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Strength and Stability Testing of High Chairs

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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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Accident reports from hospital emergency rooms were surveyed to determine the probable causes of accidents involving high chairs. Possible test methods for determining if the characteristics of the high chairs leading to the accidents are present in a given item were investigated, including the test methods recommended in the Juvenile Products Manufacturers Association Voluntary Safety Standard for High Chairs. These tests included tests for tray strength, chair static strength, foot rest strength, restraining strap strength, and stability. These test methods and performance characteristics are intended to supply information leading to federal safety standards.

Key Words: Accident reports; high chairs; infants; safety standards; stability and strength; test methods.

1.0 INTRODUCTION

Accident reports received through the National Electronic Injury Surveillance System (NEISS) at the Bureau of Product Safety (now part of the Consumer Product Safety Commission) listed many injuries to 8-24 month old children as a result of accidents involving high chairs. These injuries included mostly lacerations, contusions and abrasions, and a few fractures. The injuries resulted from a variety of causes, including finger lacerations in oversized tray adjustment holes, falls from the high chair, a child pulling the chair over onto himself from the floor, failure of folding mechanisms, and overall instability (chair tipped over with child in it). An investigation was undertaken at the National Bureau of Standards to determine what characteristics of the high chairs possibly contributed to injury producing accidents, to determine if these characteristics were present in most or only a few of the items on the market, and to determine appropriate test methods and performance characteristics which might be written into federal safety standards. Tests performed included tests for tray strength, chair static strength, foot rest strength, restraining strap strength, and stability. In addition, some dimensional measurements important to the safety of the high chairs were taken. Some tests were variations of the tests recommended in the Voluntary Safety Standard for High Chairs sponsored by the Juvenile Products Manufacturers Association (JPMA), draft dated October 17, 1972. These tests are presented in the Appendix.

2.0 TEST SPECIMENS

Nine high chairs were purchased from local retail stores. These included both tubular frame and wooden chairs, some folding and some non-folding. These nine covered the range of styles available during the period of this investigation. These chairs were designated as test specimen numbers 101 through 109 inclusive.

3.0 TEST PROGRAM

3.1 Falls From the Chair

Many injuries resulted from the child falling from the chair, although the specifics of the accident sequence are not known. One can envision four possible causes for these falls: 1) The tray and/or restraining strap were not used or improperly adjusted, allowing the child to slide out or stand and fall, 2) Although the tray was properly latched, too much clearance between the tray and the seat back allowed the child to stand if not strapped in, 3) The tray latch mechanism failed and 4) The restraining strap failed. The solution for the first case is to educate the parents about the importance of proper usage, either through government publications or manufacturers' instruction manuals. The second case is a human engineering design problem that must be considered. The tray must be capable of being positioned so as to prevent the child from standing. Table 1 shows the tray-to-seat back clearance with the tray adjusted to the tightest position for nine high chairs. Possibly the human factors experts can determine if these distances are acceptable in proportion to the sizes of infants who use the chairs. The third case involves a structural design requirement. The tray latch mechanism must be capable of withstanding the forces exerted on it by the child. Child strength data gathered by Brown et al (ref. 1) at NBS indicate that the 95 percentile push force applied by a 2 year old male is about 23.5 lbf (104 N). The forces exerted by a child in a high chair may be higher since the child can brace himself against the chair back. Test 2A in the JPMA standard requires that the tray withstand a 20 lbf (89 N) horizontal force applied at the front center and side center. All nine high chairs, when tested as shown in fig. 1, met these requirements. They also passed the same test with a test load of 50 lbf (22 N). All chairs also passed test 2B of the JPMA standard, which requires the chairs to withstand 20 lbf (89) vertical forces applied independently at the front and back center of the tray (fig. 2). These tests were repeated with a test load of 50 lbf (222 N) and all chairs passed except specimen number 102, which failed by uncoupling of the tray latch mechanism when the force was applied to the front center. Two additional tests related to the mechanical integrity of the tray, a drop test and a static load test (JPMA test numbers 3 and 4.3) were performed. The tray from specimen number 104, a wooden chair, broke into two pieces when dropped. All others passed this test. All chairs passed the tray static load test (fig. 3) when 50 lbf (222 N) was applied, but specimen number 102 failed when 100 lbf (445 N) was applied. All others passed with the higher load. The fourth case also involves a structural design requirement. The restraining strap must have sufficient strength to hold the child in the chair if the tray is not attached. Only five of the nine chairs tested were equipped with restraining straps (see table 1). These five were subjected to JPMA test number 6, with a test load of 22 lbf (98 N), and all passed (see fig. 5). With a test load of 50 lbf (222 N), specimen numbers 106 and 107 failed because the belt slipped more than 1 in (25 mm) in 30 seconds.

The results of all of these tests are summarized in table 2.

3.2 Stability

The JPMA test for stability (JPMA test number 5) concerns itself with the chair tipping over with the child in it, although the origin of the specific loads, e.g. 25 lbf (111 N) weight and 5.5 lbf (24 N) applied force, are not obvious. All nine chairs passed when subjected to this test (fig. 4, table 2). The forces tending to tip an occupied chair are external forces, such as from the child pushing or pulling on a table or counter, or inertial forces from the child's movements. No work was done in this investigation on the latter case since no human factors information on the forces generated by the movements of a child in a high chair could be found. However, some consideration can be given to the problem of a child pushing or pulling. The locations of the centers of gravity for five high chairs were determined. The weight of an average 2 year old child was taken to be 30 lb (14 kg) (ref. 2). For a 30 lb (14 kg) child seated in the center of the seat, the horizontal forces at tray height required to rotate the chair forward were calculated. These values ranged from 11.2 to 17.2 lbf (49.8 to 76.5 N). Similar values would be obtained for sideways rotation. Again referring to Brown's data (ref. 1), the 95 percentile pull strength of a 2 year old is about 38 lbf (169 N) which is well above the force required to rotate the high chairs tested in this investigation. Of course other factors must be considered, such as distances from the child to the counter. However, once it has been determined that the child could reach the counter, the forces a child could apply are much larger than those applied in the JPMA recommended test.

The problem of a child pulling the chair over onto himself is a difficult one. The moments required to tip over unoccupied chairs were calculated for five chairs. These values ranged from 66 to 176 lbf-in (7.5 to 19.9 N-m), with the higher values corresponding to the heavier chairs. Children in the 1-2 year old range can easily apply this moment to even the heavier chairs by grasping a leg brace and pulling or falling. Increasing this required moment could make the chairs impractically large and/or heavy. Some improvements in design that could lessen the frequency and severity of injuries are: 1) minimize the use of cross braces between legs that children can pull on or climb on, 2) minimize the chair weight to lessen the injury potential if the chair does fall, and 3) pad certain elements of the chair similar to what is now done on some playpens and porta-cribs.

3.3 Lacerations Related to Oversized Holes

The JPMA standard restricts hole diameters to less than 0.125 in (3.2 mm) or greater than 0.375 in (9.5 mm). Strangely, all six of the chairs that had tray adjustment holes failed this requirement with hole diameters being 0.19, 0.25, or 0.31 in (4.8, 6.4, and 7.9 mm).

3.4 Other Static Load Tests

All high chairs passed the seat and footrest static load tests in the JPMA standard (test numbers 4.1 and 4.2).

4. DISCUSSION

The performance of the nine chairs as determined by the JPMA tests and modified tests are summarized in table 2. The test configurations recommended by JPMA appear to be suitable for testing the overall static strengths of high chairs. However, based on a limited amount of data on the strengths of children, the test loads recommended by JPMA appear to be inadequate in several cases. The application of larger loads more consistant with the strengths of infants produced failures in a tray latch, a tray, and two restraining straps that had passed the JPMA tests.

The JPMA test for stability appears to have no relation to the push or pull strengths of infants. However, the human engineering aspect of occupied chair stability are very important and should be considered in any stability test. The problem of unoccupied stability can be eased somewhat with simple design changes.

The test methods described in the appendix, with increased load values determined by appropriate human factors studies could probably be used as a basis for writing a strong federal safety standard. Additional work in the areas of occupied stability, fatigue resistance, and abuse testing should also be considered.

5. CONCLUSIONS

The test configurations recommended by the JPMA Voluntary Safety Standard for High Chairs appear to be suitable for strength testing of high chairs. However, larger applied loads, more consistant with the limited available infant strength data, produced failures in four high chair elements that had passed the JPMA tests. Additional test methods for stability, fatigue resistance, and abuse testing should be developed.

6. REFERENCES

1. Brown, W. C., Buchanan, C. J., and Mandel, J.: A Study of the Strength Capability in the Two Through Six Year Old Age Groups. NBSIR 73-156 (1973).

2. Fryer, B., et al.: Growth of Pre-school Children in the North Central Region, J. Amer. Diet. Assn., 60: 30-37, 1972.

APPENDIX

TESTS IN JPMA STANDARD

TEST NO. 2A

Tray - Horizontal Force Test

Step 1. The chair is to be affixed securely (all legs on the floor) so it cannot move in the direction the force is being applied. Second, a pulley is affixed at a location in front of the chair at a height whereby a rope or cord passing over it is horizontal with the chair tray. Third, a pull scale capable of measuring at least 25 pounds of force is attached to the center front of the tray in such a way that it would not affect the natural shape of the tray when force is applied at that point. Next, a nylon cord is passed over the pulley and weight or force applied gradually to the end of the cord until the scale indicates 20 pounds for 30 seconds.

Step 2. Make a similar test under the same conditions as Test No. 2A but with the chair affixed in a position so that the horizontal force of 20 pounds is gradually applied perpendicular to the center of each side of the tray for 30 seconds each.

TEST NO. 2B

Tray - Vertical Force Test

Step 1. The chair is to be affixed securely in its normal standing position so that all legs stay in contact with the surface on which they rest. Second, a pulley is affixed in a location above the chair at a position so a nylon cord passing over it is perpendicular with the front center of the tray. Third, a scale capable of measuring at least 25 pounds of force is attached by one end to a nylon cord and the other in whatever manner possible to the front center of the tray in such a way that it would not affect the natural shape of the tray when force is applied. Now a vertical up force of 20 pounds is gradually applied by the means of pulling on the nylon cord for a period of 30 seconds.

Step 2. Perform the same test as Test No. 2B but with the chair positioned so that the 20 pound vertical force is gradually applied perpendicular to the rear center of the tray.

TEST NO. 4

Static Load Test

Step 1. Seat Test. The chair is placed in an upright position with all legs on the floor. Next, a total weight of 100 pounds will be placed on the center of the seat and be distributed over an area of 36 square inches upon a six-inch by six-inch wood block nominally one-inch thick. The load shall be applied for a 60-second period.

Step 2. Step or Footrest Test. The chair is placed in an upright position with all legs on the floor. If the step or footrest is adjustable, adjust to low position. Next, a total weight of at least 50 pounds will be placed on the center of the step or footrest and be distributed over an area of 18 square inches upon a three-inch by six-inch wood block nominally one-inch thick. The load shall be applied for a 60-second period.

Step 3. Tray Test. The chair is placed in an upright position with all legs on the floor. If tray is adjustable, adjust the tray to middle position.* Next, a total weight of at least 50 pounds will be placed at the center top surface of the tray distributed over an area of 18 square inches upon a three-inch by six-inch wood block nominally one-inch thick. The load shall be applied for a 60-second period.

TEST NO. 5

Stability

Step 1. The chair is placed in an upright position with all legs on the floor. The tray is attached, if adjustable, in middle position.* Then a weight of 50 pounds is centered on the seat upon a six-inch by six-inch wood block and affixed to the seat in such a way so that it will not tip in the direction of the force when the force is applied. Then an angle or bar will be placed on the floor against the legs or leg closest to the force in such a manner as to prevent the chair from sliding on the floor, but not to prevent it from tipping. Next the force will be applied horizontally with reference to the floor by pulling on the scale. The chair will be tested for stability in the following instances:

1. Front - Horizontal pull applied at center front edge of tray at the height of the tray.

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*Relates to trays that have an odd number of positions. If there is no middle position, then adjust to the next colsest position to the back.

2. Sides - Horizontal pull applied at the center of each of the arms at the height of the tray.

3. Rear - Horizontal pull applied at center of back at the height of the tray.

In all directions the force must equal or exceed 11 pounds without vertical displacement of more than one-fourth inch.

Step 2. Under the same conditions as Test No. 5 but with a 25 pound weight affixed to the seat instead of 50 pounds. In all directions the force must equal or exceed five and one-half pounds without vertical displacement of more than one-fourth inch.

TEST NO. 6

Restraining Strap Pull Test

The chair is to be affixed securely so it cannot move in the direction the force is being applied. Second, a pulley with a nylon cord is affixed in a position so that a nylon cord passed from the pull scale over it will be four inches above the top of the seat of the chair, and approximately in the center of its width. Third, a cylinder eight inches in diameter by eight inches in height is placed in the seat with the restraining strap placed across it in the engaged position. A nylon cord is attached to the cylinder above and below the safety strap and both ends attached to a pull scale capable of measuring at least 25 pounds of force. The other end of the scale shall be attached to the nylon cord that passes over the pulley. Now a force of 22 pounds is gradually applied to the cylinder by means of pulling on the nylon cord. The force shall be applied for a 30 second period.

Table 1 - Tray-to-seat back clearance with tray adjusted to the tightest position.

Specimen number	Clearance		Restraining strap
	in	cm	
101	4.75	12.1	No
102	5.88	12.9	Yes
103	8.00	20.3	No
104	5.00	12.7	No
105	7.50	19.0	Yes
106	4.75	12.1	Yes
107	4.75	12.1	Yes
108	4.75	12.1	Yes
109	8.75	22.2	No

Table 2 – Performance of Nine High Chairs Subjected to Various Safety Tests

Specimen Number	Tray horizontal strength		Tray vertical strength		Tray drop test	Tray static load test		Hole size	Seat static load	Footrest static load	Stability	Restraining strap strength test	
	JPMA 2A	Modified (a)	JPMA 2B	Modified (a)	JPMA 3	JPMA 4.3	Modified (b)	JPMA	JPMA 4.1	JPMA 4.2	JPMA 5	JPMA 6	Modified (c)
101	P	P	P	P	P	P	P	F	P	P	P	NA	NA
102	P	P	P	F	P	P	F	NA	P	P	P	P	P
103	P	P	P	P	P	P	P	NA	P	P	P	NA	NA
104	P	P	P	P	F	P	P	F	P	P	P	NA	NA
105	P	P	P	P	P	P	P	F	P	P	P	P	P
106	P	P	P	P	P	P	P	F	P	P	P	P	F
107	P	P	P	P	P	P	P	F	P	P	P	P	F
108	P	P	P	P	P	P	P	F	P	P	P	P	P
109	P	P	P	P	P	P	P	NA	P	P	P	NA	NA

P – Pass
F – Fail
NA – Not applicable

(a) 50 lbf (222 N) test load applied instead of 20 lbf (89 N) as recommended by JPMA.
(b) 100 lbf (445 N) test load applied instead of 50 lbf (222 N) as recommended by JPMA.
(c) 50 lbf (222 N) test load applied instead of 22 lbf (98 N) as recommended by JPMA.

Figure 1 - High chair tray horizontal strength test.

Figure 2 - High chair tray vertical strength test.

Figure 3 - High chair tray static load test.

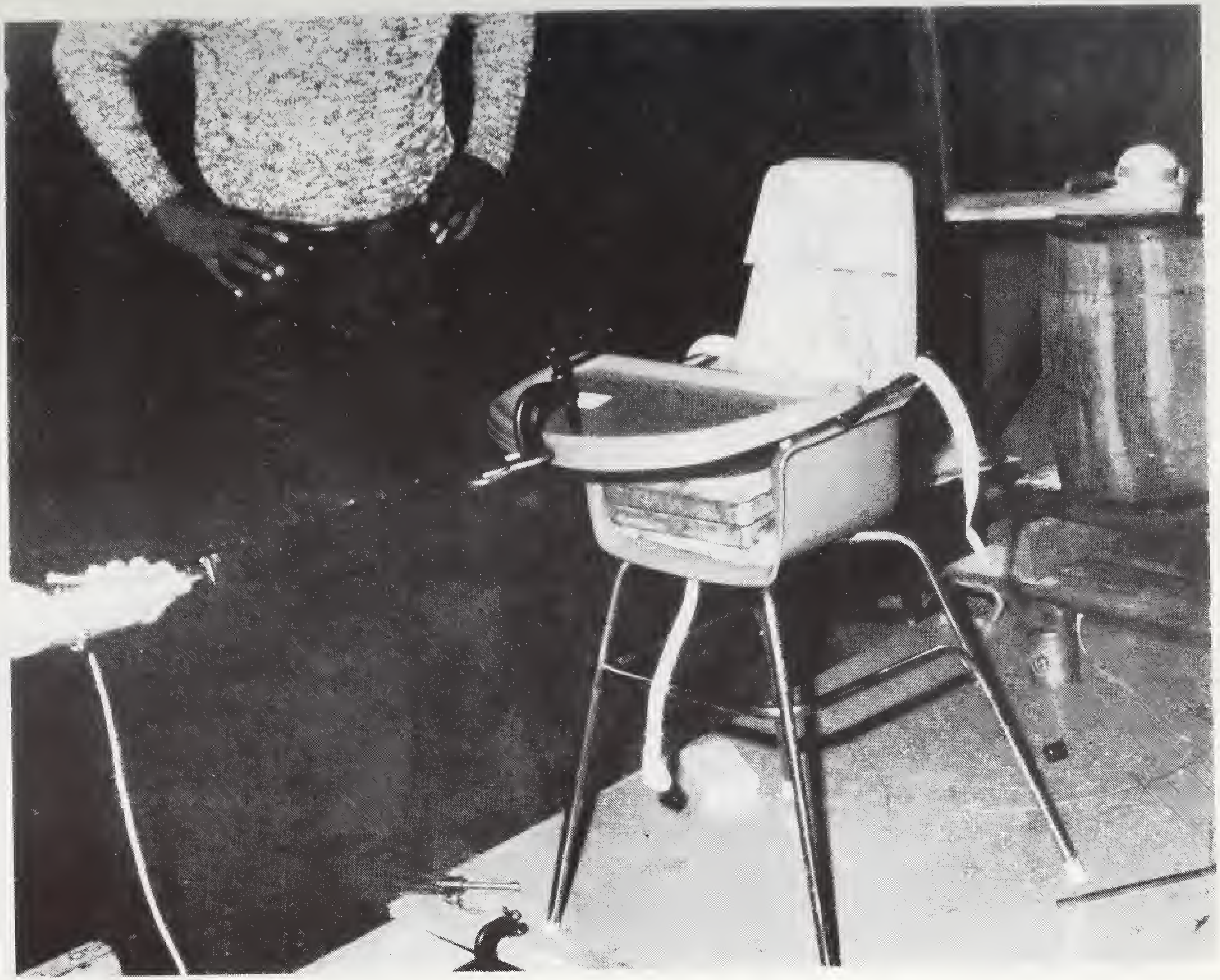

Figure 4 - High chair stability test.

Figure 5 - High chair restraining strap pull test.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Accident reports from hospital emergency rooms were surveyed to determine the probable causes of accidents involving high chairs. Possible test methods for determining the characteristics of the high chairs leading to the accidents were investigated, including the test methods recommended in the Juvenile Products Manufacturers Association Voluntary Safety Standard for High Chairs. These tests included tests for tray strength, chair static strength, foot rest strength, restraining strap strength, and stability. These test methods and performance characteristics are intended to supply information leading to federal safety standards.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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