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The impact of the safety belt used for chairs used in buses and minibuses with small-speed collisions

Marek Jaśkiewicz*, Dariusz Więckowski**

* Kielce University of Technology, Department of Motor Vehicles and Transport
25-314 Kielce, Al. Tysiąclecia Państwa Polskiego 7,
e-mail: m.jaskiewicz@tu.kielce.pl; mateuszmarciniewski@vp.pl
** Automotive Industry Institute (PIMOT)
03-301 Warszawa, ul. Jagiellońska 55, e-mail: d.wieckowski@pimot.org.pl

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Abstract
The article presents the analysis of the impact of the safety belt used onto a man sitting in a chair. The tests were conducted for small-speed collisions for three centile groups: 5, 50 and 95-centile group respectively. Each of those groups comprised men between 20 to 35 years of age. The tests were conducted on the inclined plane type device simulating the collision of a vehicle with the speed of approx. 12 km/h. Three types of safety belts were used for the tests: two-point, three-point and four-point belts. The results of analyses are presented in this article.

Introduction

More and more emphasis is placed on the safety of people travelling by bus and minibus nowadays [1]. First of all, passengers' chairs and other applied devices, which can raise the level of safety of travellers, are taken into consideration [2, 3]. After several recent well-known road accidents, great emphasis has been placed on travellers' safety. The level of safety largely depends on the structure of chairs, their mounting to the floor [4, 5] as well as the applied personal protection equipment for each person [6, 7, 8].

The aim of the paper is to show the impact of the applied safety belt on the movement of the head during a collision. The tests have been conducted for safe, i.e. small-speed, collisions (approx. 12 km/h) [9].

Description of the testbed

The testbed used for simulated collision tests with small collision speeds was created at the Kielce University of Technology in Kielce. It is a completely novel solution for which two patents have been given.

The diagram of the testbed for collision tests is shown in figure 1. The testbed consists of the track which comprises two straight sections of the length of L_1 = 1.5 m and L_2 = 5.5 m. On the moving track there is a cart with the mounted seat. Moreover, the seat is equipped with the hydro-pneumatic brake, a winch and an electric bolt. The height of the testbed track may be adjusted with the use of the screw gear driven with an electric motor.

Conducting tests on the testbed

The tests have been conducted on the inclined plane type testbed (Fig. 2).

The test consisted in that a person participating in the test sat in a chair and was secured with a suitable type of the safety belt. Then, the chair with the person was pulled up on the top of the inclined plane with the use of the winch. After the disconnection of the electromagnet, the chair drove down and a collision occurred (Fig. 3). At the same time, the quick rotating camera was activated and the whole test was recorded. Each examined person did the test for two-point, three-point and four-point belts. Tests were conducted for three centile groups of men. Each group consisted of 10 people. Three

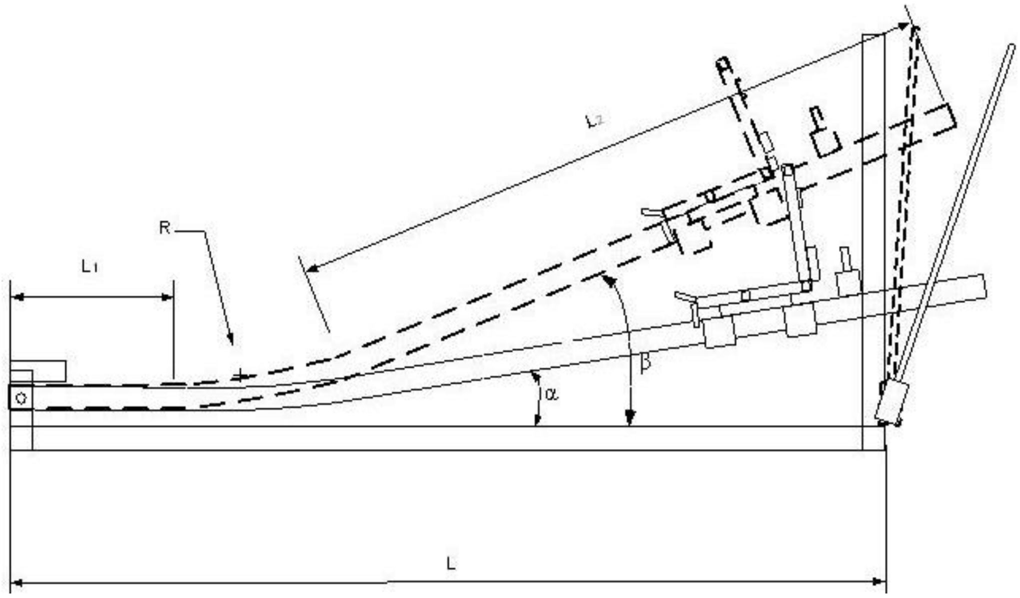

Fig. 1. The diagram of the testbed for collision tests

Fig. 2. The diagram of the testbed for collision tests

Fig. 3. The diagram of the testbed for collision tests [9]

measurements were taken for each of the examined people. In total, 90 measurements were registered and analysed [9].

The film recorded with the Phantom v310 camera was analysed with the use of the Tema Automotive software. Figure 3 shows the stuck markers (e.g. on the head) thanks to which we can do the full analysis of movement of the examined object.

Analysis of the registered results

Due to the large amount of data, the following diagrams only show head trajectories in each centile group for each type of safety belt.

Analysis of results for 5-centile group

The following four figures show head movement trajectories for the group of 5-centile men. Figure 4 shows head movement trajectory for an examined person marked as "student1" for three different safety belts.

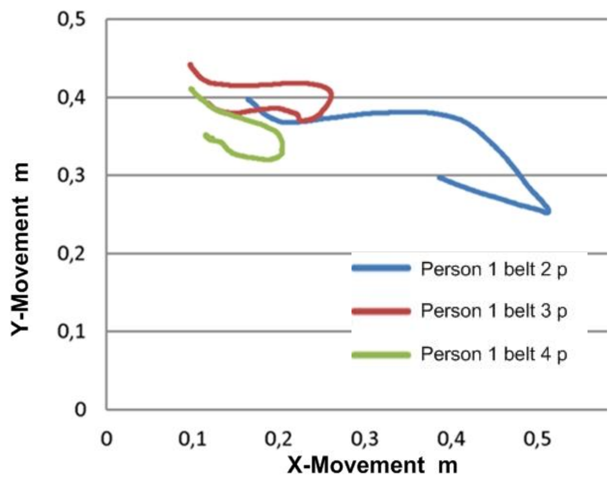

Fig. 4. Head movement trajectory of "person 1" for 3 different safety belts

Figure 5 shows head movement trajectory for 5-centile group for the two-point safety belt. Figures 6 and 7 show an analogous situation for a three-point and four-point belt.

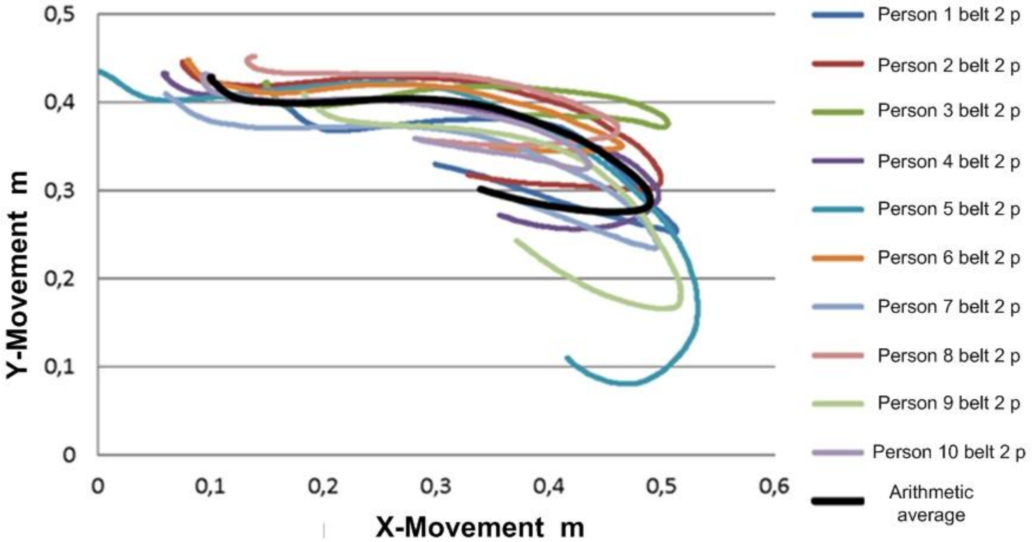

Fig. 5. The diagrams of head movement trajectory for 5-centile group for the two-point safety belt

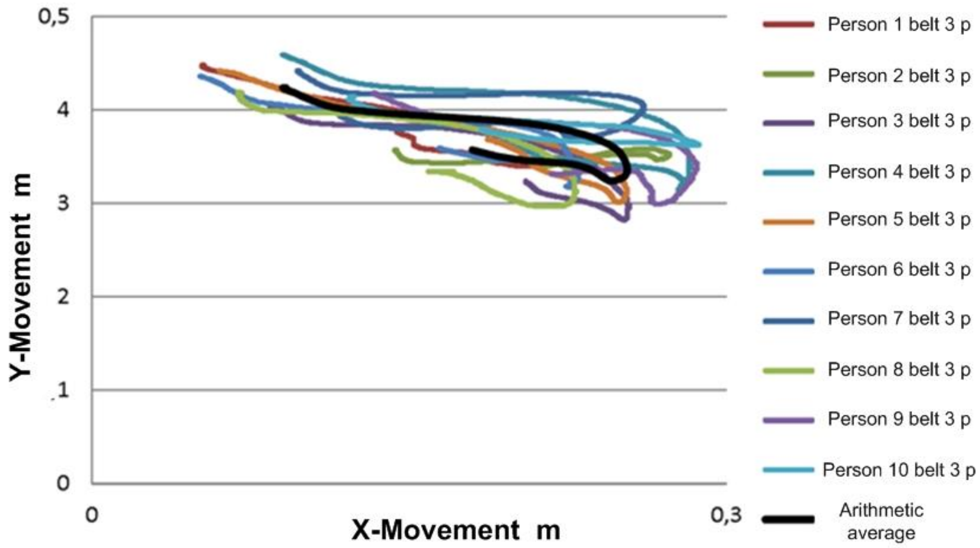

Fig. 6. The diagrams of head movement trajectory for 5-centile group for the three-point safety belt

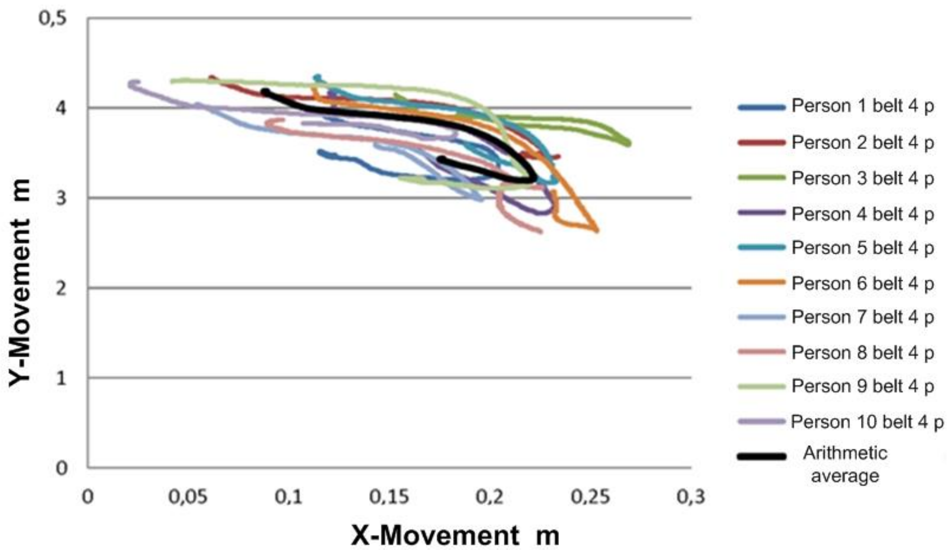

Fig. 7. The diagrams of head movement trajectory for 5-centile group for the four-point safety belt

It appears from figures 5, 6 and 7 that the biggest head displacement both in a horizontal as well as in a vertical direction occurs in the case of the two-point belt. For three-point and four-point belts vertical head displacements fall in the same range. As for horizontal displacements, they are the smallest for the four-point belt.

Analysis of results for 50-centile group

The figures 8, 9, 10 and 11 show head movement trajectories for the group of 50-centile men. Figure 8 shows head movement trajectory for an examined person, qualified for the 50-centile group, marked as "student11" for three different safety belts.

Figure 9 shows head movement trajectory for 50-centile group for the two-point safety belt. Figures 6 and 7 show an analogous situation for a three-point and four-point belt.

Head movement trajectory in the 50-centile group is similar as in the case of the 5-centile group. The biggest head displacement both in a horizontal as well as in a vertical direction occurs in the case of the two-point belt shown in figure 9. For the three-point belt shown in figure 10 and the four-point belt shown in figure 11 vertical head displacements fall in the same range. As for horizontal displacements, they are the smallest for the four-point belt.

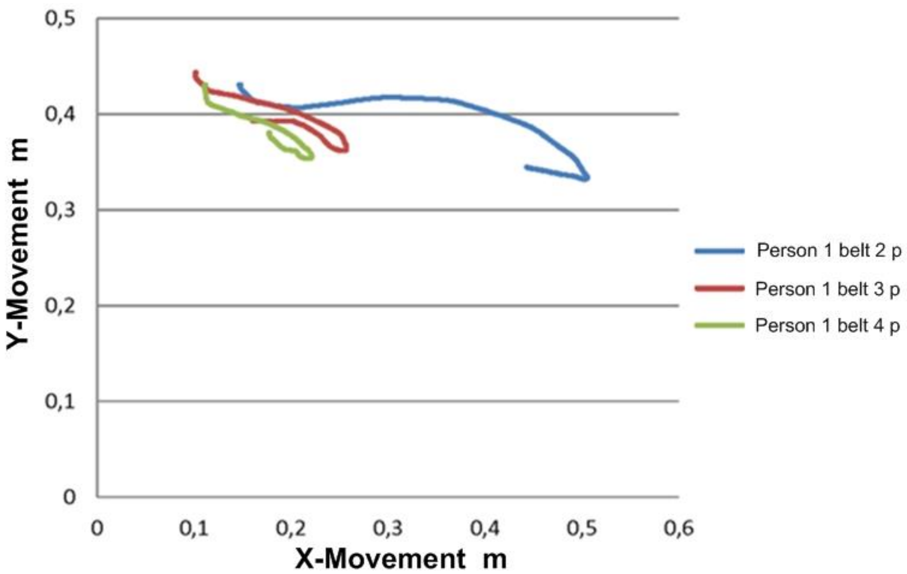

Fig. 8. Head movement trajectory of "person 11" for 3 different safety belts

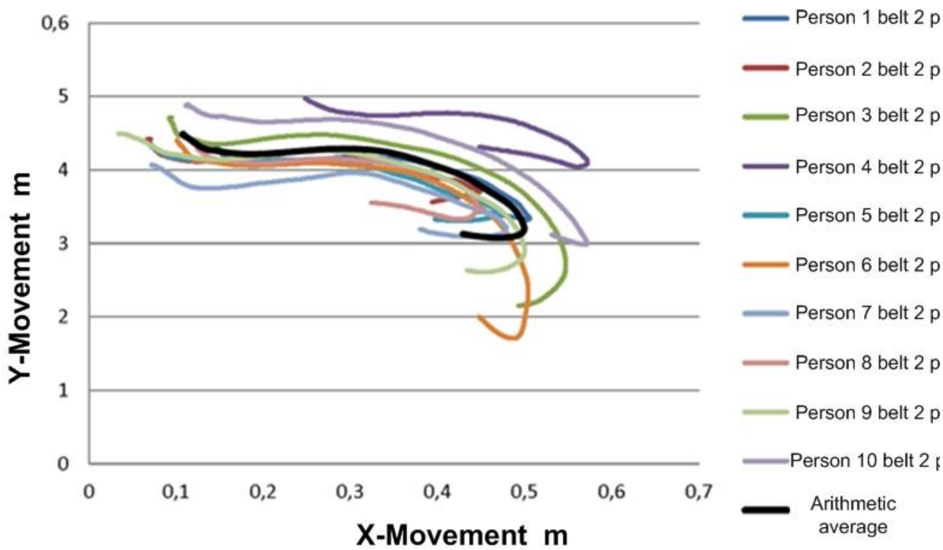

Fig. 9. The diagrams of head movement trajectory for 50-centile group for the two-point safety belt

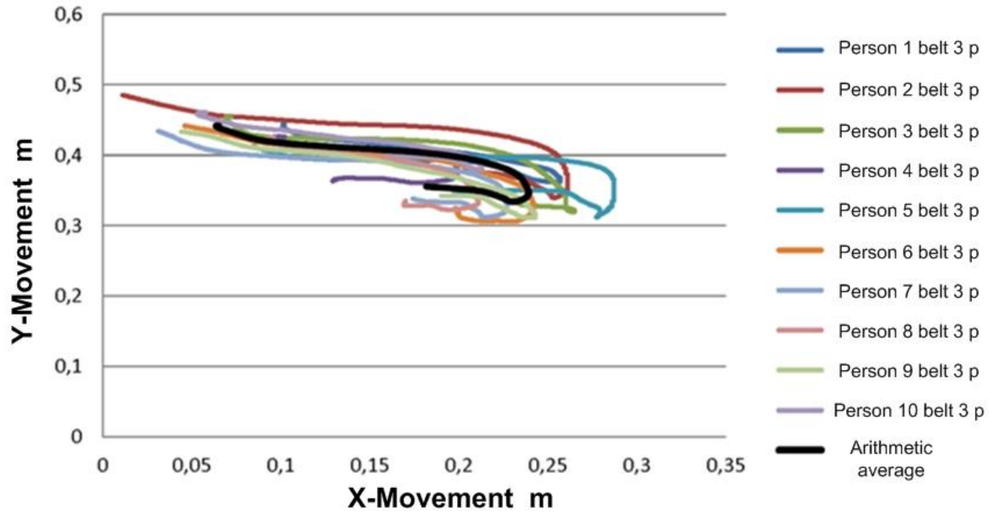

Fig. 10. The diagrams of head movement trajectory for 50-centile group for the three-point safety belt

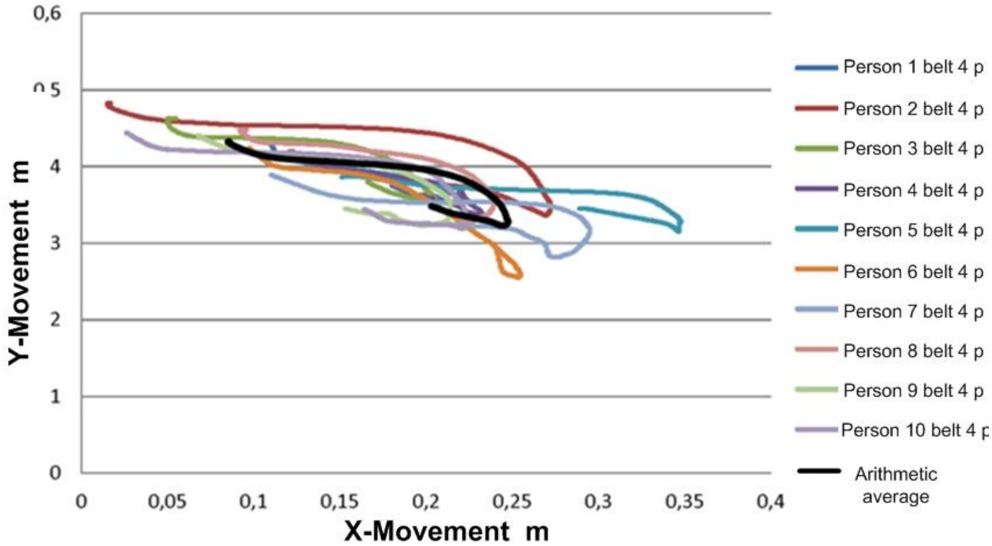

Fig. 11. The diagrams of head movement trajectory for 50-centile group for the four-point safety belt

Analysis of results for 95-centile group

The figures 12, 13, 14 and 15 show head movement trajectories for the group of 95-centile men. Figure 12 shows head movement trajectory for an examined person, qualified for the 95-centile group, marked as "student21" for three different safety belts.

Figure 13 shows head movement trajectory for 95-centile group for the two-point safety belt. Figures 14 and 15 show an analogous situation for a three-point and four-point belt.

Head movement trajectory in the 95-centile group is similar as in the case of the 5-centile group and the 50-centile group. The biggest head displacement both in a horizontal as well as in a vertical direction occurs in the case of the two-point belt shown in figure 13. For the three-point belt shown in figure 14 and the four-point belt shown in figure 15 vertical head displacements are on the similar level. As for horizontal displacements, they are slightly smaller than for the three-point belt.

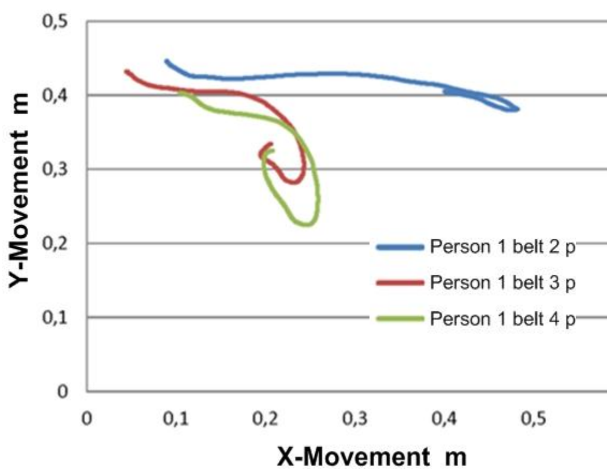

Fig. 12. Head movement trajectory of "person 21" for 3 different safety belts

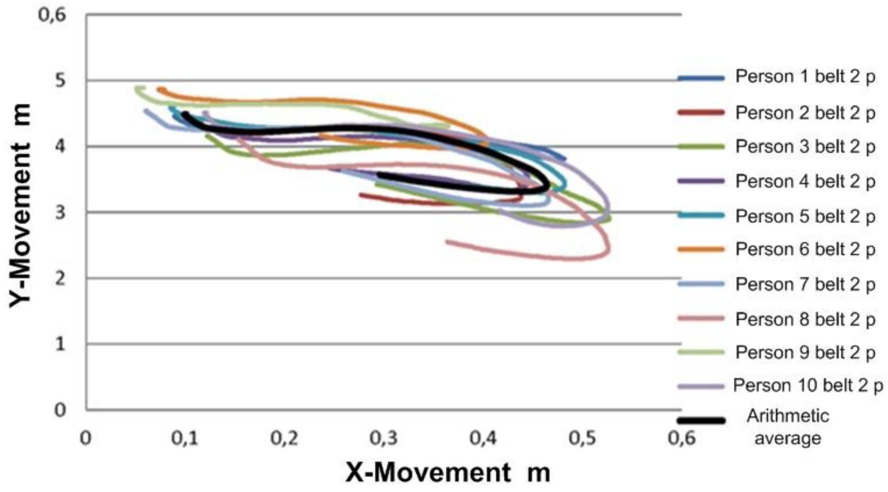

Fig. 13. The diagrams of head movement trajectory for 95-centile group for the two-point safety belt

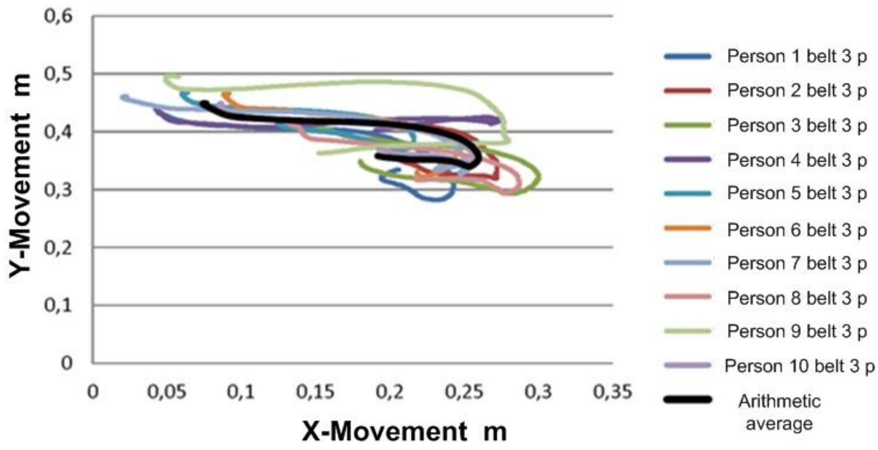

Fig. 14. The diagrams of head movement trajectory for 95-centile group for the three-point safety belt

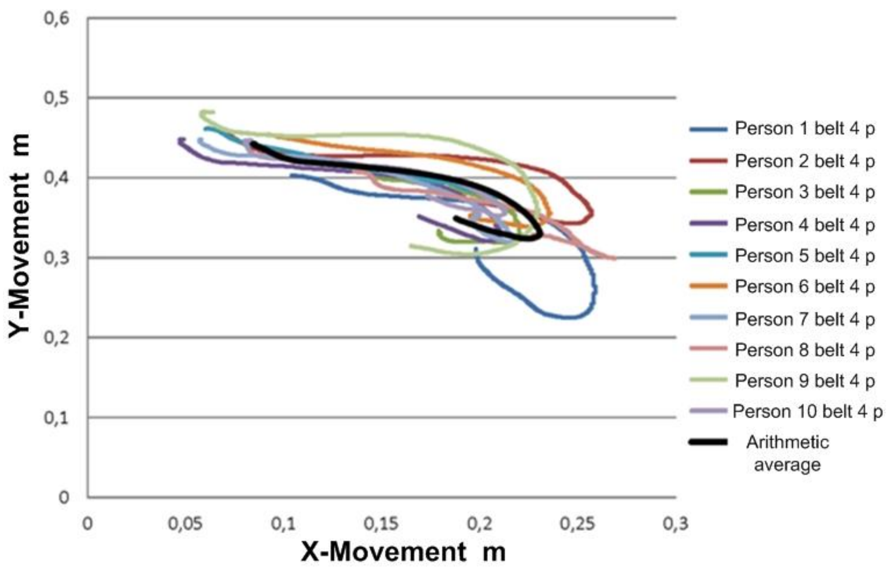

Fig. 15. The diagrams of head movement trajectory for 95-centile group for the four-point safety belt

Comparison of arithmetic means

Previous figures showing head movement trajectories also show arithmetic means separately for each group and for each type of the safety belt. The following figures show the comparison of those trajectories in relation to the type of the safety belt used. Figure 16 shows the comparison of arithmetic means for a two-point belt, figure 17 for the three-point belt and figure 18 for the four-point belt.

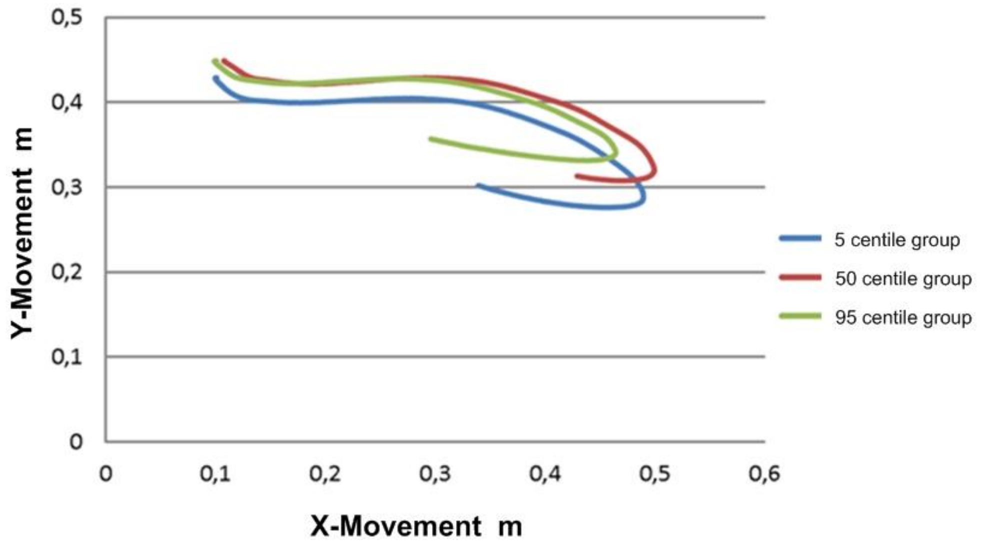

Fig. 16. The comparison of arithmetic means of trajectories for a two-point safety belt for three centile groups

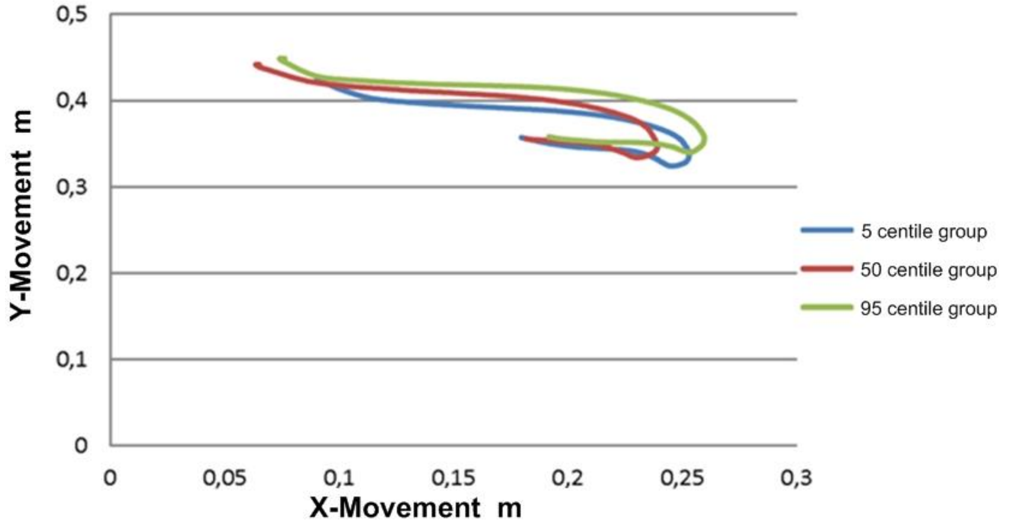

Fig. 17. The comparison of arithmetic means of trajectories for a three-point safety belt for three centile groups

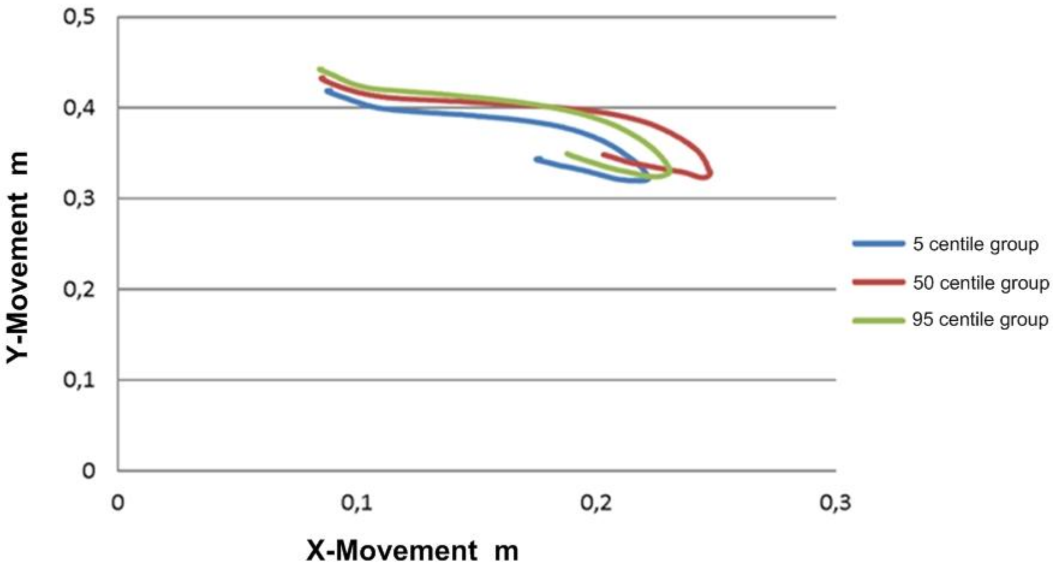

Fig. 18. The comparison of arithmetic means of trajectories for a four-point safety belt for three centile groups

It appears from the three figures that the type of the centile group has a small impact on head displacement. The type of the safety belt used has a much bigger impact on head movement.

Conclusions

Comparative analysis of head trajectories with the use of all types of safety belts was made after calculating the arithmetic mean from each centile group. The smallest head displacement of men occurred for the four-point belt. The value of the displacement for that belt amounted to 20 mm for the 5-centile group, 240 mm for the 50-centile group and 220 mm for the 95-centile group. That belt holds the body well and decreases head horizontal displacement by 0.02 m in relation to the three-point belt. The two-point belt turned out to be less effective as the head displacement amounted to 500 mm.

If we assume that the standard space between the seats is 750 mm, then there is the reserve of 250 mm for the two-point belt provided the head touches the seat. It should be noticed that those displacements are determined for collision speeds amounting to approx. 12 km/h. With greater speeds the displacement is much bigger. If there is a head-on collision and the head moves by more than 750 mm, it heats the preceding chair and there is a high risk of injury of the upper section of the spine.

That is why, an important conclusion is that the two-point belts presently used in buses do not protect us against head-on collisions. Those belts only provide protection during a turn of a vehicle keeping a person in the seat.

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