Female Rider Posture Variability on a Touring Motorcycle

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I. INTRODUCTION

Powered two- and three-wheeler (PTW) riders are considered the most vulnerable road user (VRU) group [1]. While passive safety systems can help reduce injuries, their effectiveness is limited by crash variability, with rider posture being an important factor influencing head and chest injury risk [2-4]. However, perhaps due to a lack of available data on holistic, whole-body posture variability, rider surrogates like finite element human body models (FE-HBMs) are typically positioned in a single posture in PTW safety evaluations.

Building on a previous study [5], in which posture variability data for 50th percentile male riders was compiled, this study complements these data with 50th percentile female rider data on a touring motorcycle (MC). The dataset will support representative positioning of human surrogates for a more diverse rider population, explore potential posture differences between male and female riders, and support future PTW research on the potential necessity to broaden anthropometric considerations for PTW rider postures.

II. METHODS

This study analyses postures from 10 50th percentile female volunteers (163.0±3.4 cm and 60.9±3.8 kg) with previous riding experience on a 2008 BMW R 1200 RT touring motorcycle (MC), following the methodology of [5]. Through palpation, 51 reflective markers were placed on anatomical landmarks and the preferred riding posture of the female volunteers was recorded in a photogrammetric laboratory.

Principal Component Analysis (PCA) was performed to determine the average posture and principal components (PCs) capturing the posture variability. To interpret the variability in postures described by the PCs, 'extreme postures' for each PC were generated by multiplying the PC loadings with the ±2 standard deviations (SDs) of the volunteers' scores across PCs. A kinematic linkage model was then used to translate the 3D marker data into an interpretable rider posture.

To compare male (from [5]) and female postures, left- and right-side angles were averaged, when available. Welch's independent two-sample t-test was used, and statistical significance was determined at the $p<0.05$ level.

III. RESULTS

The PCA resulted in nine PCs, with the first four explaining 81% of the total posture variability.

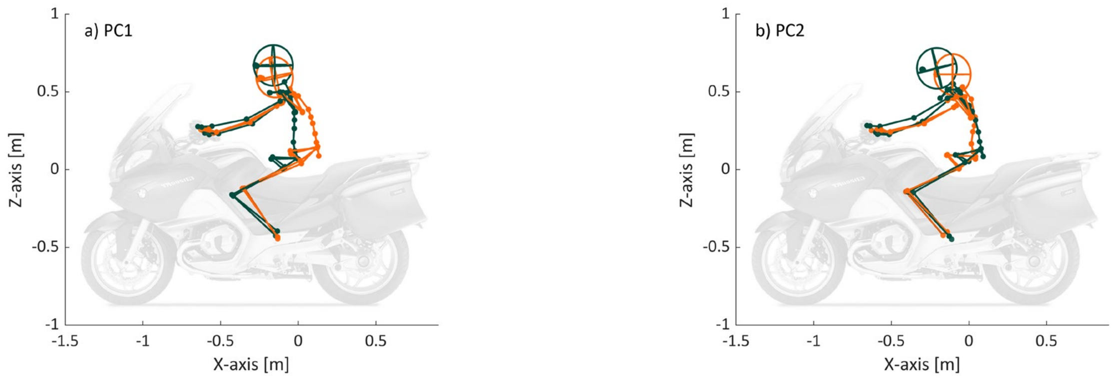

Fig. 1. The ±2 SD 'extreme postures' describing posture features captured by PC1 and PC2, respectively. In this Figure, posture vs. PTW comparisons are unreliable due to non-comparable suspension travel and possible distortion effects. (Background photo ©BMW Motorrad.)

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The first PC accounted for 33% of the variance, primarily reflecting variability in: fore-aft seat position (±55 mm in X), spinal curvature (lumbar ±5°, thoracic ±11°), scapular protraction-retraction (±15 mm in X), anterior-posterior pelvic tilt (±6°), and head pitching (±6°) (Fig. 1 left). The second PC (23% of variance) described variability in lumbar spine curvature (±5°), anterior-posterior pelvic tilt (±9°), and head pitching (±7°) (Fig. 1 right).

Figure 2, showing the average riding posture for the female and male [5] sample, reveals that on average the female riders sit 26 mm further forward, with a smaller pelvis angle (14°), larger hip angles (mid-sagittal 13°, horizontal 4°) and knee angles (10°), and greater lower spine angles (6–9°). The female head position is also 35 mm lower to the motorcycle, while elbow, shoulder, and upper spine angles are similar to the male riders. The statistically significant ($p<0.05$) posture differences found for the pelvic, hip, knee and lumbar spine angles support the visual differences.

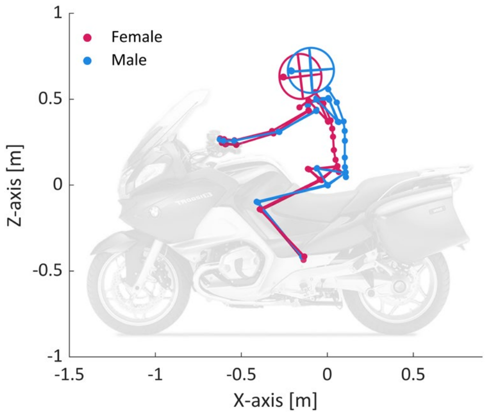

Fig. 2. Average postures for the 50th percentile female and male [5] sample. In this Figure, posture vs. PTW comparisons are unreliable due to non-comparable suspension travel and possible distortion effects. (Background photo ©BMW Motorrad.)

IV. DISCUSSION

The first two PCs from the PCA captured differences in seat position (fore-aft), spinal curvature, pelvic tilt, and scapular movement. The remaining PCs and their associated variability are detailed in [6]. These results provide representative postures for 50th percentile female riders on a touring motorcycle, covering both average posture and whole-body variability. Furthermore, with the *Landmark Positioning tool* introduced in ANSA v.25.1.0 pre-processor (BETA CAE Systems), supported FE-HBMs can be positioned easily using the study's findings (see [6] for data). This enables direct application of the postures in crash analysis and offers the potential to enhance the robustness of safety system design.

PC1 revealed a vertical head position difference of 76 mm (±2SD), and a thoracic spine curvature change of 22° (±2SD), differences which have been reported to influence kinematics and interactions with opposing vehicles in the commonly occurring PTW front-to-car side crash [2-4].

The differences between the 50th percentile female and male average postures highlight the need to account for anthropometric variability in crash-related posture evaluation. However, further research is needed to first determine whether the observed differences between the two samples stem from sex, stature, or both, and if the differences persist across PTW types.

A dataset limitation was a slight (~6°) steering axis misalignment in some participants, inadvertently captured in the PCA. Moreover, the small sample size reduces statistical power, making it challenging to detect more subtle differences that could be significant between the groups. Despite this, the study provides valuable insights into female rider postures (average and variability).

V. ACKNOWLEDGEMENTS

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