Assessment of the Influencing parameters on the Kinematic Behaviour of the BioRID-II Anthropometric Test Device (ATD) by Analysing Seat Design Parameters Tested by the European New Car Assessment Programme (Euro NCAP)

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I. INTRODUCTION

The effects of whiplash associated disorder (WAD) still result in an estimated social and economic cost totalling € 5-10 billion in Europe alone [1]. The medical and legal implications of WAD are being studied by experts and engineers who are trying to develop counteracting measures, with the aim of preventing WAD. However, the influence of seat design parameters on the kinematic behaviour of the BioRID-II Anthropometric-Test-Device (ATD), are yet not fully understood. This study provides quantified information on the influence of seat design parameters on the kinematic behaviour of a BioRID-II ATD by applying methods of multivariate data analysis.

II. METHODS

The underlying dataset consists of 118 seats tested by the Euro NCAP. The data recorded by the BioRID-II ATD includes: force, momentum, displacement, velocity and acceleration readings. The crucial question here is: which parameters of a seat design have significant influence on the kinematic behaviour of a BioRID-II ATD?

Firstly, exploratory data analysis methods were used to identify structures and dependencies contained in the dataset. Subsequently, the identified structures were utilised for hypothesis formation. The principal component analysis (PCA) describes the variability among the observed data. The aim was to condense the number of variables, and to explore the individual factor loadings on the identified factors.

Using hierarchical cluster analysis it is possible to find groups of different seat designs with similar properties. The variables were standardised using the Z-Score. Seat designs within similar sized groups were identified by the Ward-Method in combination with the Square-Euclidian-Distance criteria. The significance of each parameter for the identified group is represented by the F-values and t-values. The F-value describes the heterogeneity of variables within the identified group. The t-value gives an indication as to whether the value is under- or over-represented. The mean values of the identified significant parameters per group are then compared to the mean parameters of the dataset, allowing analysis of the kinematic behaviour.

III. INITIAL FINDINGS

The PCA identifies six factors with an eigenvalue greater than 1 shown in Tables I-III. Results with a Kaiser-Meyer-Olkin value greater than 0.5 for the low, medium, and high-pulse were considered acceptable. In the tables below, positive factor loadings greater than 0.3 magnitude are marked with a "+" and negative factor loadings are marked with a "–".

It was found that a greater backset increases the neck injury criteria (NIC), the head contact time (HCT) and the lower extension Moments ($M_{y\_low\_ext}$). An increase in the seat-back deflection (SBD) has a significant influence on the reduction of the X-acceleration at the T1 accelerometer, but also increases the forces on the upper load cell in the Z-direction. A greater thickness of the foam on the headrest and the backrest was found to increase the upper flexion Moments. An increase in the backrest height results in a greater extension moment of the upper load cell. The higher X-distance between the head rest to the upper part of the backrest results in an increase of the N_{km}, upper shear and tension forces, the upper flexion moments and the lower extension moments.

The cluster analysis allows the formation of seven groups following the elbow criteria rule. The first cluster represents seat designs with a high backset, high HCT and a high shear force but with a low tension force and a low upper extension moment. However, the obtained NIC values can be regarded as average to the mean of

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TABLE I

ENCAP LOW PULSE FACTOR ANALYSIS

Rotated Component Matrix[a]

	Component					
	1	2	3	4	5	6
LowNICmaxm2s2	+					
BacksetHRMDmm	+					
Headcontactstartms	+	+				
LowLOWERNeckTensionFzN	+	+				
FoamthicknessBackrest		-		+		
LowReboundheadvelrelativedms		+				
LowUPPERNeckTensionFzN	+	+				+
HighMaxSeatBackDynamicDeflectiondegree		+	+			-
LowLOWERNeckShearFxheadrwN		+	+			+
LowLOWERNeckFlexionMyN			-			
LowLOWERNeckExtensionMyN	+		+			
DistanceBetweenHeadrestAndBackrest			-		+	
LowUPPERNeckShearFxheadrwN	+		+			
LowUPPERNeckFlexionMyN		+	+	+		
FoamThicknessHeadrest				+		
HeightHRMDmm				+		
LowUPPERNeckExtensionMyN					+	
HeightBackrest					+	
LowNkm						-

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 7 iterations.

TABLE II

ENCAP MEDIUM PULSE FACTOR ANALYSIS

Rotated Component Matrix[a]

	Component					
	1	2	3	4	5	6
MedUPPERNeckFlexionMyN	+					
MedLOWERNeckShearFxheadrwN	+				-	
DistanceBetweenHeadrestAndBackrest	-					
MedUPPERNeckShearFxheadrwN	+					
MedUPPERNeckTensionFzN	+					+
MedLOWERNeckExtensionMyN	+	+				
HeightBackrest	-			+		
BacksetHRMDmm		+				
MedHeadcontactstartms		+				
MedT1xaccg			-			
HighMaxSeatBackDynamicDeflectiondegree			+			
MedUPPERNeckExtensionMyN				+		
MedNkm				+	+	
MedLOWERNeckFlexionMyN		-			-	
MedReboundheadvelrelativedms					-	
FoamThicknessHeadrest						-
MedLOWERNeckTensionFzN			+	-		+

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 9 iterations.

TABLE III

ENCAP HIGH PULSE FACTOR ANALYSIS

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
HighLOWERNeckShearFxheadrwN	+	+			
HighUPPERNeckTensionFzN	+		+		
HighUPPERNeckShearFxheadrwN	+	+			
HighNkm	-	+			
DistanceBetweenHeadrestAndBackrest	-				
HighUPPERNeckFlexionMyN	+				+
BacksetHRMDmm		+			
HighHeadcontactstartms		+			
HighT1xaccg			-		
HighMaxSeatBackDynamicDeflectiondegree			+		
HighLOWERNeckTensionFzN	+		+		
HighUPPERNeckExtensionMyN				+	
HeightBackrest	-		+	+	
Foam Thickness Backrest			-		+
HighLOWERNeckExtensionMyN	+				-
Foam Thickness Headrest	+	+			+
HighNICmaxm2s2		+		-	-

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 10 iterations.

the dataset. The second cluster, including 16 seats, show significant low HCT, low NIC and low upper extension Moment values, but also higher flexion moment and T1 X-acceleration values. The third group consisting of nine seats, demonstrates a better performance for the low pulse compared to the high pulse for the HCT, NIC, T1, My_up_Ext and the upper tension and lower shear force values. The fourth group, consisting of nine seats, show a significant low backset, HCT as well as low extension moments and low upper tension force values.

IV. DISCUSSION

The identified PCA factors enables interpretation of positive and negative influence parameters of the seat design on the kinematics of the BioRID-II ATD measured by the available sensors. This enables the developer to control the influence of the kinematic behaviour of the BioRID-II ATD by adjusting specific parameters. The obtained results are based on a Kaiser-Meyer-Olkin (KMO) criteria, with a magnitude between 0.5 and 0.6, which are within the acceptable parameters. One possible reason for the low KMO criteria is the small size of the dataset compared to the investigated variables. This would be expected to improve when analysing a bigger data set.

The analysis of the identified groups enabled predictions of the kinematic characteristic of specific seat designs. Analysing further seat design characteristics allows a more defined segmentation and accurate prediction of the kinematic behaviour. The elbow criteria of the cluster analysis suggest a greater number of groups than the chosen group size of seven. Due to the available size of the dataset, a smaller group size was chosen. With a greater dataset further characteristics as well as ordinal scaled characteristics for the identified groups can be analysed.

V. REFERENCES

[1] Schmitt K.-U. et al , Trauma-Biomechanik, 2014.