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Dynamic Response of the Dummy in Case of Child Cyclist Collision with Passenger Car

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Abstract:- The safety of pedestrians and cyclists is justified especially in terms of prevention. This paper deals with the biomechanical analysis of load exerted on the child cyclist in configuration typical for cyclists (sudden enter the road or the case of non-giving way; the car front vs. the left side of the cyclists). Two tests were performed in the same configuration and nominal collision speed, the first one with a bicycle helmet and the second one without the helmet. Using the accelerometers in the head, chest, pelvis and knee of the dummy acceleration fields were detected, which is the cyclist exposed during the primary and secondary collision. In conclusion, the results will be interpreted by values of biomechanical load and severity of potential injuries including kinematic and dynamic comparison with a pedestrian vs. vehicle collision.

Keywords:- child cyclist, passenger car, helmet, dynamic test, collision configuration, biomechanical load.

I. INTRODUCTION

Pedestrians and cyclists are exposed to strongly incompatible impact within a collision with vehicle. The passive safety of cyclists colliding with a vehicle still remains, unlike the passive safety of pedestrians at the edge of interest. The pedestrian safety is nowadays a very important criterion for vehicle safety evaluation. . In the case of passive safety of cyclists the kinematic conditions are very different. Similar test methods related to passenger car front parts does not exist, while the cyclist's body comes into contact with other vehicle parts than the pedestrian of the same height. In frame of the basic research and expert verification tests, partial tests of the cyclist´s collision with vehicle are carried out. The aim of these tests is to follow the kinematics of the whole collision, values of biomechanical loads are usually not detected. The legislation concerning cyclists is divided into regulations related to bicycles, bicycle helmets and rules for cyclists´ behaviour in the road traffic. Testing of bicycle helmets is the only area that is screened in terms of passive safety of cyclists. According to EN 1078[1] bicycle helmets that are properly mounted on a dummy head are tested. The following tests are performed: the helmet impact resistance while dropping on a flat surface or "curb", fixing buckle strength and ease of its release, the fixing efficiency of helmet polster and range of the visual field. The main problem is that the bicycle helmets' wearing is not compulsory in many EU countries. In most cases it is compulsory only for children under 15 or 18 years of age.

The CTU in Prague, Faculty of Transportation Sciences, performed in frame of basic research a set of dynamic passive safety tests on a passenger car (M1 cat.) collision with a P6 dummy in the role of the cyclist. There were 3 tests executed, two of them in the nominal collision speed 20kmph (with and without the helmet) and in a following collision configuration: the vehicle front part/the cyclist´s side.

II. EXPERIMENT

A. Initial conditions of experiment

With respect to the technical specifications and the possibility of the comparability with the previous measurement, the following initial conditions were formulated:

a) collision of a passenger car (M1 category),
b) P6 dummy, (6 years; 1.17m; 22kg),
c) bicycle type corresponding with dummy „age“ and height.,
d) configuration (Figure 1on the left)**:** passenger car frontal part – left side of the cyclist (represents sudden cyclist´s entering the roadway, non-giving way…), 2 tests were performed in the 1. configuration: the first one with helmet and the second one without the helmet,
e) proposed collision speeds: per configuration 1: 20 kmph; per configuration2: 30 kmph,
f) the vehicle is starting to break at the moment of the crash contact.

Fig. 1: Test configuration

B. Collision partners

P6 dummy

- weight: 22 kg
- height: 1,17 m
- clothes: ankle boots with rubber soles, tracksuit, long sleeved shirt, head was wrapped in a protective adhesive tape,
- protective equipment: child protection helmet (new for each test), Producers: Crivit, size: S
- the dummy was calibrated before every test according to the manual.

Dummy instrumentation:

- head: 3-axis accelerometer, directions x,y,z, 1000 g range,
- thorax: 3-axis accelerometer, directions x,y,z, 1000 g range,
- pelvic region: 3-axis accelerometer, directions x,y,z, 500 g range,
- knee joint: 1-axis accelerometer, direction x, 500 g range,

Note: directions x, y, z corresponds with three dimensional reference system for vehicles according to ISO 4130-78 (x – collision direction, y – direction perpendicular to the collision, z – vertical direction).

Bicycle BMX 20 (Fig. 2)

- saddle height: 700 mm
- handlebars height: 910 mm
- bicycle axis height - crank: 335 mm

Fig. 2: Bicycle BMX 20

Vehicle M1 category

Skoda Yeti, 1.8 TSI 118 kW 6-speed manual. 4x4, model year 2010 (Picture No.3)

- max. power: 118 kW
- max. torque: 250 Nm/1500-4500 min^{-1}
- total displacement: 1798 cm^3
- curb weight with driver: 1505 kg
- max. speed: 200 kmph

The passenger car was equipped with an antireflection coating and impact zones on the bonnet due to the EuroNCAP (v 5.3),[2] for pedestrian protection testing see Figure 3 – for cyclists no special zones are defined.


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Fig. 3: Vehicle M1 category - Skoda Yeti.

C. Course of the experiment

Two experiments were performed:

- 11_00854_102 – passenger car frontal part – left side of the cyclist, test with the helmet,
- 11_00854_202 – passenger car frontal part – left side of the cyclist, test without the helmet,

Test 11_00854_102, collision speed 20,0 kmph

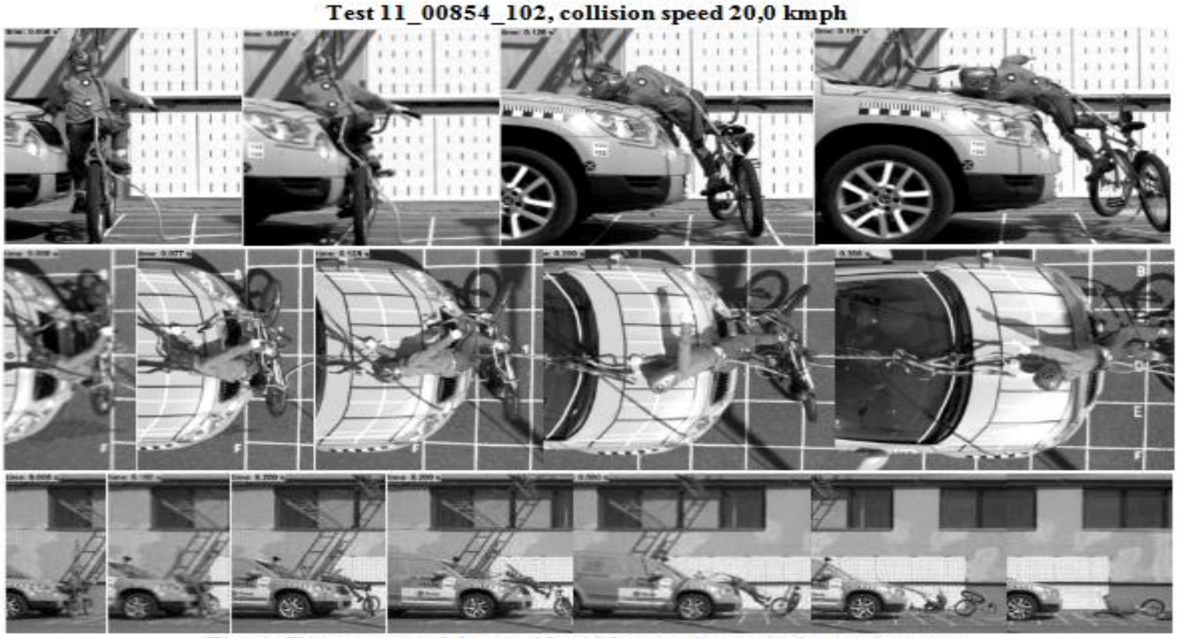

Fig. 4: Time course of the test No. 102 according to high speed camera

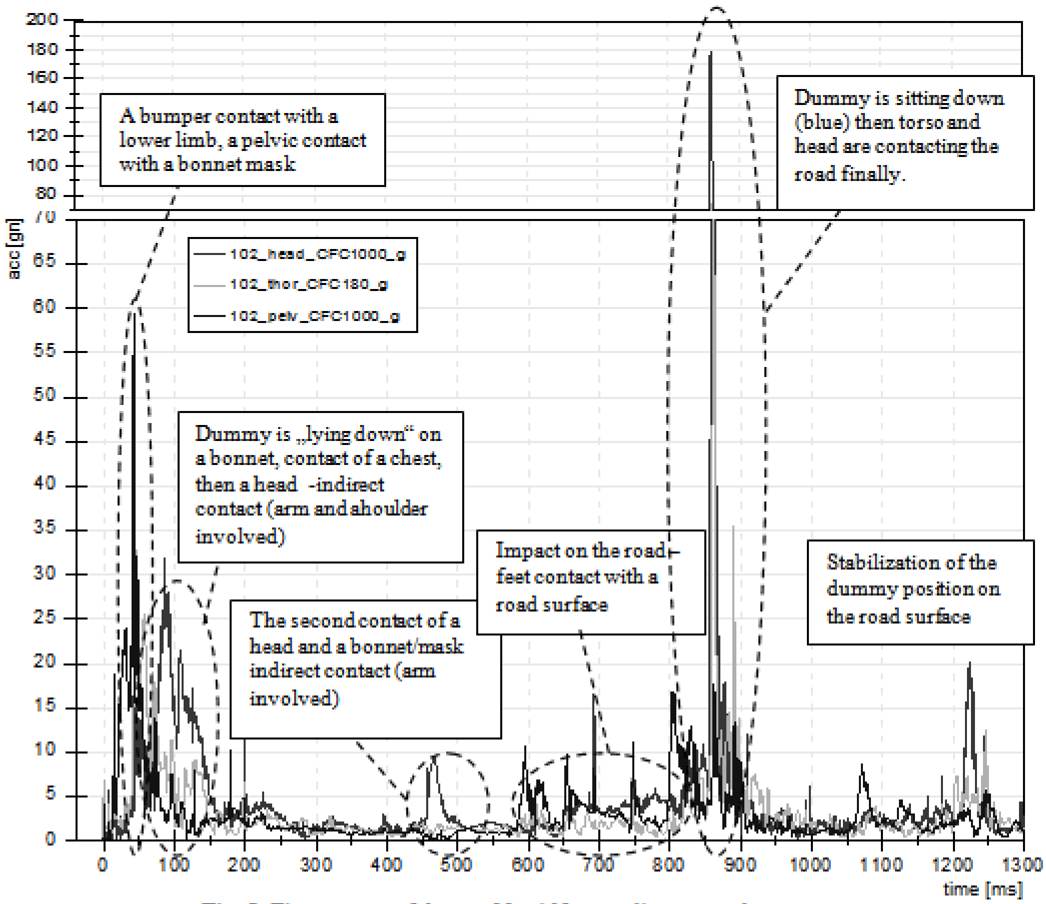

Fig. 5: Time course of the test No. 102 according to accelerometers

Final position of objects

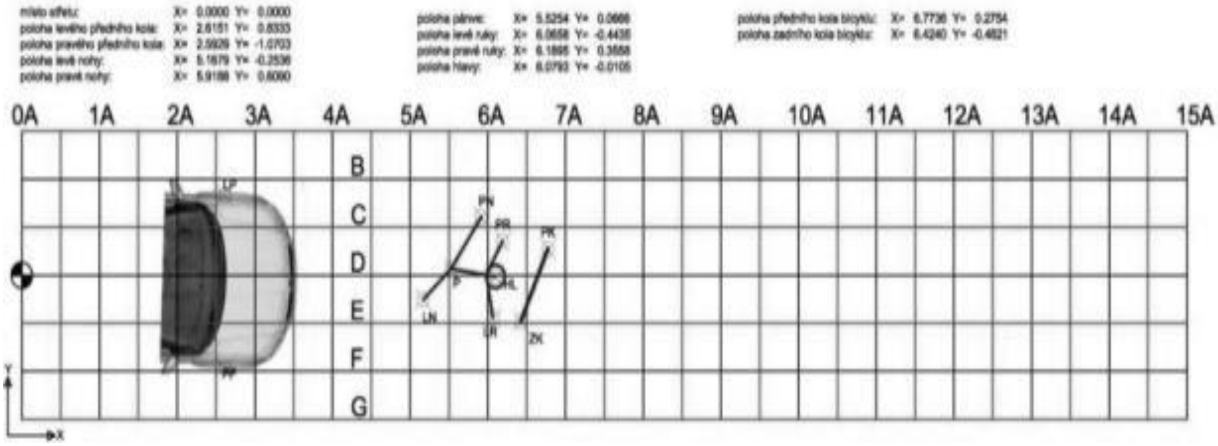

Fig. 6: Final position of objects after collision - test No. 102 – scheme

Fig. 7: Final position of objects after collision - test No. 102 – photodocumentation

Damage description

- **Passenger car:** significant carved mark on the bonnet from the left handlebar, mark of abrasion on adhesive tape on WAD 1000, abrasion near the longitudinal bonnet crimp behind WAD 1000 (see Figure 8).
- **Dummy:** without damage, clothes shows signs of abrasion from secondary impact.
- **Bicycle:** without damage, released/turned saddle and handlebars.

Fig. 8: Vehicle damage after collision - test No. 102

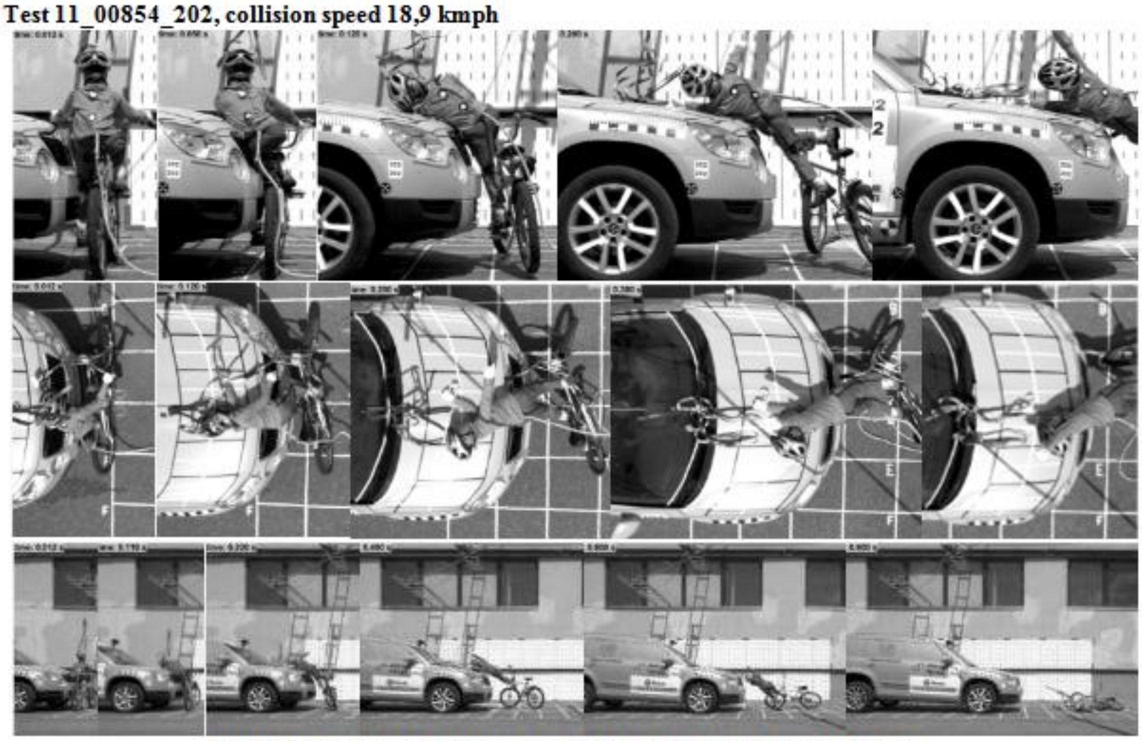

Fig. 9: Time course of the test No. 202 according to high speed camera

The moment of vehicle impact to the cyclist body is situated to 12. ms. Picture sequence of collision is demonstrated in the Figure 9. Time course of resultant acceleration with the plot description is in the Figure 10.

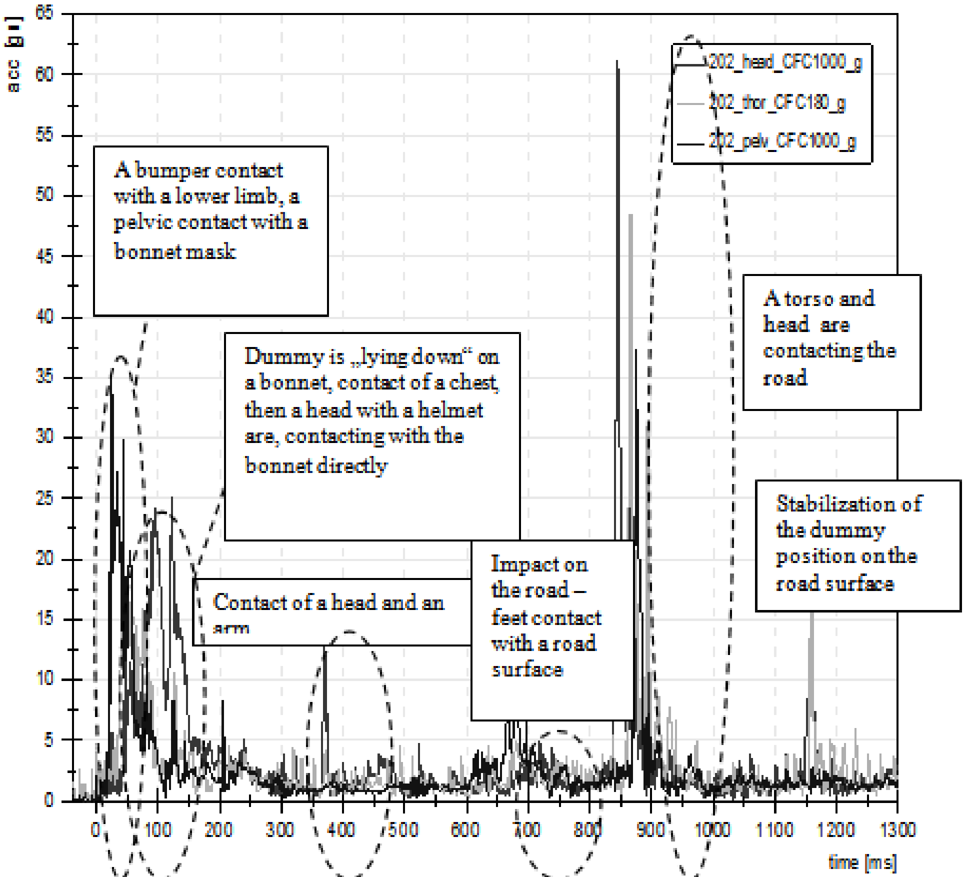

Fig. 10: Time course of the test No. 202 according to accelerometers

Final position of objects

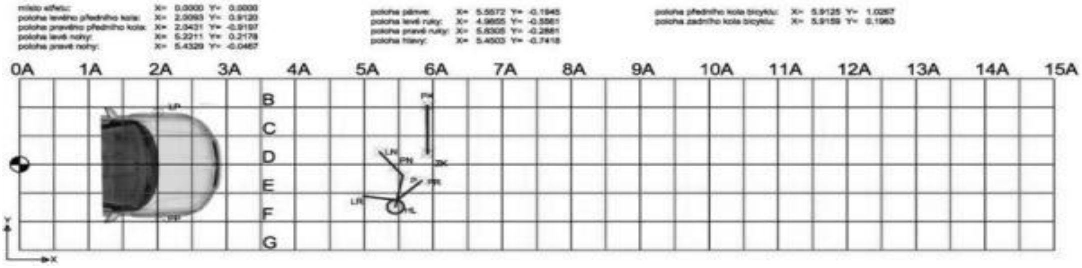

Fig. 11: Final position of objects after collision - test No. 202 – scheme

Fig. 12: Final position of objects after collision - test No. 202 – photodocumentation

Damages description

- **Passenger car:** significant carved mark on the bonnet from the left handlebar, mark of abrasion on adhesive tape on upper bumper edge (see Figure 13)
- **Dummy:** without damage, clothes shows signs of abrasion from secondary impact,
- **Helmet:** right rear part damage from direct impact on road, cracked foam (see Figure 14)
- **Bicycle:** without damage, released/turned saddle and handlebars.

Fig. 13: Vehicle damage after collision - test No. 202

Fig. 14: Helmet damage after collision - test No. 202

III. TESTS RESULTS DISCUSSION 11_00854

For the interpretation of crash tests consequences regarding the potential injury risk AIS /Abbreviated Injury Scale/ the most obvious classification scale of trauma seriousness based on anatomical-clinical assessment of patient.[3]

AIS coding was first introduced by AAAM / Association for the Advancement of Automotive Medicine / in 1971 as a system for assessing the seriousness of injuries resulting from traffic accidents. This system is continually updated and revised. This scale categorizes the type of injury, and assigns a severity of his eight-speed range:

0 – without injury	4 – severe injury
1 – minor injury	5 – critical injury
2 – moderate injury	6 – maximal injury (fatal)
3 – serious injury	9 – unknown injury

There is considered the individual injury in eight body regions (head, face, neck, chest, abdominal and pelvic cavity, spine, upper and lower limbs), the ninth group of the external injuries, burns, and others.

Head injury

Performed tests illustrated the benefits of protective equipment for cyclists, particularly the helmet, what was reflected mainly within secondary collision. According to the test No. 102 results the child cyclist will suffer fatal injury in 16 % as a consequence of secondary collision, in 38 % injury of AIS 5 seriousness, in 28 % head injury AIS 4. According to the test No. 202 results (with the helmet) the child cyclist will suffer minor injury only in 8 % as a consequence of secondary collision, in 89 % there will be no injury.

Primary collision in both tests represents no threat to the cyclist health with respect to head injuries.[3,4]

Note: The difference between calculated head performance criteria is not given only by the helmet use. As it was already published before in previous research papers dealing with collision with pedestrians, secondary collision is a phenomenon with a high degree of uncertainty. On the video records there is evident a difference in the form of secondary collisions in both tests (No. 102 and 202) consisting in larger share of tangential forces in test No. 202, which reduces the resulting biomechanical load.

Chest injury

The limit value of 3ms criteria for a 6-year-old child's thorax (55 g according to the ECE 44 should not act longer than 3ms)[5] was slightly exceeded in test No. 102 within secondary collision. This detected value means 58% risk of injury AIS 3+ for potential cyclist (lungs contusion, or heart contusion with hemothorax or pneumothorax). In test No. 202 this value is below the threshold, as well as the values of this criterion for primary impact of both tests, where cyclist will be exposed to injury risk of AIS 2+ in 10%, resp. 17%.[3,4]

Injury of pelvic region

The maximum acceleration limit a_{max} 130g was not exceeded in any executed test for the primary or secondary impact. The highest value within the test series was detected in test No. 102 in primary impact, where a minor injury such as contusion can be expected.

Knee injury

The limit value of maximum acceleration for the knee (170 g) was not exceeded in any executed test. There is low probability of slight contusion of the knee joint.

Executed tests of cyclists – passenger car collision were compared with set of test with child pedestrian which was executed on the 5th July 2011 with the same vehicle Skoda Yeti.

The main differences consist in post-crash kinematics, mainly in contact zones on the vehicle front part, which the dummy collides with, in primary impact time duration and in biomechanical load of particular segments as the consequence of primary impact.

Collision configuration of P6 dummy and passenger car Skoda Yeti is demonstrated by figures 15 a 16 (primary impact and place of primary impact of head with the bonnet).

Fig. 15: Child pedestrian vs. passenger car crash configuration, from the left: the first contact, the first contact of the head wit the bonnet

Fig. 16: Child cyclist vs. passenger car crash configuration, from the left: the first contact, the first contact of the head wit the bonnet

Comparison of biomechanical load values:

- **primary impact of head** - comparable values of head performance criterion,
- **chest** – primary impact – half values of a_{3ms} in comparison to passenger car vs. child pedestrian test,
- **secondary impact** – ca double values of a_{3ms} in comparison to passenger car vs. child pedestrian test,
- **pelvis** – half values of a_{max} in comparison to passenger car vs. child pedestrian test,
- **knee** – ca half values of a_{max} in comparison to passenger car vs. child pedestrian test.

IV. CONCLUSIONS

The CTU in Prague, Faculty of Transportation Sciences, performed a set of dynamic passive safety tests on a passenger car (M1 cat.) collision with a P6 dummy in the role of cyclist. The specific conclusions and findings are included in the discussion part of this paper. The collision partner of cyclist was Skoda Yeti. There were 2 tests executed in the configuration representing sudden cyclist´s entering the vehicle corridor. The results of the tests in collision speeds 20,0 and 18,9 kmph confirmed positive influence of helmet especially in case of contact with the road surface, which was commented in discussion. Results clearly show the need for bicycle helmets as in particular with regard to its effect within the secondary impact. The main aim was to analyse the head contact with the bonnet and with the road surface in botrh cases (with/without the helmet) and the comparison with child pedestrian kinematics.

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