VEHICLE PERFORMANCE CHARACTERISTICS AND SEAT BELT EFFECTIVENESS IN LOW SPEED VEHICLES AND GOLF CARS

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ABSTRACT

Low Speed Vehicle (LSV) use on public roads is currently experiencing a tremendous increase in usage in the United States. There currently exists a debate concerning the impact these vehicles will have on our roadways and the occupant injury exposure resulting from their usage. Of particular controversy are the potential safety benefits and trade offs associated with the use of seat belts in LSV's and golf cars.

In an effort to create uniform safety guidelines for these vehicles the United States National Highway Traffic Safety Administration (NHTSA) has created a new category of "Low Speed Vehicle" (LSV) to regulate small, 4-wheeled motor vehicles, other than a truck, with top speeds of 20 to 25 miles per hour. Any vehicle capable of exceeding 25 mph would fall under the Federal Motor Vehicle Safety Standards for passenger cars. LSV's, which include modified personal neighborhood vehicle (PNV), neighborhood electric vehicles (NEV) and golf cars, having a maximum speed greater than 20 mph, but not greater than 25 mph, fall under the Federal Motor Vehicle Safety Standard No. 500 (49 CFR 571.500). At present, golf cars with a maximum speed of less than 20 mph are not required to comply with the LSV standard but are still subject to state and local regulation.

Vehicle dynamic and occupant kinematics studies conducted by the authors indicate that golf cars moving at speeds as low as 11 mph are capable of rapidly producing the lateral accelerations necessary to quickly eject an unbelted occupant even with the hip restraints provided by most golf car manufacturers. The testing included a variety of LSV's and golf cars ranging from a typical golf car with a top speed of 11 mph to an advanced LSV capable of reaching a top speed of 25 mph. In all cases the unbelted occupants were ejected in J-turn maneuvers while the belted occupants remained in the original seat. This study demonstrates that the safety benefits of seat belts in these vehicles are significant and should be required as safety devices when operated on roadways.

INTRODUCTION

The usage of LSV's and golf cars on public roadways is currently experiencing a rapid growth. The phenomena started in the early 1990's in various resort and retirement communities across the United States. The city of Palm Desert, California was a pioneer in recognizing the rising use of LSV's and golf cars on their public roadway and the potential safety problems it could present to its citizens. In 1993 the city took the initiative to pass minimum safety requirements for the use of LSV's and golf cars on their roadways. Some of the vehicle safety requirements included front and rear turn signal indicator lights, headlights, rear lights, brake lights, mirrors, red reflectors and safety belts. The requirement for safety belts was controversial due the fact that almost all of the golf cars available did not have safety belts as original equipment and it was the position of the National Golf Car Manufacturers Association (NGCMA), which represents the original equipment manufacturers of 95% of all golf cars manufactured and distributed in the United States, that seat belts are more of a safety detriment to the occupant than beneficial. It was the position of the NGCMA that a vehicle without a rollover protection system (ROPS) required that the occupants have the ability to jump from a moving car during a rollover event. The city of Palm Desert nevertheless went forward with and maintained the seat belt requirement.

In 1997 NHTSA proposed a new category of motor vehicle be established called "Low Speed Vehicle"(LSV) [1]. Initially it was proposed that an LSV would be any vehicle, other than a motorcycle, whose top speed does not exceed 25 mph. The new class of vehicles would be equipped with certain basic items of motor vehicle safety equipment, including seat belts, in lieu of complying with the Federal motor vehicle safety and bumper standards that would apply if the vehicles were categorized as passenger vehicles. NHTSA indicated at this time that it did not intend to regulate "golf carts" that have a top speed of less than 15 mph and are used to carry golfers on golf courses, though "golf cars" that are used to carry golfers on golf courses and that had a top speed that exceeds 15 mph but not 25 mph would be a motor vehicle. The agency had concluded that a golf cart with a maximum speed that does not exceed 15 mph is a vehicle that is not primarily manufactured for use on public roads and is therefore is not a motor vehicle. The agency went on to state "that if a golf cart manufacturer decides to increase the maximum speed capability of its golf carts to above 15 mph in response to the decision in some states to increase their speed thresholds in their definitions of "golf carts" and to allow such vehicles to operate on certain public roads, it seems evident to NHTSA that such a manufacturer intends its vehicles to be used on public roads as well on golf courses" [1]. NHTSA was faced with the dilemma of attempting to avoid the regulation of "golf carts" whose sole use was for carrying golfers on golf courses and anticipating their eventual use of public roadways due to the increasing number of state and local laws specifically anticipating their use. It was decided at that time that NHTSA would create a new Federal motor vehicle safety standard called Standard No. 100 Low Speed Vehicles and that the proposed speed bracket for this class of vehicles would be between 15 and 25 mph. Among other requirements a seat belt of Type 1 or Type 2 would be required.

Subsequent to NHTSA's proposed rulemaking a final rulemaking was made changing the standard to FMVSS 500 and with a significant change in the lower speed threshold from 15 to 20 mph. This change of the speed threshold was made due to a representation by the NGCMA. It was the understanding of NHTSA at the time of proposed rulemaking that an appropriate dividing line between golf cars manufactured for golf course use and those manufactured for both on-road use and golf course use was 15 mph. Subsequent to NHTSA's proposed rulemaking NGCMA informed NHTSA that 1% of Club Car's fleet cars (golf cars designed solely for use on golf courses and sold to golf courses) and 75% of their personal cars (cars designed for use on golf courses and public roads) have a top speed of over 15 mph. Based on this new information NHTSA decided a better dividing line between vehicles designed for use on the golf course and vehicles designed for on road use was a minimum top speed of 20 mph. Subsequent to this decision NGCMA notified NHTSA the information regarding Club Cars was incorrect and that, in fact, Club Car does not design any fleet cars (golf cars designed solely for use on golf courses and sold to golf courses) to travel over 15 mph, nevertheless NHTSA left the final bracket at 20 to 25 mph.

The decision as to whether or not seat belts should be required was investigated by NHTSA during this rulemaking. NHTSA decided to examine the city of Palm Desert's Golf Cart Transportation Plan. This transportation plan included the requirement of safety belts and this requirement appeared to not have any negative impact with regard to occupant safety over the years since its implementation. However, it was noted by NHTSA during its proposed rulemaking that the NGCMA viewed the seat belt requirement as "antithetical to the personal safety of drivers and occupants of golf cars" [2] and cited ANSI/NGCMA Z 130.1-1993 [3] which required a ROPS for any golf car containing seat belts. NGCMA also commented that seat belts enhance the risk of injury or even death if the occupant is restrained in the vehicle by a seat belt assembly upon rollover. NGCMA went on to explain golf cars are equipped with a standard hip or hand hold restraint located towards the outside of the seat. This restraint, according to NGCMA, does not prevent the occupant from jumping or leaping out of the golf car to avoid injury if the golf car is about to rollover. For this reason, in lieu of seat belt requirement for golf cars, the NGCMA believes a hand hold or hip restraint should be required as set forth in ANSI/NGCMA Z 130.1. NHTSA also investigated golf car injury statistics found in the Consumer Product Safety Commission's National Electronic Injury Surveillance System (NEISS).

In its final ruling NHTSA concluded that "the conjecture by some commenters that it would be valuable to be able to jump out of an LSV are unsubstantiated speculation that is especially unpersuasive given the volume of data showing that ejection is extremely dangerous and that seat belts are remarkably effective at preventing ejection" [2]. The agency concluded that it is desirable to require seat belts in LSV's.

NHTSA emphasized in its ruling that it has not decided or implied that vehicles with a top speed of less than 20 mph should not be subject to any safety regulation by state or local authorities. Moreover, since the agency is not treating those vehicles as passenger motor vehicles, its standard setting activities cannot pre-empt any state or local regulation. State and local jurisdictions may continue to adopt such equipment requirements as they deem appropriate for vehicles, including golf cars, with a maximum speed of 20 mph or less.

Thus, with NHTSA's final ruling it left the local communities to decide what safety devices it would require for golf cars with a top speed of less than 20 mph. A significant portion of the golf cars currently on the road today were previously leased through golf courses and subsequently turned over to dealerships for sale and rent to the general public. These relatively inexpensive vehicles are seeing a surge in demand as the popularity of golf cars on public roadways increases. The current situation has left local communities with a dilemma on how to regulate these golf cars. On one hand the NGCMA has notified them that they would not endorse the use of seat belts on their golf cars and yet parents are wondering how to put their children in the golf cars. Furthermore, some authorized golf car dealerships in California are proceeding to install seat belts in golf cars with a top speed of less than 15 mph even though the NGCMA recommend against it.

Research into the hip restraint effectiveness found standard on most golf cars today appears to be non-existent as does research into the safety benefits and potential detrimental effects of seat belts in golf cars. Current existing standards such as the ANSI/NGCMA Z 103.1-1993 [3] and the SAE Surface Vehicle "J" 2358 Standard [4] appear to be almost identical with both standards not recommending belts for golf cars with a top speed of under 20 mph. With this recommendation though is the statement "that the person operating the vehicle be qualified and trained in the proper operation of the vehicle" [4]. For general public use, however, expecting that the "operator be qualified and trained in the proper operation of the vehicle" doesn't seem to be appropriate nor realistic. The basis for the determination of not recommending seat belts for golf cars with a top speed of less than 20 mph cannot be determined.

BACKGROUND

Literature and research searches conducted by the authors revealed a dearth of information regarding golf car and LSV performance and restraint effectiveness. In fact, fewer than four papers were located concerning golf car related injuries. This is consistent with the findings completed by NHTSA. One paper, authored by Passaro et al, [5] is the most complete investigation into injuries associated with golf car use on public roadways. The paper's research was conducted in the North Carolina community of Bald Head Island and included interviews with the injured parties in an effort to ascertain the specific circumstances of each event and to ensure the injury was related to occupants involved in the usage of golf cars as transportation. The golf cars involved in the reported accidents involved the four-passenger type and none had seat belts. The mean top speed for the cars was reported to be 14 mph with two having a top speed of 18 mph. Twenty-two occupants were included in the case series. It was determined from the investigations that of the twenty-two people in the case series fifty-nine percent (59%) were injured following being ejected from a moving car and all reported injured parties were passengers. Children 10 years of age and younger were involved in thirty-two percent (32%) of the cases. It was also reported that fifty-nine percent (59%) of the injuries were sustained to the head or face and ranged in severity from scalp laceration to skull fracture. The conclusions of this study recommended installation of appropriate occupant restraints should be seriously considered.

The only vehicle dynamics testing found in literature was testing completed by NHTSA in their report titled "Inspection and Testing of Low Speed Vehicles"[6]. The vehicles evaluated were the Bombardier and GEM neighborhood electric vehicles and a Yamaha gasoline powered golf car. The tests conducted included 1) measurement of the c.g. and static stability factor (SSF) for each vehicle, 2) measurement of lateral stability in a constant 50 foot radius turn, and 3) straight line braking on both a high coefficient surface and low coefficient surface. The reported SSF's for the unloaded Bombardier, GEM and Yamaha were reported to be 1.4, 1.0 and 1.3 respectively. The reported SSF's in the loaded condition for the Bombardier, GEM and Yamaha where found to be 1.2, 0.86 and 0.88 respectively. The study concluded that an LSV with a static stability factor below 1.0 with two occupants could probably tip easily in a tight turn at 20 mph. The 50 foot turning radius reported relative stability for the Bombardier and relative instability for the Yamaha, though it should be noted the throttle linkage was adjusted on the Yamaha to achieve 20 mph during the testing. The stability on the GEM at 20 mph could not be determined.

Injury statistics for golf cars can be found through the Consumer Product Safety Commission's National Electronic Injury Surveillance System (NEISS). The system allows a search for injuries involving various product codes and one of the codes available is "golf carts". NEISS is a probability sample of hospitals in the U.S. and its territories that have at least six beds and an emergency department. Patient information is collected nightly from each NEISS hospital for every patient treated in the emergency department for an injury associated with consumer products. National estimates are made of the total number of product related injuries treated in U.S. hospital emergency departments based on the NEISS data collected from these hospitals. Each incident contains a brief description of the event and circumstance surrounding the injury producing event. The authors have obtained and filtered the data for the years 1993-2003 for occupants contained in a golf cart. The summary of reported injuries for golf cart occupants can be seen in Figure 1. As seen in Figure 1, there were 67,017 total estimated injuries for occupants riding in a golf cart over this time period. Of this total 52% were due to occupants falling from a moving cart. Examining the data regarding the injuries to those occupants that fell from the moving cart (34,484 occupants) indicated that approximately 35% of those individuals (11,976) sustained head injuries over this time period. This data also indicates a steady increase in the estimated number of head injuries occurring each year, as shown in Figure 2.

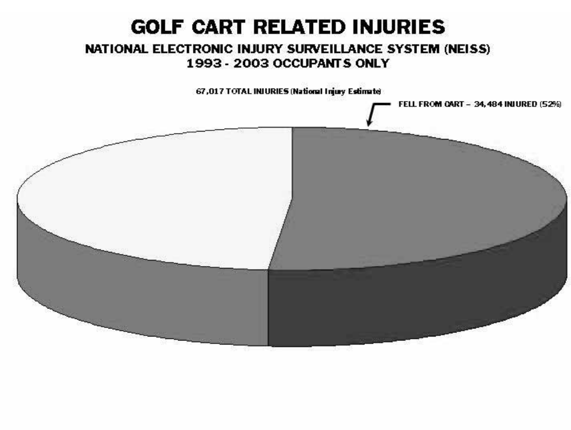

Figure 1 – NEIS data for golf car occupants, 1993-2003

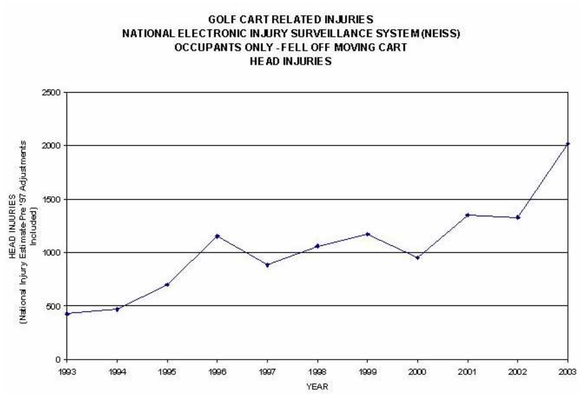

Figure 2 – NEISS data for occupants sustaining a head injury

TEST PROCEDURES

Four vehicles were obtained for testing, three of the vehicles can be categorized as golf cars (top speed less than 20 mph) and one can be categorized as a Low Speed Vehicle (LSV – top speed less than 25 mph). Each vehicle would be run through a series of tests as follows:

1. Acceleration test with driver only (both directions on track)
2. J-Turn test (straight approach followed by a counter-clockwise steering maneuver) with a belted driver and dummy passenger in a belted and unbelted condition.
3. In-line brake tests with a belted driver and dummy passenger in a belted and unbelted condition.

The test vehicles are depicted in Figures 3 through 6. The vehicles have designated seating positions for two or four occupants and all came equipped with either lap belts (Type 1) or lap/shoulder seat belts (Type 2) as original equipment or had been installed by the dealership. The dummy utilized in the series of test is a 50th percentile Alderson dummy.

Two methods of collecting performance data for the tests were employed. A triaxial array of accelerometers (IC Sensors 3031-050) was affixed to the vehicle's approximate static center of gravity. The accelerometers attached to the test vehicles were gain adjusted for a ±10 g range. All accelerometer data were collected following the general theory of SAE Recommended Practice: Instrumentation for Impact Test - J211/1 Mar95. The axis systems were in accordance with SAE J1733 Information Report with the positive X, Y and Z axes forward, rightward and downward, respectively. All accelerometer data were collected at 1000 Hz and filtered using a SAE Class 60 filter (TDAS Pro, Diversified Technical Systems, Inc., Seal Beach, CA). In addition to accelerometer data, vehicle performance data were measured using a GPS-based system (VBOX, Racelogic Ltd., Buckingham, England). Three-dimensional speed and positional data were collected at 100 Hz.

Figure 3 – Test vehicle 1, 2002 Ford Think

Figure 4 – Test vehicle 2, 2003 Club Car

Figure 5 – Test vehicle 3, 1998 EZGO golf car

Figure 6 – Test vehicle 4, 2000 EZGO golf car

TEST RESULTS

Vehicle test results from the GPS-based VBOX system can be found in Table 1. The results include top speed, peak acceleration and acceleration to peak velocity. The peak acceleration for this data is the average of the sustained peak acceleration and not a single peak acceleration value. The acceleration to peak velocity is the average acceleration from the initiation of movement until the peak velocity was attained.

Table 1.

VBOX Acceleration Test Results

Cart	Test	Top Speed (mph)	Peak Acceleration (g)	Acceleration to Peak Velocity (g)
1T	1_1	12.47	0.15	0.08
	1_2	12.77	0.16	0.10
1D	1_3	24.10	0.26	0.08
	1_4	24.20	0.27	0.07
2	2_1	16.60	0.19	0.07
	2_2	dl	dl	dl
3	3_1	11.50	0.23	0.05
	3_2	12.88	0.37	0.04
4	4_1	14.30	0.26	0.11
	4_2	14.50	0.28	0.12
	4_3	14.50	0.27	0.13
	4_4	14.40	0.30	0.13

Accelerometer data for all the tests can be found in Tables 2 through 4. Table 2 shows the peak accelerations for the top speed tests. Table 3 presents the average peak sustained lateral acceleration attained when completing the J-turn maneuver. The J-turn tests resulted in an average peak lateral acceleration of approximately 0.7 g's with a turning radius of approximately 14'. In each of the unbelted occupant tests the passenger dummy was ejected over the hip restraint and onto the ground whereas each of the belted occupant tests resulted in the occupant remaining within the confines of the passenger's seat. The resulting occupant kinematics from each test is located in Appendix A. The results of braking tests for each LSV and golf car are shown in Table 4. The values in Table 4 represent the average peak deceleration values. In braking test 1_7 the unbelted passenger dummy came out of the seat and struck it's head on the windshield header, as seen in Figure 7.

Figure 7 – Dummy occupant head strike on windshield header

Table 2.

TDAS Acceleration/Top Speed Results

Cart	Test	Peak Acceleration (g)
1T	1_1	0.20
	1_2	0.19
1D	1_3	0.31
	1_4	0.31
2	2_1	0.23
	2_2	0.24
3	3_1	0.33
	3_2	0.42
4	4_1	0.30
	4_2	0.33
	4_3	0.33
	4_4	0.33

Table 3

TDAS J-Turn Lateral Acceleration Tests

Cart	Test	Average Peak Lateral Acceleration (g)
1	1_5	0.67
	1_6	0.70
2	2_3	0.67
	2_4	0.64
3	3_3	0.63
	3_4	0.56
4	4_5	0.74
	4_6	0.65

Table 4

TDAS Braking Results

Cart	Test	Average Peak Deceleration (g)
1	1_7	0.88
	1_8	0.87
2	2_5	0.53
	2_6	0.52
3	3_5	0.54
	3_6	0.47
4	4_7	0.46
	4_8	0.44

CONCLUSIONS

The research contained in this paper provides a part of the critical data required for agencies (both national and state) and local communities to make informed decisions regarding their LSV/golf car transportation plans. Previous decisions in some communities relied on simply anecdotal evidence and testimony.

The data from the testing supports the implementation of rules and regulations requiring seat belts in LSV's and golf cars which are to be utilized on roadways by the general public, regardless of whether or not their top speed is less than 20 mph. The potential for ejection is significantly higher for an unbelted occupant during a cornering maneuver as opposed to a rollover event, even for vehicles with a maximum speed of only 11 mph. The potential for a rollover event decreases at the lower speeds, thereby significantly decreasing the theoretically detrimental effects that a belted could present over an unbelted occupant. The theory that an occupant is better off jumping from a moving cart on a roadway is simply speculation and fails to consider, among other factors, the age and health of the occupants. Observations made from the J-turn tests demonstrate how ineffective the hip restraints become to an unbelted occupant due in part to the forward migration of the occupant resulting from the longitudinal accelerations occurring during the turns. The high slip angle on the front wheels not only produce high lateral accelerations but also significant longitudinal accelerations. During this forward migration the high lateral accelerations tend to pull the occupant up and over the hip restraint which acts as tripping mechanism. This trip orients the ejected occupant into a head first dive into the ground as shown in Figures 8 and 9. The ejection process

Figure 8 – Ejected occupant kinematics resulting from the J-turn maneuver during test 1_5

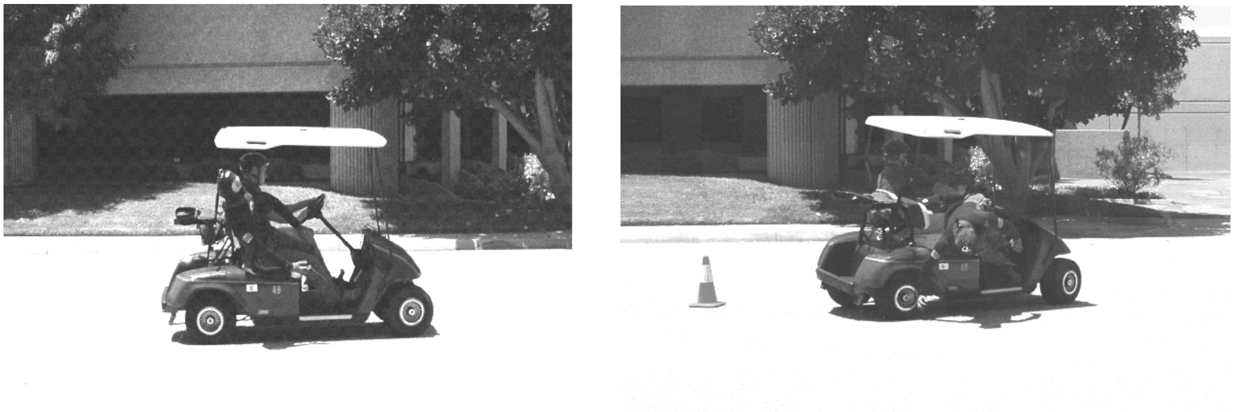

Figure 9 – Ejected occupant kinematics resulting from the J-turn maneuver during test 4_5

occurred rapidly with the time from initiation of the turn to the ejected occupant contacting the ground averaging between approximately one and two seconds. Thus, an unanticipated turn presents little time for an occupant to brace themselves prior to ejection. Additionally, in the case of vehicles that have rear facing seating positions, the exposure to an unanticipated turn and therefore ejection is significantly increased. It should be noted that during the J-turn steer inputs the driver of the vehicle noted little difficulty controlling the vehicle during the entire duration of the turn. It should be also be noted that the lower speed vehicles have a significantly lower tendency to roll over and in fact if the vehicle did roll the energy dissipated getting the vehicle to the roll position would likely only produce a ¼ roll. This scenario would limit the protection offered by a ROPS. Furthermore, a rollover event presents a scenario in which an occupant is likely to be injured, potentially seriously, regardless of whether they are belted or not belted in the vehicle. The theory that injuries will be mitigated by allowing the occupants to jump from a moving LSV or golf car during a rollover, thereby justifying the lack of belts, cannot be supported by this research.

REFERENCES

[1] National Highway Traffic Administration, 49 CFR Part 571, Docket No. 96-65; Notice 2.

[2] National Highway Traffic Administration, 49 CFR Part 571, Docket No. 98-3949

[3] ANSI/NGCMA Z130.1-1993, "American National Standard for Golf Cars – Safety and Performance Requirements"

[4] SAE J2358, 2002-03, "Surface Vehicle Standard – Low Speed Vehicles"

[5] Passoro K., Cole T., Morris P., Mathews D., MacKenzie W., 1996. "Golf Cart Related Injuries in a North Carolina Island Community, 1992-4", Injury Prevention

[6] Elias J., 1998. "Inspection and Testing of Low Speed Vehicles" NHTSA Report No. VRTC-83-0461.

APPENDIX A

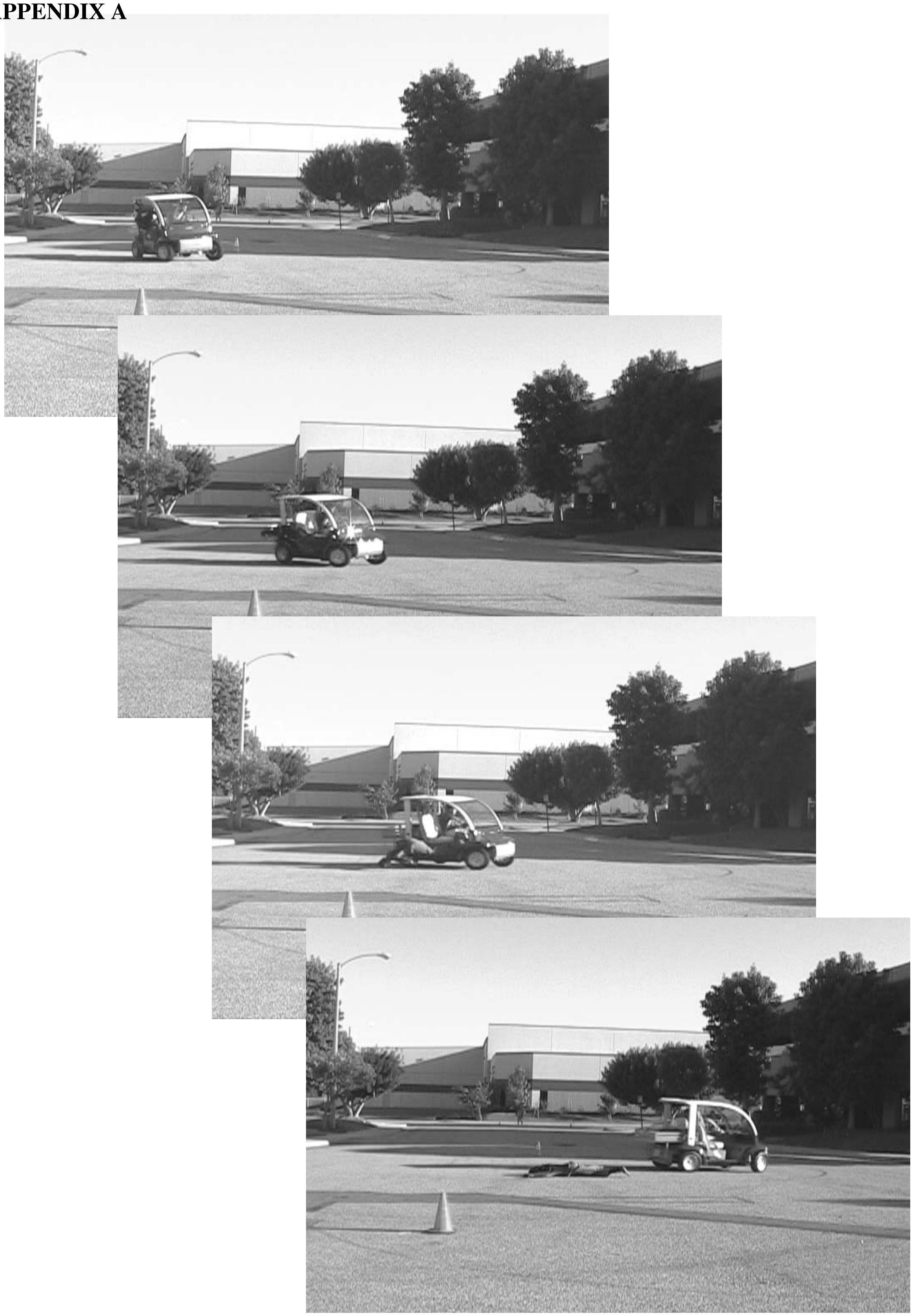

Figure A1 – Test 1_5 ejection of unbelted occupant during J-Turn maneuver

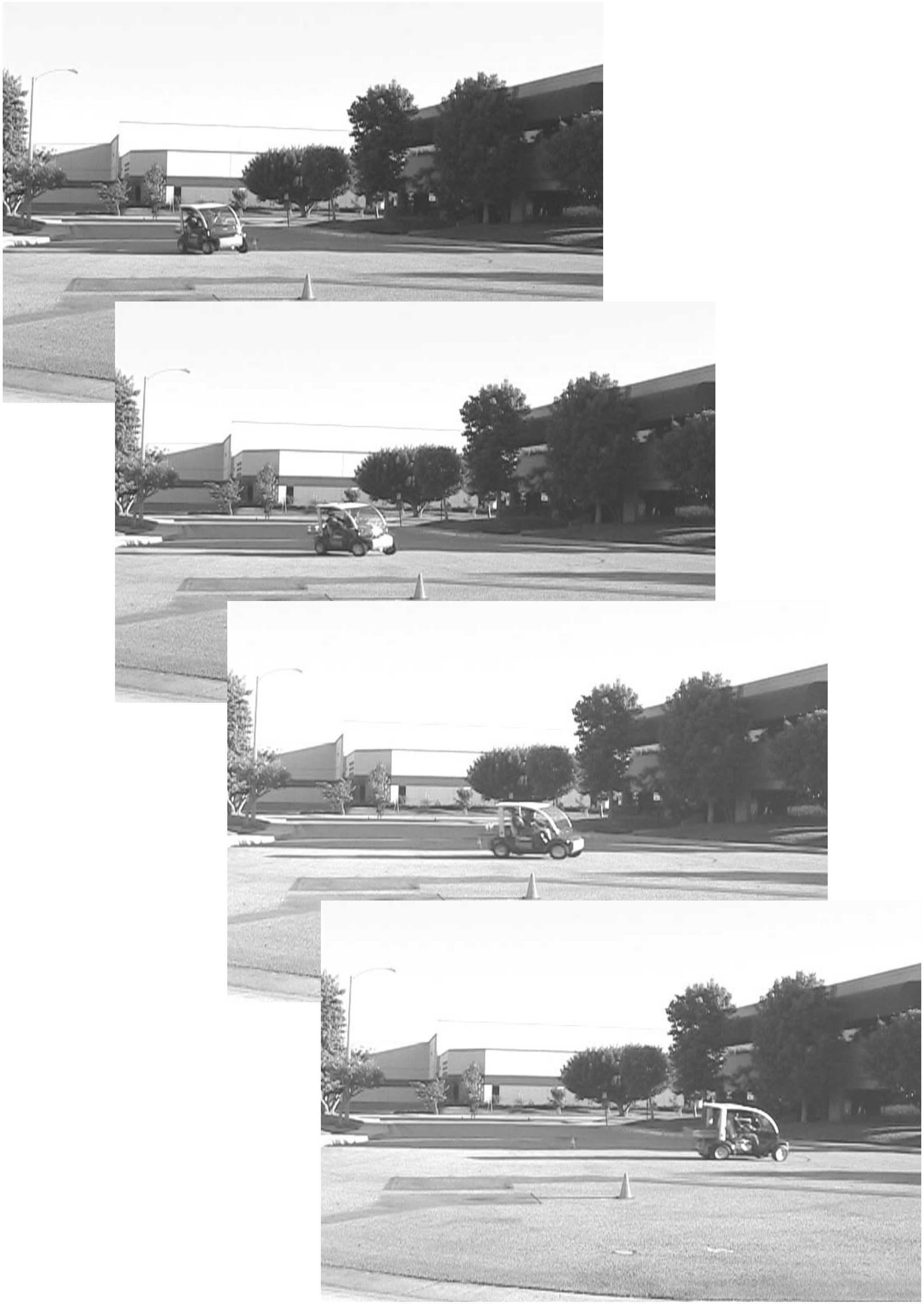

Figure A2 - Test 1_6 retention of belted occupant during J-Turn maneuver

Figure A3 – Test 2_3 ejection of unbelted occupant during J-Turn maneuver

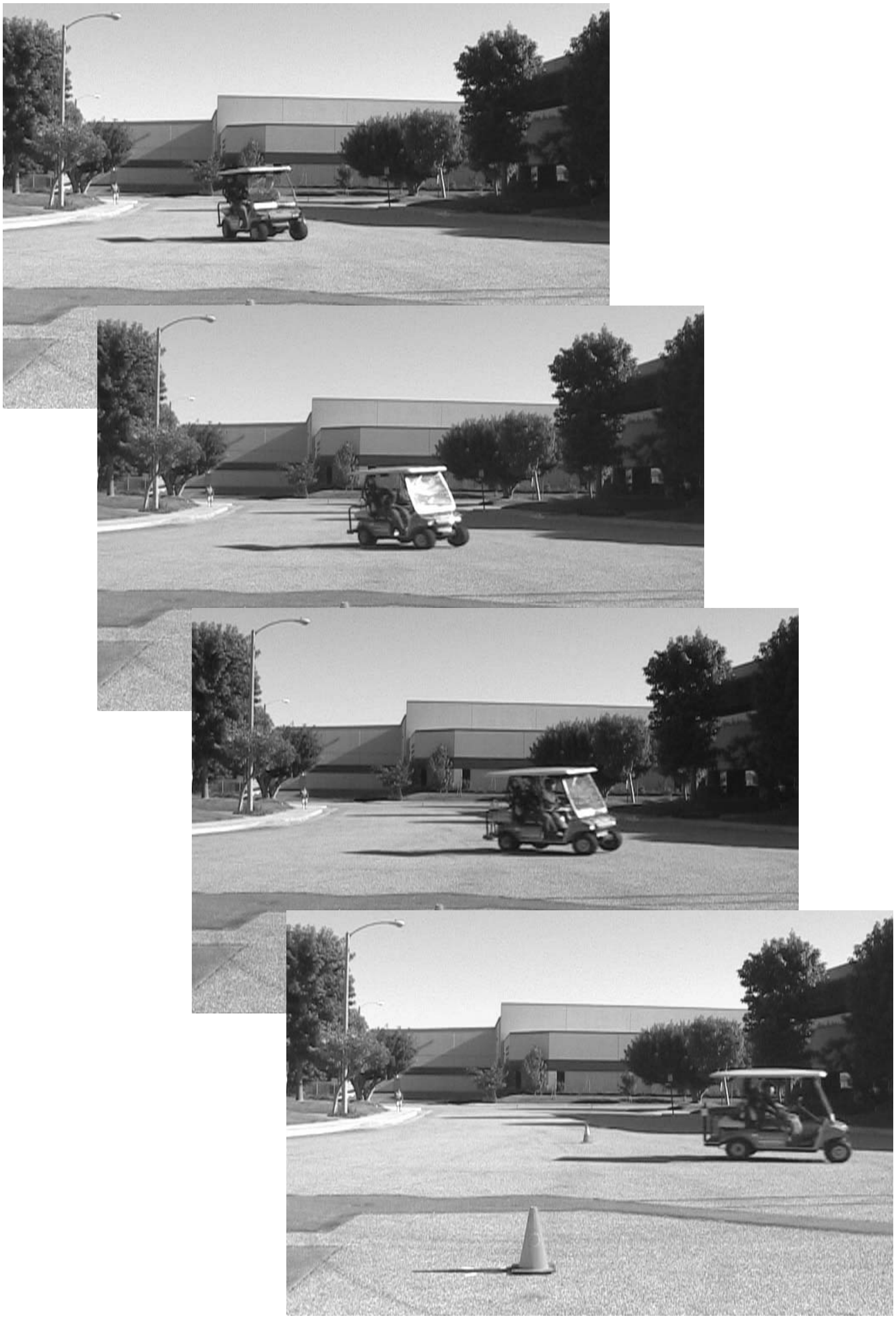

Figure A4 – Test 2_4 retention of belted occupant during J-Turn Maneuver

Figure A5 – Test 3_3 ejection of unbelted occupant during J-Turn maneuver

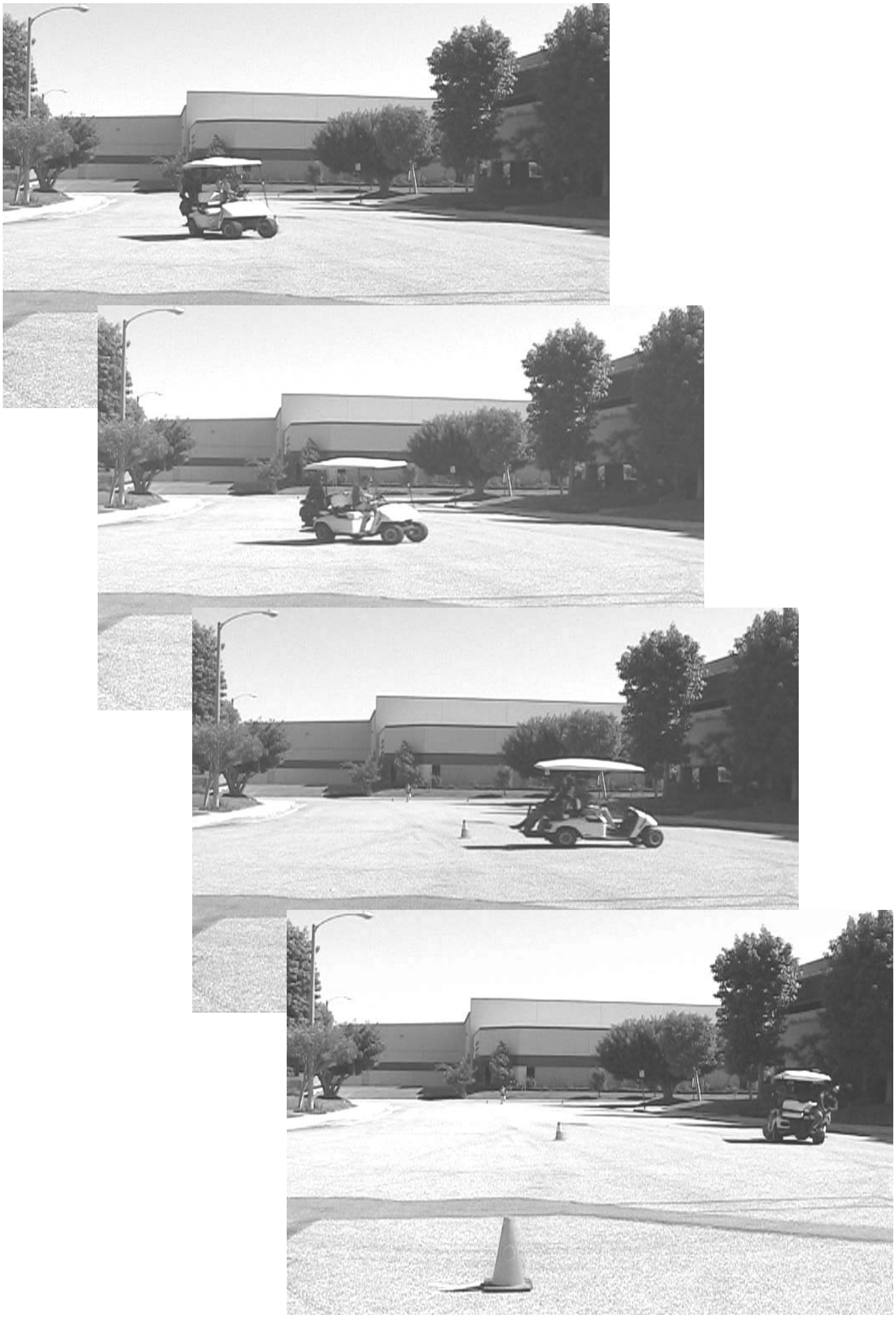

Figure A6 – Test 3_4 retention of belted occupant during J-Turn Maneuver

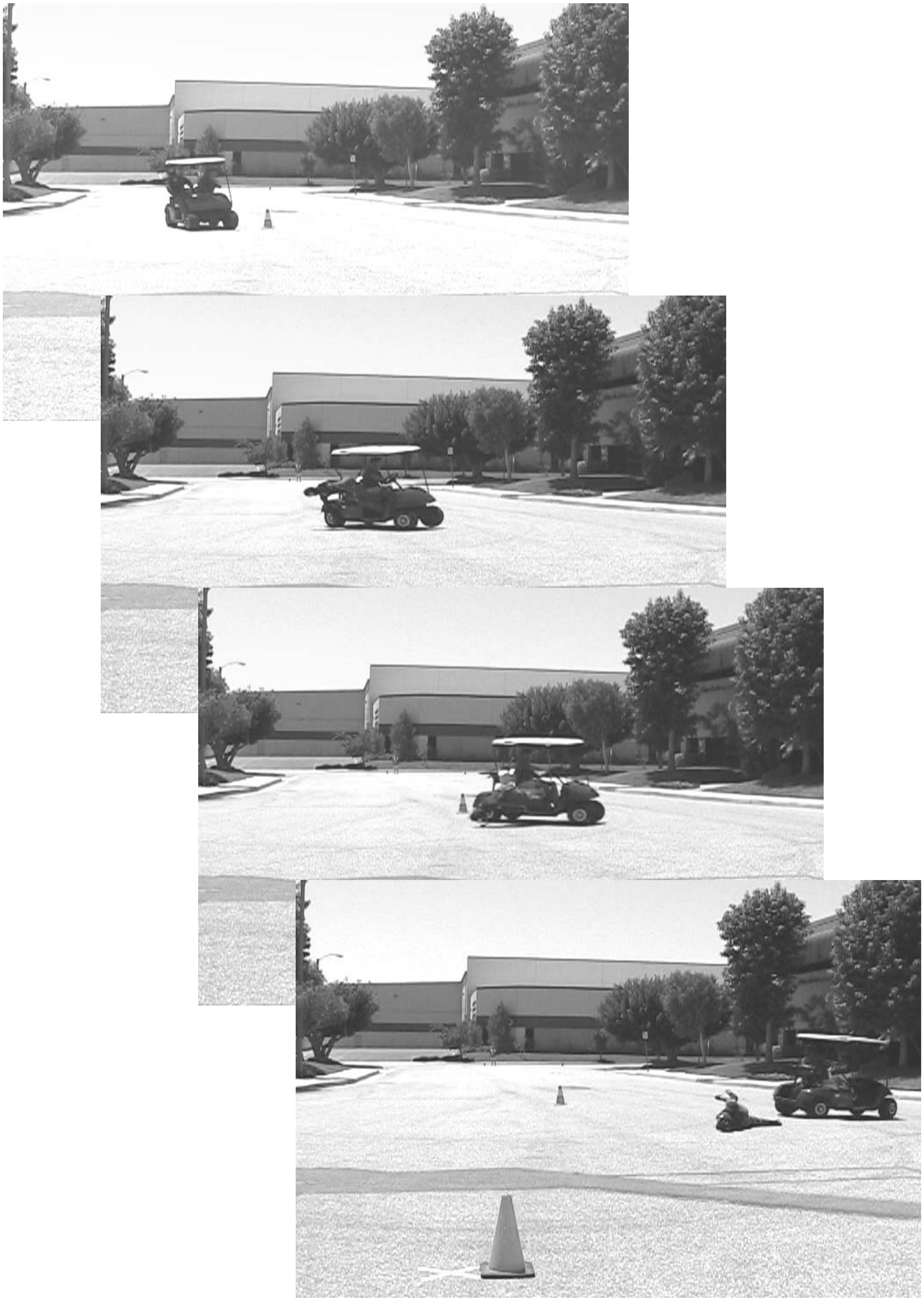

Figure A7 – Test 4_5 ejection of unbelted occupant during J-Turn Maneuver

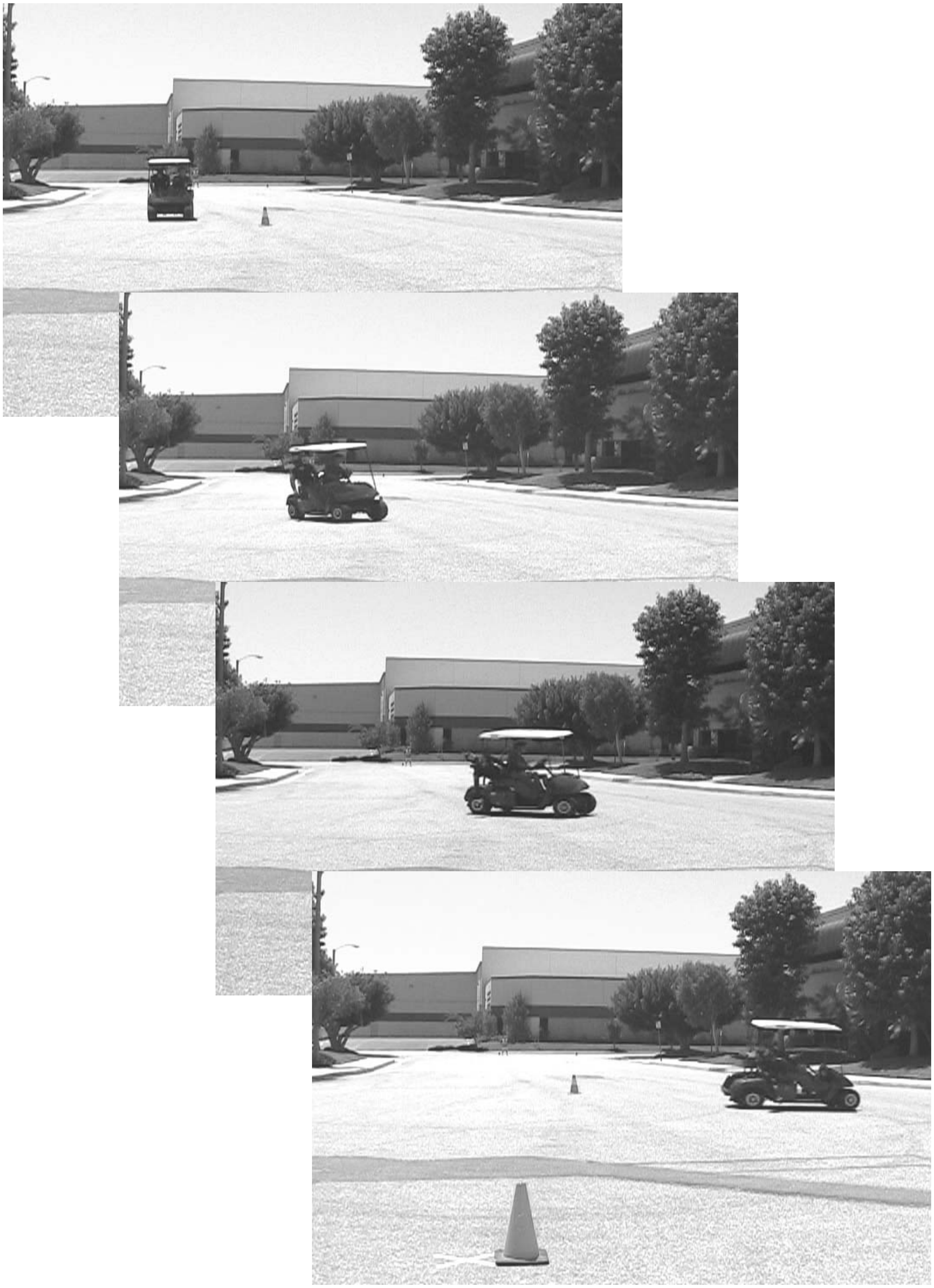

Figure A8 – 4_6 retention of belted occupant during J-Turn Maneuver