# Downhill Bicycles Full Scale Simulation of Crashes and Falls with a Hybrid III Dummy and a Launching Catapult.

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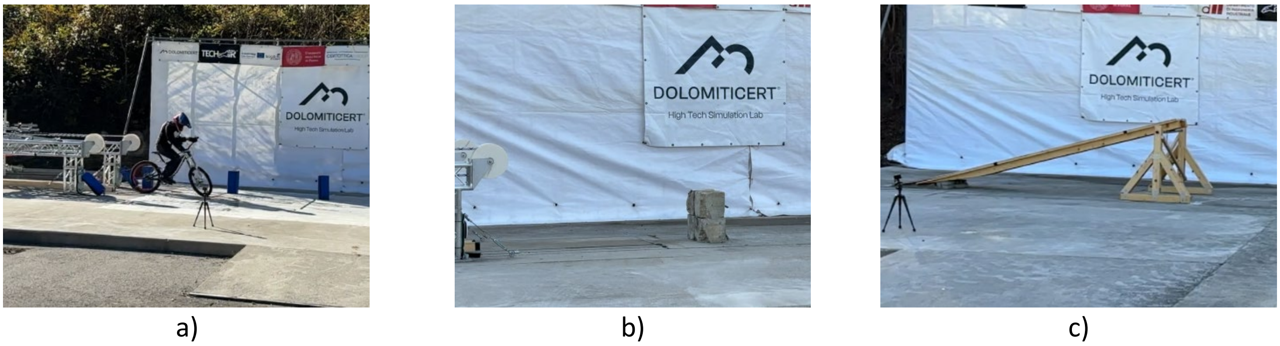
## I. INTRODUCTION

Downhill biking can result in falls and crashes against obstacles similarly to other two-wheeled disciplines like motocross. The nature of the sport and the surroundings of the slopes make riders particularly prone to injuries such that covering body regions with protective garments and devices is crucial to limiting the injurious outcome of accidents. Protective devices are innovating with conditional deployment and protection systems. Full-scale simulations of accidents allow testing of devices behavior under realistic and hazardous rider kinematics. In particular the simulation of such falls is of fundamental importance towards the analysis of electronically activated protective devices. Given the similarities with motorbikes, the testing procedures and protocols currently under investigation for motorcycle full-scale simulations could be adapted to bikes. In particular, Petrone *et al*., reported experiments conducted with a launching catapult in which different motorbikes were used to simulate typical road accidents [1]. In this work, the same launching catapult is adapted to perform experiments using downhill bicycles, aiming to collect data in bicycle-specific accident simulations.

## II. METHODS

These experiments were carried out using a launching catapult which accelerates the downhill bicycle and the dummy using elastic bunjees previously preloaded with an electrical winch. The development of the catapult was explained by Petrone *et al*. in a previous study [1]. The structure was adapted to fit the bicycle in position with slight adjustments of the carrier. The target exit speed from the catapult was 50 km/h.

Catapult setup for the different tests is shown in Fig. 1. Briefly, the fall was obtained with a braking rope and a sliding sheet to induce a slippage of the bicycle; the rigid block consisted of a concrete block with a height of 0,5 m; the landing after the jump was achieved by putting a ramp after the catapult which recreated the jump, the dimensions of the ramp were calibrated such that the dummy impacted onto a pile of sand positioned 15 m after the exit of the catapult.




a) b) c)

Fig. 1: Setup of the catapult for the different tests: (a) fall with sliding sheet, (b) rigid block made of concrete cubes; (c) wood ramp used to make the dummy jump on the sand.

The dummy was dressed in protective garments and a motorcycle helmet and loaded in the riding position over the bicycle. The dummy was equipped with a triaxial accelerometer and a triaxial gyrometer in the head embedded in the same sensor (6DX-PRO-A, DTS, USA; full scale: 500 g/8000 dps) and another triaxial accelerometer (3x A64C, DTS, USA; full scale: 500 g) and triaxial gyrometer (ARS3-PRO, DTS, USA; full scale: 8000 dps) all synchronously collected with an embedded datalogger (SLICEnano, DTS, USA) at a 10 kHz rate. Raw data

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were imported to MATLAB, low-pass filtered with a CFC1000 filter and used to calculate common injury metrics. Each test was also video recorded using a fixed high-speed camera (CUBE, MotionBlitz, Germany) with a 1 kHz rate. Individual photograms were extracted from the video recording and blended to obtain a visual representation of the dummy from the beginning of the accident to the impact on the ground.

## III. INITIAL FINDINGS

These tests recorded the dummy kinematics in the three studied accident scenarios. The in-dummy sensors provided continuous head and trunk kinematics recording, while high-speed camera were used to capture the global dummy motion from a lateral perspective. Individual frames from the camera were overlaid to show the dummy motion. Examples of the dummy motion are shown in Fig. 2.


a) b) c)

Fig. 2: Dummy trajectory in the three tests: (a) fall, (b) rigid block; (c) landing over sand.

Injury metrics were also calculated to assess the most critical impacts among the ones tested and results are reported in Table 1.

TABLE 1: HEAD AND TRUNK RESULTS FOR THE DIFFERENT TESTS

| Injury criteria | Units | Fall | Rigid Block | Jump landing |
|---|---|---|---|---|
| Head Peak Linear Acceleration | g | 135 | 53,75 | 72,56 |
| HIC [2] | - | 654,6 | 71,3 | 153,2 |
| Head Peak Rotational Acceleration | rad/s$^2$ | 32736 | 33150 | 9890 |
| BrIC [3] | - | 1,12 | 0,631 | 0,318 |
| Trunk Peak Linear Acceleration | g | 113,5 | 31,6 | 53,74 |

## IV. DISCUSSION

These first results demonstrate another application of the launching catapult earlier discussed by Petrone *et al*. [1]. The first point under investigation was the feasibility of recreating different accident scenarios with a different mass ratio between rider and vehicle. On a qualitative basis the simulations were successful, offering a benchmark for protective devices at least for simplified scenarios. With regards to injury metrics, despite having used a motorcycle helmet instead of downhill helmets, which makes the absolute values less relevant, results could still indicate which could be the most severe type of impact. In particular the low-side test appears to be the most critical, as the dummy is thrown into the ground hitting with the head. A future experimental test session focused on protective equipment could focus on the reconstruction of this particular accident with different layers of protection for the dummy rider. Another improvement could be the use of other dummies more suited for representing vulnerable road users during falls and crashes.

In the test against the rigid block, most of the damage is observed on the bike while the dummy is redirected over the obstacle and gains a rotational motion rather than impacting straight onto the ground. The pile of sand resulted in the less hazardous impact since the impact surface was less stiff. On a different perspective, the pile of sand could be the trickiest obstacle to test algorithms of electronic devices, since the impact is less abrupt.

## V. REFERENCES

[1] Petrone *et al.*, IRCOBI, 2025.
[2] Versace *et al.*, Stapp Car Crash C., 1971.
[3] Takhounts *et al.*, Stapp Car Crash J., 2013.