# Influence of Motorcycle Design and Rider Anthropometry on Posture: Implications for Crash Simulation Accuracy

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## I. INTRODUCTION

Unlike enclosed vehicles, motorcycles offer no protection to the rider and therefore, motorcyclists are disproportionately represented in crash-related fatalities, as fatality rates per kilometer travelled for motorcycles are ~30 times higher than for car occupants [1-2]. The first point of contact experienced by a rider in a frontal collision is against the fuel tank of the motorcycle and often results in injury to the rider's pelvic region [3]. These injuries occur in approximately 13% of the riders involved in a crash [4]. The prognosis for pelvic injuries is generally poor and often involve prolonged recovery times and deterioration in an individual's quality of life [5]. While there have been advancements in protective gear and safety mechanisms for motorcycles, there have been limited targeted interventions developed to address the risk of pelvic injuries to motorcyclists [7-8]. Furthermore, motorcycles vary in design drastically which position the riders differently across different motorcycle types [9-10]. How this change in position affects the rider's pelvis is still unknown. Therefore, this study aims to investigate riding posture and pelvic orientation of a rider across different motorcycles and develop an adjustable motorcycle rig to replicate real-world riding postures, enabling accurate and reproducible analysis of rider postures across multiple motorcycle categories.

## II. METHODS

The study recruited two participants – 1 male (Experience: 10 years; Height:172 cm; Weight: 75 kg) and 1 female (Experience: None; Height: 165 cm; Weight: 51 kg). Forty-six motorcycles were studied. The motorcycles were grouped into four categories based on their design – Adventure (Dual Sport), Cruiser, Sports and Naked (Standard). Each motorcycle was secured using wheel chocks and straps. The participants wore tight fitting clothes (with shoes). Black styrofoam balls of 25 mm diameter were placed on key anatomical joint locations as per [12]. Additional markers were placed on the medial femoral condyle (knee) and medial malleolus (ankle) to calculate knee and ankle joint centres respectively. Each participant was asked to assume riding position on all motorcycles while a researcher 3D scanned them using a white-light handheld scanner (EinScan HX). Anatomical coordinates in 3D space were acquired from the scans in MeshLab and processed in MATLAB to generate joint angles using a customised script. A univariate two-way ANOVA was performed on each lower limb joint angle (pelvic tilt, hip flexion, hip abduction, knee flexion and ankle flexion) against the gender and motorcycle types (adventure, cruiser, sport and naked) to investigate whether lower body position (joint angles) of the rider changes across different motorcycle types. A 3D scan of each motorcycle was also taken to obtain key measurements of motorcycles (Figure 2).

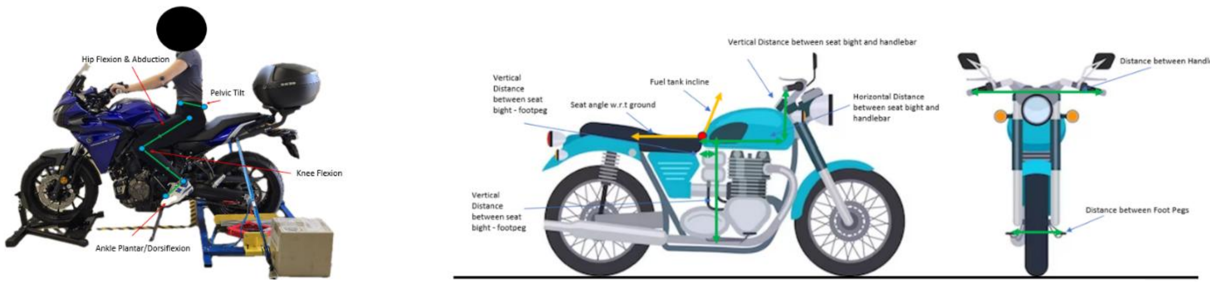


Figure: Experimental Setup (Left); Motorcycle measurements (Right)

## III. INITIAL FINDINGS

Statistical analysis revealed significant differences in pelvic tilt ($p < 0.001$), hip flexion ($p < 0.001$), hip abduction ($p < 0.001$), and knee flexion ($p < 0.001$) and ankle flexion ($p < 0.001$), the angle significantly differed across motorcycle types with some outliers. Sports motorcycles showed a significantly greater anterior pelvic tilt when compared to adventure, cruisers and naked motorcycles (Table 1). Larger hip flexion was observed in cruisers and sports motorcycles than naked and adventure bikes. Highest hip abduction was seen in sports motorcycles at

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**TABLE 1**
LOWER LIMB JOINT ANGLES ± MEAN STANDARD DEVIATION(DEGREES)

| *Participant* | *Type* | Pelvic Tilt | Hip Flexion | Hip Abduction | Knee Flexion | Foot Flexion |
|---|---|---|---|---|---|---|
| *Male (Height:172cm)* | *Adventure* | -10.71±3.9 | 66±5.7 | 56.52±4.2 | 105.24±2.9 | 63.27±4.4 |
| | *Cruiser* | -13.73±3.5 | 7.41±2.7 | 53.49±2.4 | 65.78±11.2 | 116.72±8.7 |
| | *Naked* | -9.77±5.7 | 70.12±6.5 | 55.64±4 | 110.26±5.8 | 60.48±9.9 |
| | *Sports* | 2.99±5.1 | 75.93±6.8 | 59.63±2.7 | 121.78±5.7 | 41.13±11.4 |
| *Female (Height: 165cm)* | *Adventure* | -10.41±5.4 | 51.86±6.3 | 56.25±7.6 | 105.34±5 | 50.82±6.5 |
| | *Cruiser* | -8.99±5.2 | 74.75±8.3 | 50.97±4.9 | 59.41±12.9 | 117.97±10.8 |
| | *Naked* | -11.77±4.9 | 54±4.5 | 52.19±5.6 | 113.55±5.1 | 44.65±8 |
| | *Sports* | 5.72±9.1 | 67.51±8.4 | 62.09±4 | 119.18±4.7 | 36.39±8.4 |

~61° and the least on cruisers at ~52°. Moreover, cruiser motorcycles demonstrated the least knee flexion (~62°) and ankle plantarflexion while sports motorcycles demonstrated the most knee flexion (~120°) and dorsiflexion of the ankle. Analysis of the 3D scans of motorcycles revealed significant differences in handlebar and footpeg positioning along with fuel tank angle across the four motorcycle types, albeit with some overlap as shown in the ergonomic triangles (Figure 3). The average handlebar positioning for sports motorcycles with respect to the seat was more forward (~52cm) and lower (~11cm) compared to the other three motorcycle types. Furthermore, cruisers had handlebars higher (~31cm) and closer (~28cm) to the seat with footpegs forward (~39cm). Handlebar positioning for naked and adventure motorcycles was similar, while the adventure motorcycles had a lower footpeg position (~56cm) compared to other types (~47 ± 2cm).

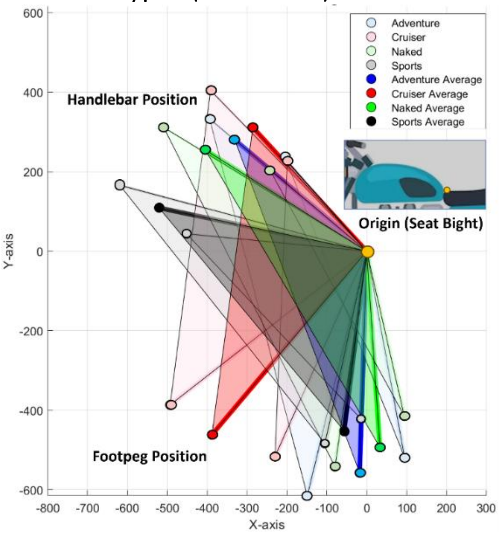


Figure: Ergonomic triangle – Mean and Standard deviation of Handlebar and Footpeg Position

## I. DISCUSSION

Different motorcycle types induce different riding postures, where different locations of seat, footpeg and handlebars result in different hip, foot and hand positions and thus joint angles. Postural differences were evident even within the same motorcycle type too, influenced by variations in motorcycle design. This study shows the wide variation in rider posture in different motorcycles, and thus the importance of individualised rider positioning in crash simulations. The findings of this study are a key first step towards more accurate representation of the rider/fuel tank interface to be used for development of countermeasures for rider population. Furthermore, an adjustable motorcycle rig was developed based on average ergonomic triangles for each motorcycle type to capture population variations due to design differences. This information is critical to accurately simulate motorcycle crashes using either anthropometric test devices (ATDs) or human body models, as this influences the initial loading condition and overall kinematics of the rider in a crash.

## II. REFERENCES


[1] AIHW, 2024
[2] R. Huggins *et al.*, Acc Anal Prev, 2013
[3] L. Meredith *et al.*, Traffic Injury Prev, 2016
[4] H. H. Hurt *et al.*, The Administration, 1981
[5] H. Abdelrahman *et al.*, J Orthop Surg Res, 2020
[7] D. H. Blanco *et al.*, J Sport Eng Tech, 2014
[8] T. Pallacci *et al.*, Procedia Structural Integrity, 2019
[9] IIHS-HLDI, "Motorcycles,"
[10] M. I. N. Ma'arof *et al.*, SEANES, 2012
[11] Plug-in Gait Guide, Vicon Motion Systems, 2023