Isolated Standing Mil-LX to Assess Injury Risk for Standing Occupants in Under Belly Mine/IED Injury Risk Assessment Tests.

Tim Westerhof, Tarik Hartuç, Dominik Soyka, Mat Philippens

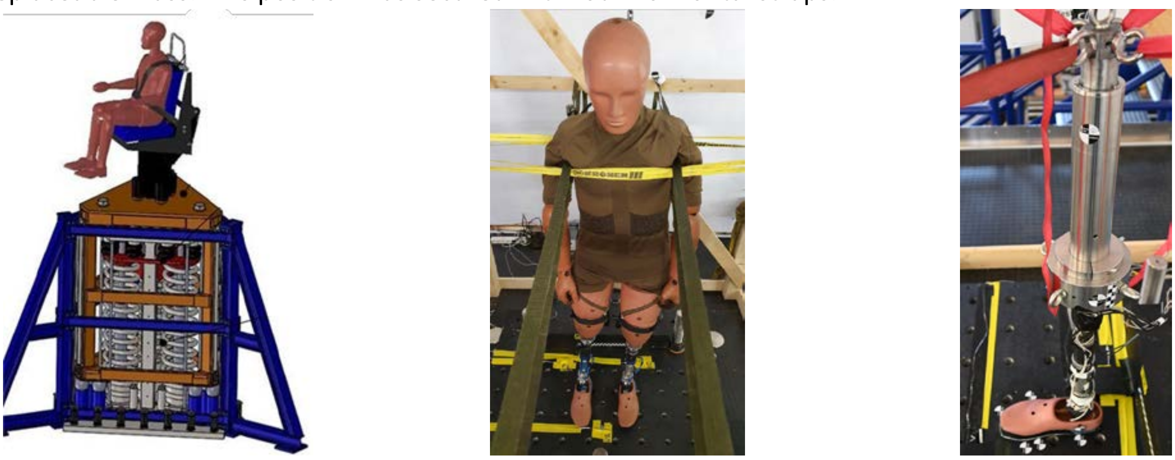
I. INTRODUCTION

STANAG 4569, Protection Levels for Occupants of Logistic and Light Armoured Vehicles [1], requires testing of seat positions with Anthropomorphic Test Device's (ATD's) against mine/Improvised Explosive Device (IED) threats. There is a need for an injury risk assessment for standing positions, e.g. gun mounts, however STANAG 4569 AEP-55 Volume 2 (mine) and Volume 3 (IED) have no requirements for standing positions. Trials to use the pedestrian 50th percentile Hybrid III (HIII-Ped) showed poor repeatability due to stabilising difficulties of the standing position in vehicle underbelly blast (UBB) testing.

Therefore, TNO developed an isolated standing lower leg test setup (St-Mil-LX), using the Military Lower Extremity (Mil-LX), for improved and reproducible positioning in vehicle UBB testing. The STANAG 4569 lower leg injury criteria of the sitting ATD are proposed to be used for the standing scenario until a more adequate criterion becomes available [2-3]. The St-Mil-LX contains an adjustable mass on top of the lower leg, simulating the recruited upper body (effective) mass. This mass has yet to be determined. The mass of the HIII-Ped on each leg is approximately 33 kg. Previously performed MADYMO simulations provided additional insight in this effective mass [4]. Now, Mine Blast Simulator tests (MBS) [5] with a HIII-Ped with two Mil-LX (HIII-Ped-LX) and the St-Mil-LX were performed in cooperation with the WTD91, Meppen, Germany, to determine the effective mass of a HIII-Ped-LX which loads the lower leg and to apply it on the St-Mil-LX. These tests along with the results are described in this document.

II. METHODS

The HIII-Ped-LX and St-Mil-LX were subjected to vehicle UBB representative loads, performed by the MBS. The MBS is a large shocktable of the WTD91, capable of delivering vertical impact loads to vehicle seats and other structures (Fig. 1a). The HIII-Ped-LX was placed standing on the MBS, with tightened joints as worst case approach. Horizontal front and side straps were used to position the HIII-Ped-LX, while maintaining the full mass of the HIII-Ped on the two Mil-LX (Fig. 1b). In other tests, the St-Mil-LX was placed on the MBS (Fig. 1c) and was vertically aligned using tilt sensors at the foot, distal and proximal end of the lower leg and an angle meter at the replaceable mass. This position was secured with four horizontal straps.



a. b. c.

Fig. 1: a.) schematic view of the MBS with a seated ATD, b.) HIII-Ped-LX on the MBS, c.) St-Mil-LX on the MBS

Tim Westerhof (email: tim.westerhof@tno.nl, tel: +31615165071), Tarik Hartuç and Mat Philippens are Research Scientists Biomechanics at the Explosions, Ballistics and Protection department of TNO in The Hague, The Netherlands. Dominik Soyka is an Occupant Safety Technician at the Technical Centre for Weapons and Ammunition, WTD91 – 450 in Meppen, Germany.

Both subjects were loaded with three different impact velocities (1.6, 2.5 and 3.3 m/s) starting with the HIII-Ped-LX. Next, the St-Mil-LX was tested with multiple masses to find the similar maximum upper tibia force levels compared to the HIII-Ped-LX tests. Each test was performed three times.

III. INITIAL FINDINGS

The tests with the St-Mil-LX were performed with a mass of 14, 15, 16, 17, 18, 20 and 23 kg on top of the Mil-LX. The mean, minimum, maximum of the maximum upper tibia forces and the coefficient of variation (CoV, ratio between standard deviation and the population mean) of the upper tibia of the HIII-Ped-LX and the St-Mil-LX with 17 kg are listed in Table I. Only the St-Mil-LX with 17 kg results are listed because initial analysis showed that this mass measured the smallest difference in the mean upper tibia force compared to the HIII-Ped-LX upper tibia force for the three impact velocities combined.

TABLE I
UPPER TIBIA FORCES OF HIII-PED-LX AND ST-MIL-LX

	Upper tibia force (N)					
	HIII-Ped-LX			St-Mil-LX with 17 kg		
Impact velocity	1.6 m/s	2.5 m/s	3.3 m/s	1.6 m/s	2.5 m/s	3.2 m/s
Mean	2280	3597	5126	2174	3664	5226
Min	2010	3098	4494	2159	3644	5144
Max	2553	3756	5418	2197	3682	5322
CoV	8.9%	8.8%	5.1%	0.9%	0.5%	1.4%

The STANAG 4569 injury criterion of the Mil-LX (2600 N) is exceeded for the two higher impact velocities 2.5 and 3.3 m/s. The mean of the St-Mil-LX for 1.6 m/s is lower compared to the HIII-Ped-LX, while the mean of the St-Mil-LX for 2.5 and 3.3 m/s is higher compared to the HIII-Ped-LX. The CoV for the St-Mil-LX (0.5% to 1.4%) is smaller compared to the HIII-Ped-LX (5.1% to 8.9%)

IV. DISCUSSION

These tests provided insight into the effective mass of the HIII-Ped on the Mil-LX, to be used for the St-Mil-LX. Initial findings showed that a 17 kg mass approximates the HIII-Ped-LX effective mass by measuring similar upper tibia forces.

These test results show a velocity dependency of the effective mass, however the minimum and maximum upper tibia forces in the St-Mil-LX fall within the range of the HIII-Ped-LX minimum and maximum forces. Further analysis is required to show whether this velocity dependency poses a problem for the setup. Furthermore, the injury criterion of the Mil-LX is exceeded at 2.5 and 3.3 m/s, resulting in only one impact condition below the injury criterion. As a result, additional test at the lower impact velocities may be required.

The reported tests do not include boots, while STANAG 4569 tests use boots for the seated ATD. While the Mil-LX is less sensitive to combat boots compared to the HIII lower leg, the setup needs to include the effect of boots in some way.

The repeatability of the St-Mil-LX is higher compared to the HIII-Ped-LX, due to the lower CoV. While the reproducibility of the St-Mil-LX has to be determined, these tests show promising results for further development. It is recommended to test the St-Mil-LX on other mine blast representative test setups, to evaluate its usability, reproducibility and response at different loading conditions.

V. REFERENCES

[1] North Atlantic Treaty Organization, NATO Standardization Agency, 2014
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[3] HFM-148, NATO Standardization Agency, 2012
[4] Westerhof, T.A.T., MADYMO Simulations of a Standing Isolated Lower Leg, TNO 2020 R10085, internal report
[5] Lammers, C., WTD91-450, 2017