# Effects of Impact Side on Medial Collateral Ligament Elongation during Vehicle–Pedestrian Impact

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## I. INTRODUCTION

The latest Euro NCAP Vulnerable Road Users assessment protocol (v11.2.2) introduces the advanced Pedestrian Legform Impactor (aPLI) and replaces the Flexible Pedestrian Legform Impactor (FlexPLI) to assess vehicle safety during vehicle-pedestrian leg impacts. The aPLI is a gradual further development of the FlexPLI [1-3]. The main difference between both impactors is the additional simplified upper body part for the aPLI, which results in more biofidelic impact kinematics than the FlexPLI [2]. Isshiki et al., in a post mortem human subject (PMHS)-to-impactor comparison, have shown that the SUV-pedestrian leg impact kinematics in particular are represented more realistically by the aPLI [4]. However, the PMHS-to-impactor comparisons are restricted to central impact positions and do not consider eccentric impact positions.

Furthermore, FEM simulations in [4] show that impacting the right or left side of a bumper of a simplified Sedan front-end with the aPLI has no effect on Medial Collateral Ligament (MCL) elongation. Impacting a human body model (HBM) using the PMHS posture also allows a basic comparison to the straight aPLI [5]. However, analysing the results in [4] of the same Sedan structure impacting a HBM in said posture, significant differences are found in MCL elongation between right and left bumper.

Therefore, the present study investigates the effect of impact side on MCL elongation in aPLI FEM simulations and in HBM FEM simulations impacting real car models. We focus on the outermost Euro NCAP test positions for several vehicles of different vehicle size classes. This paper also looks at the Euro NCAP's methodology of applying symmetry at untested grid points for the assessment of vehicle safety during vehicle-pedestrian leg impacts using the aPLI.

## II. METHODS

All simulations in the present paper were performed using the dynamic explicit solver Visual Performance Solution of the ESI group. The vehicle front-end FEM simulation models consist of more than two million elements each. The THUMS AM50 v4.02 pedestrian model is used in this study. It is positioned in the posture analogous to [4-7] (straight left leg carrying the entire weight and right leg inclined 20° forward) which resembles the PMHS posture. To investigate the effect of impact side on MCL elongation, FEM simulations were conducted at the outermost test positions of the Euro NCAP grid (Y+ on the right and Y- on the left from the driver's perspective) for the HBM and for the aPLI. This study includes 15 different vehicle models from two different manufacturers (seven sedans, one sports car and seven SUVs). For all simulations the aPLI's impact speed is 40 km/h and the HBM is impacted laterally by the vehicle at 40 km/h. The interval of evaluation for the injury criteria is set to 60 ms, starting from the initial impactor-vehicle (or HBM-vehicle) contact. For each HBM simulation the left leg is initially impacted and evaluated. The MCL elongation within the HBM's left leg is measured as the linear distance between the attachment points of the ligament. This method is equivalent to the method of measuring the MCL elongation within the aPLI [6].

## III. INITIAL FINDINGS

Figure 1 shows scatter plots in which each dot represents one vehicle's maximum MCL elongation value with regard to the test positions Y- and Y+ for the aPLI and the HBM, respectively. The aPLI results (Figure 1a) for every vehicle in the study show no dependency on impact side for the maximum MCL elongation values. They show negligible deviation from a line with a slope of the unit value, which indicates impactor symmetry as well as vehicle symmetry.

The HBM results for Sedans and the sports car (Figure 1b) show, on average, a symmetric relationship for the maximum MCL elongation values between the test positions Y+ (right) and Y- (left). Nevertheless, the samples within the Sedans and sports car cluster demonstrate slight deviations between test positions Y+ and Y- without following a specific pattern (max. deviation of 3 mm). This is consistent with the differences in impact side obtained from a simplified Sedan front-end model in [4], where the deviations were even larger (max. deviation of 5 mm). The HBM results for SUVs (Figure 1b) show higher MCL elongation values at Y- (left) compared to Y+ (right) (every value is below the line with a slope of 1). On average, the MCL elongation values are 38% smaller for the test position Y+ compared to Y-.

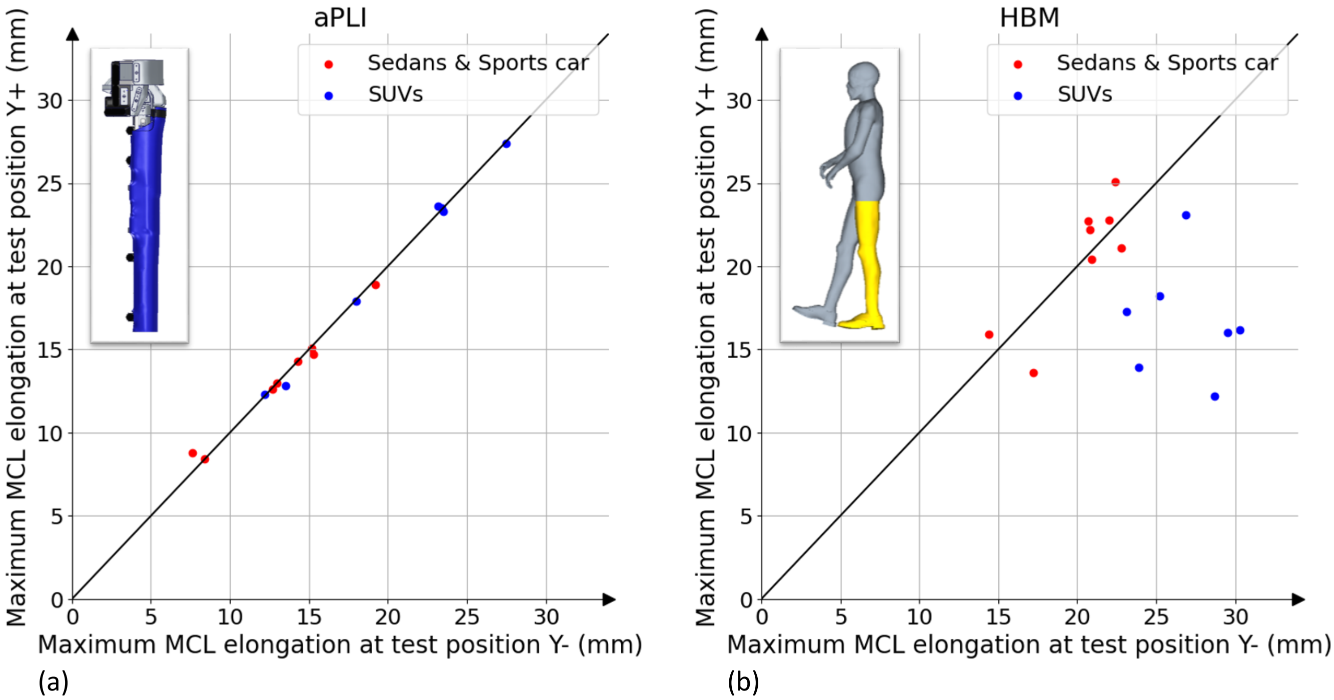


Fig. 1. Results of the maximum MCL elongation values obtained from real car model FEM simulations for the test positions Y- and Y+ using (a) the aPLI and (b) the HBM.

## IV. DISCUSSION

The aPLI results in [4] indicate no difference in MCL elongation between left and right impact side, which corresponds to the aPLI results (Figure 1a) for every vehicle in the present paper (max. deviation of 1 mm). Therefore, the Euro NCAP's methodology of applying symmetry within their latest testing protocol for the pedestrian leg impact using the aPLI seems to be sensibly chosen.

However, the present study reveals a noticeable difference in impact side for MCL elongation in SUV-HBM impacts (Figure 1b). This difference is caused by the asymmetric posture of the HBM, which resembles the PMHS posture. The non-struck leg (right leg) induces a torsional moment about the longitudinal axis of the struck-leg (left leg) at the Y- test positions that results in increased MCL elongation values compared to the Y+ test positions. The dependence on impact side is not noticeable in the Sedans and sports car cluster, which seems to be due to a lower vehicle front. This front-end geometry allows a shorter vehicle-HBM interaction, which results in a smaller torsional moment compared to the SUV cluster.

Based on this, further research can be conducted. First, repeating the study by using a posture with a more neutral non-struck leg position (e.g. 20% gait position in [8]) should show less dependency on impact side for SUV-HBM impacts. Second, explicitly investigating vehicle front-end height using the present HBM posture would show its influence on MCL elongation in the outermost test positions.

## V. REFERENCES


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