Comparative Biofidelity Evaluation of the FlexPLI-UBM and the aPLI using CORA

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I. INTRODUCTION

The assessment of injury risks to the lower extremities of pedestrians, including the femur, is currently carried out by combining test results achieved with the flexible pedestrian legform impactor (FlexPLI) and the upper legform impactor (ULI) [1-2]. Two initiatives have been developing upper body surrogates to unify these assessments based on a unique test with an improved lower legform impactor. The first is the newly developed aPLI with surrogate upper body part (SUBP) [3]. The second is the FlexPLI-UBM, which is the FlexPLI updated with the addition of an upper body mass (UBM) [4]. While the pros and cons of both approaches are keenly debated, an objective evaluation of their biofidelity is still outstanding. This short communication gives a summary of the first comparative biofidelity evaluation of FlexPLI-UBM and aPLI, achieved by means of the CORA evaluation tool [5].

II. METHODS

Human Body Model (HBM) simulations with version 4 of the Total HUman Model for Safety (THUMSv4) have been carried out against a generic Sedan frontend of the Society of Automotive Engineers (SAE Buck) as well as against an actual representative of the Van/MPV vehicle category. The results have been compared with experimental tests of the aPLI and the FlexPLI-UBM against the same test objects under identical loadcases.

FE Simulations

Four THUMSv4 simulations were performed under four different load cases: one simulation at centreline of the SAE Buck and one simulation each at vehicle centreline and at height of the left- and right-hand (LHS, RHS) end of the bumper beam of the Van/MPV.

Experimental Tests

A number of physical tests with the aPLI and the FlexPLI-UBM were carried out against the same test objects under identical load cases, as summarised in Table I. Tests with the FlexPLI Baseline were used as a reference.

CORA Rating

In order to evaluate the biofidelity of each approach, CORAplus rating with standard parameters [6] was used. Both the corridor method and the correlation method (cross correlation function, size, phase shift) were considered. The evaluation interval was fixed between 0 ms and 70 ms. Each of the four load cases and each of the 10 standard impactor signals (Femur 3-1, ACL, PCL, MCL, Tibia 1-4) were weighted equally (25% for each load case and 10% for each signal).

III. INITIAL FINDINGS

A comparison for the LHS and centreline impacts, as depicted in Fig. 2, indicates the legform impactors with upper body surrogates having superior kinematics compared to the FlexPLI Baseline. Time histories however show an occasionally significant over-oscillation of the aPLI particularly in the femur segments (Fig. 1).

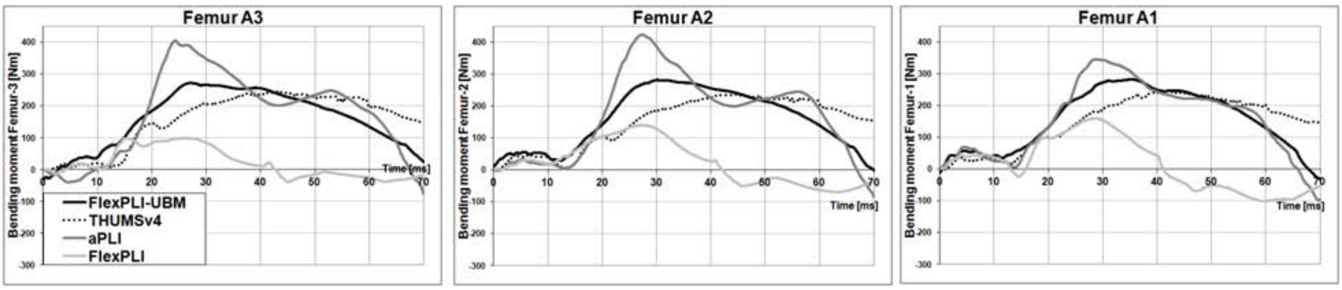

Fig. 1. Femur Bending Moments during Van/MPV centreline impacts.

TABLE I
LOAD CASES AND NUMBER OF EXPERIMENTAL IMPACTOR TESTS

Load Case	FlexPLI-UBM	aPLI	FlexPLI
MPV LHS	1	2	1
MPV Centre	3	2	2
MPV RHS	2	2	1
SAE Buck Centre	3		1

Fig. 2. THUMSv4 simulations and tests with FlexPLI-UBM, aPLI and FlexPLI Baseline against SAE Buck Centreline, Van/MPV Centreline and Van/MPV LHS at 30ms after first contact.

These general observations regarding kinematics and time histories are confirmed by the CORAplus rating for all lower extremity areas. Fig. 3 details the rating results for all impactors segmentally for each area (a-c) and summarises the results for the impactors and all assessment areas (d).

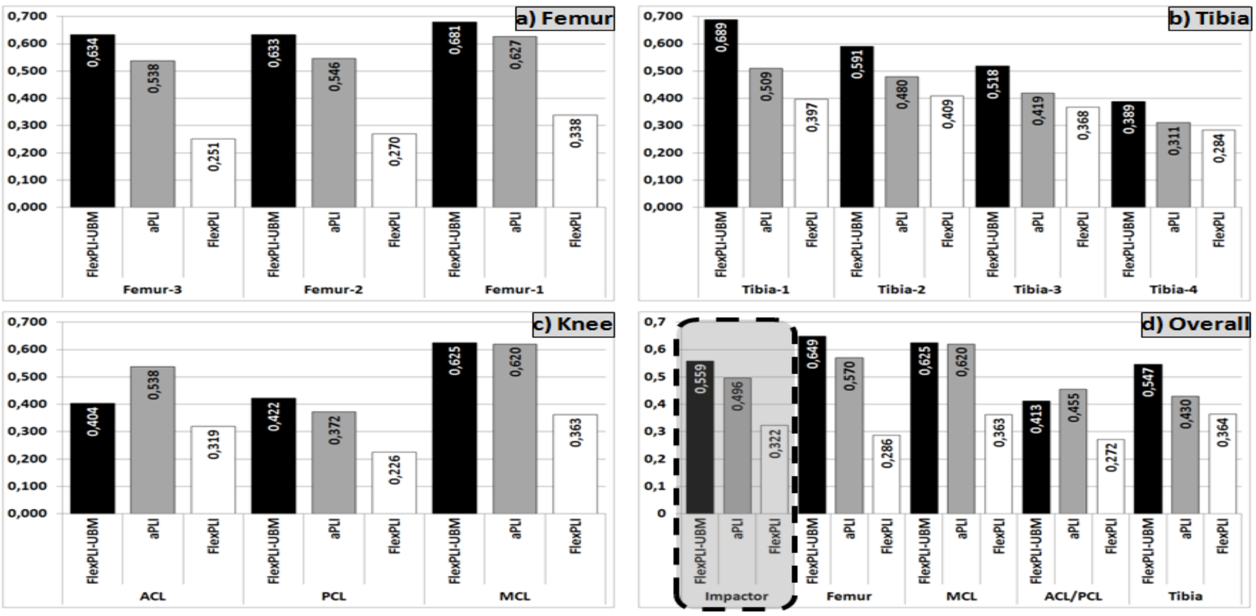

Fig. 3. CORAplus rating results.

IV. DISCUSSION

Under the evaluated load cases, an objective comparison of the biofidelity of aPLI, FlexPLI-UBM and FlexPLI Baseline using CORAplus resulted in superior biofidelity of both lower legform impactors with upper body surrogates, with further advantages of the FlexPLI-UBM in all relevant assessment areas (i.e. femur, MCL and tibia). Best ratings were achieved for MCL and all tibia and femur areas adjacent to the knee. An overall rating of 0.559 for the FlexPLI-UBM vs. 0.496 for the aPLI indicates that the FlexPLI-UBM is the better tool for the assessment of pedestrian lower extremity injuries. In the next stage this study will be extended, adding further vehicle categories and load cases to the database.

V. REFERENCES

[1] Euro NCAP Pedestrian Testing Protocol 8.4, 2017.
[2] UNECE Regulation No. 127.01, 2015.
[3] Isshiki, T., *et al.*, IRCOBI 2018.
[4] Zander, O., *et al.*, SENIORS Final Event 2018.
[5] Gehre, C., *et al.*, ESV 2009.
[6] CORAplus User's Manual 4.0.4.