Therefore, this study aims to detail the role of the steering-wheel. The interaction between the driver and the car, in particular the car ingress/egress motion. However, it is still not clear about performing dynamic analysis and looked at joint torques during a recent years, many research studies have been launched for issues that catch the attention of many car manufacturers. In ergonomics, the ease of getting in and out of a car is one of the ergonomic issues that catch the attention of many car manufacturers. In recent years, many research studies have been launched for simulating car ingress/egress motion and for understanding the perceived discomfort (see, for instance Chateauroux [2]). Most of these studies were focused on kinematic parameters such as joint angles. More recently, a few investigators tried to perform dynamic analysis and looked at joint torques during a car ingress/egress motion. However, it is still not clear about the interaction between the driver and the car, in particular the role of the steering-wheel. Therefore, this study aims to detail the role of the driver/steering wheel contact during an egress motion and to answer to the following questions: Do the drivers use it? How, when and why do they use it? Does this contact help drivers to get out by minimizing the efforts developed in the lower limb?

**METHODS**

26 young and healthy volunteers of different statures participated in the experiment. The volunteers were selected according to their stature covering a large range of French driver population from a 5th percentile female to a 95th percentile male. The experimental protocol was approved by the ethical committee of the IFSTTAR (French Institute of Science and Transport, Development and Networks).

A multi-adjustable car mock-up was used to define different car configurations. The three controlled variables were: 1/ the seat height with three levels, representing a small car (Hs1), a medium-size car (Hs2) and a minivan (Hs3); 2/ the sill width with three levels: the sill closed to the seat (Lb1), far from the seat (Lb2) and at an intermediate distance (LbM); and 3/ the roof height with three levels: the first roof height (H1), for which the subjects begin to feel discomfort due to the roof; the lowest acceptable roof height (H2), below which the subjects would not accept for getting in and out; and (HtM) the intermediate one. All other car dimensions were defined according to the seat height to simulate actual cars. In total, each subject tested 15 different car configurations.

A Vicon® motion capture system with 10 cameras, sampled at 100Hz, was used to capture the trajectories of 44 markers placed on the subject. All external contact forces between the driver and the car were recording using six axes force sensors: 1 on the ground, 1 on the car floor, 1 under the seat, and 1 on the left knee.

**RESULTS AND DISCUSSION**

The steering wheel was effectively used for 89% of the trials. Figure 2-a shows an example of the external contact forces during an egress motion. Two key frames were also illustrated: when the left foot reached the ground (Kf1) and when the buttock left the seat (Kf2). During the first part of the motion before Kf1, the driver was still in the seat. The body weight was shared between the seat, the car floor as well as the steering wheel. He/she directed the body to be in front of the doorframe, and moved the body on the side of the seat. Once the left foot on the ground, the weight started to be transferred to the left foot as well as to the right foot. During the period between Kf1 and Kf2, sometimes, one or two hand pushed on the steering wheel. After that, the hands left the steering wheel and his right foot got out of the car.
For 86% of the trials, a peak value appeared before or/and after that the left foot reached the ground (Kf1): according to contact forces applied by the driver. They were mainly observed for the low seat height configurations and for the tall stature group. Moreover, the forces of P2 were systematically higher than those of P1 and no effect of the sill width is observed. Considering the distribution force, the reaction force was -156±79N for X, -52±36N for Y and 104±29N for Z in average. Concerning X axis, the force decreases when the stature decreases. The same observation is done for Y axis, but the effect was to a lesser extent. It appeared also that the reaction force was mainly on vertical direction for the short stature. In this case, the contact with the steering wheel helped leaving the seat and probably stabilizing the motion during the weight transfer to the left foot.

To show if the steering wheel reaction force allows reducing the joint torques and making easier the motion, we compared the net joint torques at the right and left hip and knee with the corresponding joint torque generated by the wheel contact force (Table 2 and Figure 3). The contribution by the steering wheel was particularly high for the left knee extension, meaning that this reaction force helped in getting up.

### Table 2: Contribution of the steering wheel contact forces on net joint torques (Positive for extension). Values are average for all subjects (in Nm) and expressed on flexion axis in both leg joints when the force on steering wheel was maximal P2

<table>
<thead>
<tr>
<th></th>
<th>LHip</th>
<th>LKnee</th>
<th>RHip</th>
<th>RKnee</th>
</tr>
</thead>
<tbody>
<tr>
<td>net joint torques</td>
<td>40±48</td>
<td>04±21</td>
<td>-01±13</td>
<td>36±26</td>
</tr>
<tr>
<td>By St. wheel</td>
<td>-14±13</td>
<td>48±26</td>
<td>-14±13</td>
<td>26±15</td>
</tr>
</tbody>
</table>

Figure 3: Contribution of the steering wheel contact forces on the net joint torques (Red for net joint torques and blue for the contribution of the steering wheel)

### CONCLUSIONS

In this work, the hand/steering wheel contact force was investigated experimentally. It has been shown that the steering wheel was an essential element that played a role for helping drivers to get out of car. This was particularly true for the tall participants when getting out of the low seat configurations. The joint torque analysis also showed that the steering force reaction helped in producing necessary extension torque at the left knee for getting up.

### REFERENCES