle groups during travel by car,

In this context our experimental research could be in according with Wang et al. [23, 24] which made a simulation of the posture inside of the car, at different moments and analyse the comfort using questionaires and try to find the most important components of DHM (Digital Human Models).

Wang et al. underlines the importance of evaluation the muscle parameters that could be useful for ergonomy and for understand the control mechanism of movements and which are the factors that are involved in discomfort of the driver.

All of these evaluation could have a contribution to realise of the automotive controls such as the clutch pedal, the hand brake or the gear stick.

The same authors make the evaluation of the range of motion (ROM) of hip, knee and ankle, and also evaluation of maximum isometric joint torques were performed.

Our study is also in according with the study of Kawachi et al. [25] and Reed et al. [26]. They describe also two ingressions strategies.

First strategy involves the head ingression and second, hip ingression. Much more, Ait El Menceur et al. [27] speak about some specific segmentar movements like foot/hip, flexion/extension/rotation of the trunk [28]. All are components of ingression strategy in a small car or minivans.

Because all actions are complex, is need a thorough analysis, and this aspect is underline by Jung et al. [8]. He uses a VICON system for evaluation the interaction between the car and driver during ingression/egression.

The authors consider that are very usefull kinematic analysis like joint torques, compression forces at lumbar region. The results could be use for justify some strategies of incressing, and this aspect is also in our experimental research [8]. They speak about the importance of biomechanic evaluation for have informations about the relation between cause and effect and about the loading of body segments.

A similary approach about the protocol of ingression is proposed by Hossny et al. in [29] which proposes the workflow of ingression and egression and included 5 components for analysis: modeling, mapping of the markers, anthropometric scale, inverse kinematic, muscle analysis. All of these we take in consideration in our experimental research.

About paravertebral muscle behavior Nahavandi et al [14] made comparative analysed on two lots: lot of females and lot of males and compare the behavior of muscle spinae. They speak about the development of stretching at a high level for females.

Biomechanic analysis of body segments in Nahavandi study shows that during ingression the stretching mechanism has a lot of variations even at the same lot.

Also at females lot they observe an overuse of lower muscles trunk and core muscles but at males lot the oversuse exists on back muscles.

Muscles behavior is also study by electromyography (EMG) [30] and by maximal voluntary contraction (MVC) ratios [30].

3.1 Further research

We propose to continue our experiment and make the analysis for different cars (like SUV truck) not only for driver but also for passenger. Future researches are need for identify more clear the strategies in according to the car geometry and facilities. This aspect is not enough study in the present.

We consider that is useful to give for designers more dates about the oversuse of spine in correlation with the chair type. Future studies are need for approach how different technic cars parameters could influence kinematic parameters during ingression/egression like high of the chair, chair position.

Also we don’t forget the correlation between the anthropometric parameters and ingression/egression strategy, that has to be a aim of the ergonomy.

4. CONCLUSIONS

We observe that the torques have the same allure for both ingression/egression situations.

Numeral values of the torques have the same order to enlarge and the difference for maximal value is 8-10% in favor of ingression 1.

In the present analysis of the posture and movement have a role in approach the discomfort associated with ingression/egression. This support a lot of discussion because many of studies speak about what is happened to hip and elbow joints.

For this we consider that first is need to evaluate the posture in various moments of the travel by car.

Approach of postural behavior is a challenge for designers which have to reduce the assymetric overuse of the body segments or could generate overloading.

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STUDIU COMPARATIV AL COMPORTAMENTULUI MUSCULAR PARAVERTEBRAL LA INTRAREA SI IESIREA DIN MASINA

Rezumat: *Studiul are ca scop determinarea comportamentului muscular la nivel lombar, in miscarile de intrare si iesire dintr-un automobil de clasa medie. Cu echipamentul de inregistrare si analiza a miscarii tip VICON si cu softul BoB (Biomechanics of bodies), am realizat o analiza a cuplurilor de trosiune la nivelul vertebrelor din regiunea lombara si o analiza a dezechilibrului muscular stanga-dreapta, in cele doua tipuri de intrare/iesire din masina. Cuplurile de torsiune au alura asemanatoare la ambele tipuri de miscari 1 si 2, dar alura lor este foarte diferita intre intrarea si iesirea aceluiasi tip de miscare din postul de conducere al standului experimental. Valorile numerice ale acestor cupluri au acelasi ordin de marime, cu un decalaj al valorii maxime cu 8-10% in favoarea intrarii 1, iar dezechilibrul muscular major se observa la nivelul muschiului Erector spinae.*

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