

Engineering Report

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Analysis of New Rear Gate Design for Shopping Cart

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Abstract

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Dr. Joseph Russell has designed a new rear gate and child seat assembly for a shopping cart. The new design places the child substantially lower in the cart basket than previous designs. Testing and analysis revealed that this new cart/seat design provides several important safety benefits. The risk of a rear tip-over is lessened, as the child's center of gravity is lowered and moved forward, thus requiring increased torque to flip the cart. The child is positioned lower in the shopping cart, so that if an accidental fall from the seat occurred, it would commence from a lower height. The fall would thus cause less injury, on average. The sides of the shopping cart basket extend higher relative to a child's standing height, so accidental falls from the seat area are less likely if a child were to stand on the seat base. The child's ability to reach to the side is lessened, so side pull-overs of shopping carts are less likely to occur. Potential injury to extended arms or hands, and potential damaged merchandise resulting from a child accessing items located on the store shelves by reaching over the cart side are also less likely to occur.

Introduction

Dr. Joseph Russell has designed a new rear gate for a shopping cart. Dr. Russell is a practicing, board-certified pediatrician from Frankfort, IL. He has treated numerous injuries from accidents involving shopping carts and has spent eight years studying the problem and redesigning the rear gate.

The main feature of this reconfigured rear gate is that the child seat is placed significantly lower within the shopping cart basket while allowing carts of like design to nest with each other. A prototype of this cart/seat design has been constructed, using a standard cart in the market, with a newly created rear gate and child seat used to replace the standard gate/seat. The new rear gate has a collapsible seat design capable of being deployed in the lower portion of the basket.

Shopping Cart Injury Statistics

The Consumer Product Safety Commission (CPSC) tracks injury statistics related to a wide variety of consumer items. Through a series of hospitals that keep records for CPSC, known as NEISS (National Electronic Injury Surveillance System), CPSC is able to extrapolate injuries to the total U.S. population.

For shopping carts, the overall injury figures are large. The following figures are all CPSC estimates of injuries involving shopping carts that resulted in emergency room treatment [1].

Year	Total injuries	Concussions	Skull fractures	Head internal injuries	Femur fractures
2002	32,994	1,292	355	6,302	161
2001	34,744	1,033	323	6,503	224
2000	33,070	984	289	4,441	193
1997	34,102	1,455	338	4,070	183
1996	34,016	1,257	593	5,410	68
1995	36,458	1,338	372	4,762	120
1994	36,189	920	513	4,414	234
1991	33,956	803	472	4,794	129
1990	32,832	1,292	102	2,500	34

Shopping Cart Injury Patterns

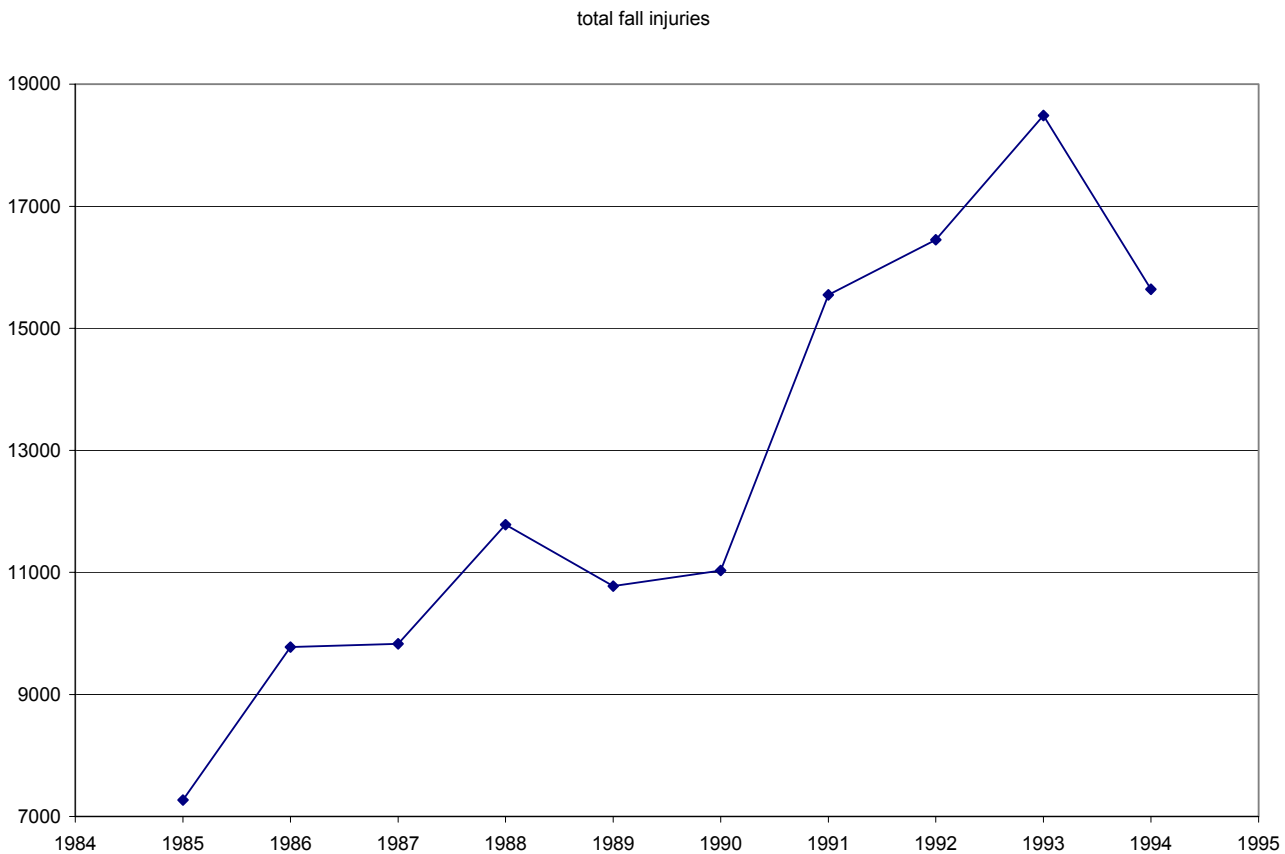
A minority of shopping cart injuries occurs from gross misuse of the product (i.e. children riding in the carts down stairways). However, the vast majority of shopping cart injuries occur within a retail store environment or in a store parking lot and a high number of them involve direct

parental supervision. In other words, at least one adult is often in very close proximity to the cart at the time of an accident.

CPSC describes several categories of shopping cart accidents. One category is falls from the basket, another is falls from the seat area. Other accidents involve rear tip-over of a shopping cart, side tip-over of a cart, contact with or running into a cart, or entrapment. Other injuries involve objects pulled from store shelves or those items already contained within the cart basket.

A detailed CPSC study on cart injuries from January 1, 1985 to June 6, 1994 [2] found the following: Falls out of carts accounted for 56% of injuries, contact with carts or running into carts was the cause of 19% of injuries, tipover was 8%, entrapment was 8% and other causes accounted for 9% of injuries. CPSC noted the rate of injuries per 1,000 children per year averaged 1.1 during that time period, for children five years of age and under. For falls from carts, the total injury rate per 1,000 children up to age five is 3.1. Hence, 3 children out of 1,000 riding in shopping carts of current design will require emergency room treatment for an injury related to a fall from a shopping cart prior to reaching five years of age.

The CPSC studied the shopping cart falls in-depth. They found that fall injuries were increasing from 1985 to 1994, even though the total injuries peaked and were decreasing. The plot above



depicts total injuries each year due to falls associated with shopping carts. The injury rate per 1,000 children from falls has continued to increase, so this effect is not just due to increasing population of children five years of age and younger.

CPSC performed telephone interviews of fall injuries from 1994 and 1995. CPSC found that 51% of the falls were from the seat area, and 49% were falls from the basket.

For falls from the seat area, 99% of the injuries were from falls inside a store, outside the store, or in the store parking lot. 91% of the time, the person pushing the cart was six feet or less away from the cart. 20% of the head injuries sustained were concussions.

According to CPSC, 83% of all head injuries treated in an emergency room in 1995 and 1996 that were associated with a shopping cart were from falls [5]. Said another way, 66% of all

shopping cart fall victims were treated for head injuries. 87% of serious head injuries were from a fall. These injuries include concussions, skull fractures and internal injuries of the brain parenchyma. In 1995 and 1996, these serious head injuries averaged 5,940 per year. Total head injuries from shopping cart falls averaged 11,000 per year in 1995 and 1996.

Applying the 51% figure to CPSC data from 1995 and 1996 one calculates 3,029 serious head injuries from seat area falls per year during those two years. This includes 572 concussions per year. Extrapolating those same percentages and applying them to the year 2002, one calculates 4,736 serious head injuries (including 564 concussions and 155 skull fractures) as the direct result of falls from the seat area. Despite preventative strategies currently in place (i.e. safety straps), a significant number of serious shopping cart injuries continue to occur.

Safety Improvements of New Rear Gate Design

Testing and analysis of the subject new gate/seat design show it makes a positive difference in several shopping cart injury scenarios. One scenario is rear tip-over. A second is falls from the seat area. A third scenario relates to injuries due to a child reaching out and over the side of the shopping cart basket.

Rear Tip-over Injuries

Testing and study of the new rear gate and seat design demonstrate it will have a significant impact in reducing the occurrence of rear tip-overs. The child's center of gravity is both lowered and moved forward in the cart with the improved redesign. The impact will vary depending on the cart design, however, since the rear gate on a shopping cart slopes toward the front of the cart, when the child seat is placed lower in the cart, it necessarily moves the child forward toward the nose of the cart. The effect of moving the child's center of gravity forward is a resultant increase in the amount of torque required to flip the cart over backwards.

There is a subsequent increase in downward force on the cart handle required to flip the cart. The larger force requirement will make the cart less likely to flip over.

At a typical gate angle of 73 degrees, lowering the seat base 6.75 inches will move the seat forward approximately 2 inches. Depending on shopping cart geometry, this can increase the required vertical force at the handle to flip the cart by approximately 10 to 15 pounds.

Increasing the force required at the rear handle for tip-over will reduce tip-over accidents.

Falls From Seat Area

Another injury scenario involves falls from the seat area. As previously indicated, the CPSC found that 51% of cart falls are from the seat area. Hence, falls from the seat area are clearly foreseeable. CPSC found that in each incident, either a safety belt had not been in use while the child was positioned in the child seat, or the child or parent had just removed the safety belt.

Study of the new seat design shows it significantly reduces the injury potential for falls from the seat area in two ways. Since the seat is in a lower position, if the child were to fall while standing on the seat base, the injuries and their severity will be lessened, on average. The new design will also reduce the quantity of falls from the seat area, since the basket sidewall rises higher relative to the standing height of the child. Essentially, the child is contained within the shopping cart.

The new rear gate design has the following dimensions from the seat base vertically upwards: to top of basket, 14-1/2 inches; to top of wire reinforcing for handle, 16-1/2 inches. The old rear gate design has the following measurements from the seat base vertically upwards: to top of basket, 7-3/4 inches; to top of wire reinforcing for handle, 9-3/4 inches. Another shopping cart owned by Ryan Engineering has a seat base to basket top height of 4-1/2 inches.

The new rear gate design provides almost a seven-inch increase in sidewall height relative to the seat area. The handle reinforcement wire on this cart covers most of the sidewall in the seat area.

The higher sidewalls in the seat area result in reduced potential for an accidental fall. As an example, a 50th percentile 24-month-old male has a height of 34.5 inches [3]. The center of gravity of this child would be 19.7 inches from the soles of his feet when standing [4]. The gate design currently in use (with the seat bottom located 7.75 inches from the basket top) would put the wire reinforcing about 28.3% of the child's height, or 49.5% of the center of gravity height. The previously described cart with a 4.5 inch deep seat has sidewalls that come up only 13% of the height of this child, and only 22.8% of the height of his center of gravity. The new gate design would put the reinforcing wire about 47.8% of child's height, or 83.8% of height of child's center of gravity.

Having the child's center of gravity lower than the cart sidewall makes it unlikely the child will fall over the side of the cart. Thus higher sidewalls (as attained by lowering the seat base) will result in a lower incidence of falls from the seat area.

The CPSC figures record large numbers of serious head injuries from seat area falls each year (e.g. 4,736 in 2002). Higher sidewalls in the seat area provided by the new cart/seat design will serve to enclose the child and thus reduce this number of serious head injuries.

Child Reaching Out Side of Cart

Some different injury scenarios involve a child located in the child seat reaching out and over the side of the shopping cart with resultant side-tipping of the cart. Injuries may also occur because a child reaches out and over the side of the cart, grabbing a retail or display object. There are no documented CPSC statistics on the prevalence of these two scenarios. However, it is certain that if the sidewalls in the seat area prevent a child from reaching out or over the

shopping cart footprint, thus substantially affecting the child's ability to reach, these injuries would also be significantly reduced.

Measurements of mid-shoulder sitting height on children [4] reveal the following (mid-shoulder height is the height from the seat base to the top of the child's shoulder while seated).

Age range in months	Sitting mid-shoulder height (inches) for 50 th percentile child, combined boys and girls
25 – 30	12.3
31 – 36	12.8
37 – 42	13.3
43 - 48	13.7

It is readily apparent that unless the shopping cart sidewalls reach a height of over 12 inches, they will not significantly impact a child reaching out and over the side of the cart. Since the new cart/seat design places the seat lower and has sidewalls over 14 inches high, it provides increased safety from a child reaching out. Once the cart sidewall rises above 14 inches, the 50th percentile child will have significantly more difficulty reaching out to the side.

Conclusion

The new rear gate and child seat design improves the overall safety of a shopping cart used to carry a child. Several safety benefits ensue from placing the child lower in the cart. The main benefit is lessening the occurrence and severity of accidental falls from the seat area. The new design substantially raises the sidewalls in the seat area. Thus, the sidewalls come up a significant portion of the height of a standing child's center of gravity, substantially reducing the likelihood of an accidental fall. Also, if a child does fall while standing on the seat, the fall occurs from a lesser height.

The lower seat location also moves the child forward in the cart, thus increasing the vertical force required at the handle to flip the cart over. The higher sidewalls also interfere with a seated child's ability to reach out from the cart, and thereby reduces the possibility for injury, damage to merchandise, or potential side tip-over of the cart.

References

[1] CPSC NEISS injury listings for 1990, 1991, 1994 - 1997, and 2000 – 2002.

[2] CPSC memo from Prowpit Adler to Barbara Jacobson, dated 11/18/94.

[3] Pediatric growth charts, Abbott Labs

[4] Physical Characteristics of Children and Related to Death and Injury for Consumer Product Design and Use, UM-HSRI-75-5 Final Report Contract FDA-72-70 May 1975.

[5] Shopping Cart Injuries: Victims 5 years old and younger, Consumer Product Safety Commission, Washington, D.C., www.cpsc.gov/LIBRARY/shopcart.html.

John S. Morse, Ph.D., PE October 20, 2004

Biographical sketch.

Dr. Morse is a senior engineer with Ryan Engineering in Siloam Springs, AR. He has a Ph.D. in mechanical engineering from Louisiana State University. He is a licensed professional engineer in four states. Dr. Morse has investigated numerous shopping cart accidents, including rear tip-overs, side tip-overs, and falls from the seat area and the basket area. He has appeared on three nationally televised newsmagazine shows discussing shopping cart safety, including Inside Edition, 20/20 and Extra.