Observations on the Protective Effect from a Bicyclist Backpack Airbag System Evaluated in Crash Tests

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I. INTRODUCTION

Bicycling offers a means of active, low-carbon travel bringing with it environmental and social benefits. However, as greater bicycling is promoted, it remains important to study the relationship between bicycle use and incidence of injury. Previous research guides us that for bicyclists the risk of injury is greater in a collision with another vehicle than in a single bicycle crash or fall [1], but the incidence of single bicycle falls far outweighs the incidence of bicycle and motor vehicle (car) crashes [2]. This position poses the question if protection can be provided to mitigate these injuries, both in bicycle crashes with cars and in single bicycle falls.

Within a wider project for Trafikverket (the Swedish Transport Administration), a study was defined to evaluate the protective effect for cyclists of protection systems on the market today. Even though fatal collisions remain an issue for bicyclists, the primary focus for this work is the assessment of the possible reduction in the risk of injury to the shoulder in typical cycling accidents. Justification is that the upper extremities are the most frequently injured body region, and the shoulder is the most frequently injured body part with regard to those injuries leading to permanent medical impairment [3] (a statement that stands both for cyclists in collisions with cars and single bicycle crashes [4]). Therefore, we sought to assess the protective effect of a new inflatable wearable intended to cover the shoulder of a bicyclist in a crash or fall.

II. METHODS

Preparatory simulations were used to define the load cases for this experimental work [5], identifying scenarios with high forces exerted on the shoulder of the rider. Subsequently, two configurations were selected for recreation physically, a car crash and a single-bicycle fall. In both cases the POLAR III pedestrian dummy [6] was used as the surrogate rider reflecting its demonstrated biofidelity when struck by the front of a car. The knee on the non-impact side of the POLAR III had been modified previously so that the dummy could be positioned in a bicycle riding posture. A matrix of 18 physical tests was conducted with setup variations within the car crash and fall configurations, but here a single test in each condition is considered. The bicycles were chosen to be a city-bike with an upright riding position as this is still a common bicycle used in European cities. In each case, the rider was equipped with a bicycle helmet and a backpack which included a deployable element: a ‘world's first’ cycling backpack with an integrated airbag and back protector. This is promoted as significantly minimising the risk of injury for modern city bikers, protecting the neck, shoulders, collar bones and chest. The dummy was instrumented to measure accelerations in the head, shoulder, chest and pelvis, forces and moments in the neck, forces in the sacrum and pubis, deflection of the chest, and strains in the lower extremities. However, this short communication concentrates on high-level observations of protective function, as timely deployment and stable positioning are prerequisites for robust protection. These observations are based on review of the video footage (both fixed field of view, 1000 Hz and lower resolution, on-board or panning, outputs from GoPro™ cameras).

Car-to-Bicycle Crash Testing

The car crash was setup to represent a 40 km/h collision (balancing survivability against the need for some potentially injurious loading and representing a common impact speed [7]) between the front of the car and the side of the cyclist. The bicycle was therefore aligned perpendicularly across the crash track presenting the left side of the rider to the vehicle. The crank for the pedals in the bottom bracket of the bicycle was set to align with the centreline of the approaching car, and the car was a modern estate (station-wagon). To support the rider on the bicycle, an overhead support was necessary, with attachment to the superior surfaces of the shoulders of the dummy (a block of wood and foam blocks were also used to support the pre-crash position of the bicycle). Immediately prior to contact between the car and cyclist, the overhead support was released so that the rider was free to wrap onto the impacting vehicle front.

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Single-Bicycle Fall Testing

The single-bicycle fall test setup mirrored that used in a previous study of head impacts during simulated crashes [8]. The bicycle was accelerated to test speed (15 km/h) in a two-wheeler support frame, the frame was then retarded so that the bicycle was released to contact a kerb-like barrier at 20° to the path of the bike, which initiated the fall to the left side (Fig. 1.). In this configuration the hands and feet of the rider were loosely taped (with packing tape) to the handlebar and pedals, in an effort to improve consistency of behaviour (and time of release). As mentioned, the rider wore a protective backpack where, in the event of a fall, the system's sensor-controlled airbag is intended to inflate in less than 0.2 seconds.

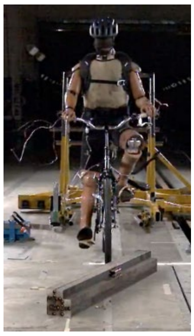

Fig. 1. Point of contact with kerb in fall test.

III. INITIAL FINDINGS

In the car-to-cyclist test, the body wrapped around the bonnet of the vehicle. The elbow of the rider broke the windscreen of the car at about 120 ms after initial contact between car and cyclist. The helmet then contacted the screen at 146 ms and the shoulder also hit the rear of the bonnet around that time (Fig. 2.). The airbag inside the backpack could be seen emerging at about 480 ms (taking 50 to 60 ms to inflate fully and stabilise), more than 300 ms too late to help mitigate in the car-to-rider contacts. Furthermore, the backpack had slipped upwards (compared with the rider's motion, being pulled downwards) so that the inflated bag did not cover the shoulder.

In the fall test, the rider fell to their left after the bicycle contacted the kerbstone. The rider's elbow touched the ground about 940 ms after the kerb contact (Fig. 3.), mitigating any direct loading to the shoulder. The airbag deployed at about 1190 ms after kerb contact, i.e. about 250 ms too late. Also, it is not clear how the airbag could mitigate shoulder, collar bone and chest loading as it did not occupy the space between the shoulder and ground.

In summary, deployment of the airbag after primary contacts suggests that the protective backpack needs improvement in both the sensing system and how it is positioned on the body before it can be expected to offer a protective function in car crashes or single bicyclist falls.

Fig. 2. Still image at time of shoulder contact (150 ms).

Fig. 3. Still image around time of elbow contact (940 ms after kerb contact).

IV. DISCUSSION

The observations presented above are a small extract of results from a test series. Nevertheless, they highlight a limitation in protective effect of the world's first airbag backpack for cyclists. In a pair of tests, the airbag failed to deploy in time or to position the bag correctly to protect the shoulders or chest of the bicyclist. Prior research has shown that timely activation is possible, but that a short duration is critical in car to bike crashes [9]. Two tests cannot do justice to the range of circumstances in which cyclists can be injured and therefore comments made about protection should be considered with regard to the limitations of only these two cases.

Limitations present themselves when using a crash dummy for evaluation of a protective device for cyclists. There is no validation data to state objectively how well the human body models (HBM) or crash test dummies match the behaviour of a cyclist. However, with joint stiffness helping to maintain an upright pre-impact posture, the dummy falls into a middle ground of being stiffer than a completely passive HBM or human subject, whilst also not having the active musculature that would put out a foot or hand to brace in a fall event. This is unlikely to influence the time to contact in the 40 km/h car test substantially but may contribute to explaining the difference between intended and observed activation time in the fall test. A sensitivity study in simulations looking at various levels of muscle response acting on an HBM may help to address that part of this limitation.

It should also be noted that these two tests with active deployment of the airbag backpack used only an upright riding posture on a city-bike (likely a common riding posture with an e-bike too). This selection was intended to match the description of the backpack function, being developed for daily cycling commutes. However, no reverse engineering was undertaken to determine sensitivity of the sensor suite to linear or rotational acceleration. Therefore, no comment is offered as to whether a different riding posture or fall kinematics would have yielded different observations, rather this is noted as an additional issue with observations made on only these tests.

V. ACKNOWLEDGEMENTS

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