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Safety and effectiveness of the novel wheelchair with a seatbelt system

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Recently, an increased number of older wheelchair users regularly travel in the rear space of motor vehicles. When these persons are suffered from motor vehicle collisions, poor seatbelt fit leading submarine phenomenon can cause severe or fatal injuries. According to our previous results of sled tests, because the lap belt did not fit the adequate position of the pelvis, the wheelchair user displaced forward and higher values of shoulder belt loads and chest deflections were observed. Therefore, for the safety of wheelchair user vehicle passengers, a novel restraint system with the following features was recommended: a sturdy wheelchair that can resist applied forces; both the shoulder and lap belts are correctly positioned across the bony parts of the chest and pelvis; force limiter is installed in the restraint system to reduce shoulder belt loads. Then, we have developed a novel sturdy wheelchair equipped with both shoulder and lap belts including force limiter. In this study, safety of this novel wheelchair was examined with sled tests and its convenience was also examined through real-world testing.

First, two sled tests representing the situations that the wheelchair user using public transportation suffers from frontal collision at 20 km/h (condition 1) and the wheelchair user riding in the rear space of the wheelchair transport vehicle suffers from frontal collision at 48 km/h (condition 2) were performed. In condition 1, Hybrid III-AF05 dummy sat on the novel wheelchair without head rest, whereas in condition 2, Hybrid III AM50 dummy was used. Kinematics of the dummy and biomechanical parameters of the dummy were examined. At the collision, because both shoulder and lap belts were correctly positioned across bony areas, the dummy was well restrained. Biomechanical parameters shown in Table 1 were within acceptable ranges.

Next, convenience of various types of wheelchairs was compared. The situations that older wheelchair user gets into and off the rear space of the wheelchair transport vehicle were reappeared. Male adults simulating caregivers loaded the wheelchairs (general type, reclining type, sturdy type, sturdy with seatbelt system) carrying a Hybrid III-AF05 dummy into the vehicle and unloaded them from the vehicle. They had to open or close the rear door, pull out or retract ramp, tie-down the wheelchair or release it, wear or remove a seatbelt. The required times for each step when loading and unloading were measured. The eleven trials were performed by three males. Among the four steps, required time marked varied when wearing or removing a seatbelt. The mean total time of loading or unloading the wheelchair users was shortest when using a sturdy wheelchair with a seatbelt system, 70 s and 60 s, respectively and longest when using a general type of wheelchair, 118 s and 87 s, respectively (Fig.1).

According to the present results, we confirmed that the sturdy wheelchair equipped with both lap and shoulder belts involving force limiter provided the sufficient safety at 20 km/h of frontal collision when boarding on the public transport and at 48 km/h of frontal collision when boarding on the welfare vehicle. Furthermore, the times required for loading and unloading the wheelchair users were markedly reduced with the wheelchair equipped with both lap and shoulder belts. The convenience of this novel wheelchair for caregivers was also confirmed.

Table 1 Maximum values obtained by sled tests.

Item	Condition 1 Hybrid III AF05, 20km/h, without head rest	Condition 2 Hybrid III AM50, 48km/h
HIC	17	222
Nij	0.29	0.52
Chest displacement (mm)	238	316
Pelvis displacement (mm)	132	220
Chest acceleration (m/s^2)	105	307
Shoulder belt load (kN)	1.0	5.9
Chest deflection (mm)	7.6	30.8

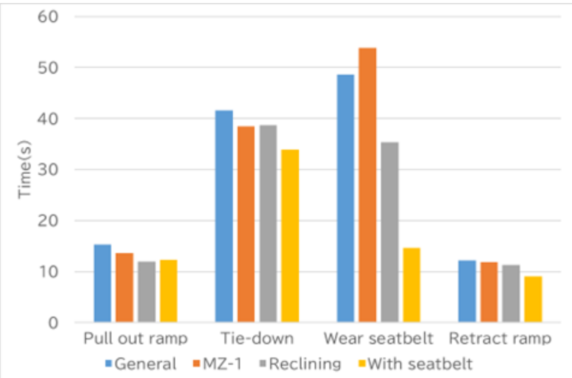

Fig.1 Required time for boarding the wheelchair