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Evaluation of the CAPP Cart[1]

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RECENT studies of juvenile amputees in the United States and Canada have revealed a sizable number of severely handicapped limb-deficient children. Fortunately, many of these amputees have been fitted with prostheses that enable them to perform skills necessary for daily activities. The quadrimembral amputee, however, presents particularly serious problems. While he may achieve considerable arm function with one or two upper-limb devices, the leg loss may not be adequately compensated for, especially in high-level amputees, and locomotion remains at best an exercise. In an effort to solve the problem of mobility for the most severely handicapped children, the Child Amputee Prosthetics Project at UCLA developed an electric cart. This article presents a study that was designed to determine the extent to which the CAPP cart assists children with quadrimembral deficiencies to achieve independent mobility.

The CAPP cart (fig. 1) is 17 in. wide and 23 in. long, and consists of a seat mounted on a chassis. In the driving position, the seat is 18 in. from the floor. The seat can be raised to 27 in. to enable the child to sit at a table or to transfer to a standard chair or bed. The cart, powered by a 12-volt battery, travels at a constant speed of I 1/2 mph. It is guided by a lever that is controlled by the chin, and which operates on a "joy-stick" principle. The control arm can be swung to the side to facilitate transfer or activities at a table or desk.

SAMPLE

Since the cart was designed for the child with quadrimembral deficiencies, priority consideration was given to such candidates. The children were selected on the basis of the number of limb deficiencies and the degree of limitation. Eleven children from ten clinics participated in the study (table 1). A twelfth child was provided with a cart (see Appendix) but not included in the sample, because this clinic already had two subjects represented in the study; additional data from the same reporters might have biased the study.

The sample included four boys and seven girls, six to fourteen years of age. Their weights ranged from 20 to 74 lb; the average weight was 30 lb. Trunk measurements were taken of each child from the bottom of the buttocks to the crown of the head. Sitting height averaged 25 in. and ranged from 20 to 32 in.

Table 2 shows the skeletal deficiencies and prosthetic fittings for the eleven children. Of the five children with bilateral proximal femoral focal deficiencies (PFFD), two had not been fitted with lower-limb prostheses. One child ambulated with a lateral-sway walker, one wore below-knee orthoses bilaterally, and one wore a "brace-prosthesis" on the left and a socket, pylon, and SACH-foot prosthesis on the right.

Four children had bilateral amelias. One wore hip-disarticulation prostheses with the knees locked, two used lateral-sway walkers, and the fourth child had not been fitted with any prostheses.

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One child had a very short below-knee stump on the right, and a knee disarticulation on the left; the last child had a fusion of the right knee and a left knee contracture. Neither had been fitted with prostheses.

Again referring to table 2, two children had bilateral upper-limb phocomelia, and neither had ever been fitted with arm prostheses.

Of the two children with bilateral amelia, one wore two conventional shoulder-disarticulation prostheses, and the other had been fitted unilaterally, alternating between an experimental Michigan feeder arm and a conventional shoulder-disarticulation prosthesis.

Of the four children with bilateral hemimelia, three wore conventional above-elbow prostheses, and the fourth was fitted bilaterally with elbow-disarticulation prostheses.

Three children had a combination of right amelia and left hemimelia. One wore a Michigan feeder arm on the left only, another wore a conventional shoulder-

Fig. 1. The CAPP cart. Power is provided by a 12-v battery; direction is controlled by the chin-operated lever.

TABLE 1. CHARACTERISTICS OF CHILDREN IN CAPP CART EVALUATION STUDY

Child and Clinic	Sex	Age (*yr*)	Weight (*lb*)	Trunk Height (*in*)	Associated Abnormalities
P. V. G., Washington, D.C.	M	8	52	24	Hearing loss; malocclusion
V. R., Los Angeles, Calif.	M	7	27	26	Hypoplastic mandible; sacral agenesis
C. N., Atlanta, Ga.	F	12	74	32	—
T. C., Memphis, Tenn.	M	8	38	27 3/8	—
S. A. M., Birmingham, Ala.	F	14	37	24 3/4	Scoliosis
M. O., West Orange, N.J.	F	7	26	22	Dislocated hips; scoliosis
T. B., Springfield, Mass.	M	10	30	22	Neuromuscular disorder; scoliosis
L. A., New York, N.Y.	F	7	29	22	—
J. S., Chicago, Ill.	F	12	64	30 1/2	High palate
A. R., Grand Rapids, Mich.	F	6	20	20	—
M. E., Grand Rapids, Mich.	F	7	30	24	Double vision

TABLE 2. SKELETAL DEFICIENCIES AND PROSTHETIC FITTINGS

Child	Upper Extremities		Lower Extremities	
	Skeletal Deficiency	Prosthetic Fitting	Skeletal Deficiency	Prosthetic Fitting
P. V. G.	Bilateral phocomelia	None	Bilateral PFFD	*R*, pylon with SACH foot; *L*, brace-prosthesis
V. R.	*R*, hemimelia; *L*, elbow disart.	Bilateral elbow-disart.	*R*, hemimelia; *L*, knee disart.	None
C. N.	Bilateral phocomelia	None	*R*, knee fusion; *L*, knee-flex. contract.	None
T. C.	Bilateral hemimelia	Bilateral standard above-elbow	Bilateral amelia	Bilateral hip-disart. with knee locks
S. A. M.	*R*, amelia; *L*, hemimelia	None	Bilateral amelia	None
M. O.	*R*, amelia; *L*, hemimelia	*R*, shoulder-disart.; *L*, above-elbow	Bilateral PFFD	None
T. B.	Bilateral amelia	*R*, none; *L*, MFA[a] and shoulder-disart.	Bilateral PFFD	Bilateral short leg braces
L. A.	Bilateral amelia	Bilateral shoulder-disart.	Bilateral PFFD	None
J. S.	Bilateral hemimelia	Bilateral above-elbow	Bilateral amelia	Bilateral hip-disart. without knee joints
A. R.	*R*, amelia; *L*, hemimelia	*R*, none; *L*, MFA[a]	Bilateral amelia	Lateral-sway walker
M. E.	Bilateral hemimelia	Bilateral above-elbow	Bilateral PFFD	Lateral-sway walker

[a] Michigan Feeder Arm.

disarticulation prosthesis on the amelic side and an above-elbow prosthesis contralateral[A], and the third had not been fitted with any prostheses.

Three of the children were scoliotic, and three had skeletal problems involving the mouth. One child had bilateral hip dislocations; another had sacral agenesis, with associated loss of muscular mass in the lower extremities and bowel and bladder incontinence. Other abnormalities included hearing and visual deficiencies, and one child had an unspecified neuromuscular disorder manifested by generalized weakness.

Five children alternated between the use of wheelchairs pushed by others or walked with their prostheses. Two children either were pushed in a wheelchair or carried by adults. Two were able to push themselves in regular wheelchairs, and one child used an electric wheelchair. One child used an adapted cart that had been constructed by his father.

Six children lived in homes with steps at the outside entrance. The families of five of the children had ramps built to accommodate the CAPP cart. The sixth child lived in a two-story house, but used the cart only at school. Five children lived in homes with no stairs either outside or inside the building.

All the children were of school age. Six attended special schools for the handicapped, and four attended regular classes in public schools. One child received private tutoring at home.

PROCEDURE

The study was conducted over a six-month period, with evaluations performed at the clinics on three occasions. The results were submitted to New York University. Each clinic was responsible for the routine maintenance of the cart, with major repairs or adjustment that required disassembly of the cart being referred to NYU.

The characteristics of each child, his physical and environmental conditions, and his prosthetic experience were recorded on the Selection Forms, which were returned to NYU.

A representative of the New York University research staff was present when each cart was delivered and described the study to the child, parents, and clinic team. The training instructions and evaluation forms were discussed with the clinic therapist, and the maintenance instructions with the parents and the prosthetist.

The child operated the cart under supervision until the clinic members felt that the child could drive it independently with safety. At the end of the training period, the therapist completed the Training Evaluation Form.

The child returned to the clinic after he had used the cart for three months. The therapist, in consultation with the child's parents, evaluated the cart in terms of design, safety factors, and function, and recorded the information on the appropriate form. A maintenance check was made, and any necessary repairs and adjustments were also recorded.

The child returned again to the clinic with the cart after six months. The clinic personnel recorded suggestions for improvements in the cart, the child was questioned as to his overall reactions to the cart, and all maintenance problems were recorded. The child's parents and teachers completed forms in which they described their reactions to the cart in terms of suggestions for cart modifications.

RESULTS

Ten of the eleven children who participated in the study preferred the CAPP cart to other modes of transportation. Their parents were equally enthusiastic about the cart. The child who ultimately rejected the cart had a personality problem from the beginning; a strong mutual dependence between the child and her father was threatened by the increased independence offered her by the CAPP cart.

The features of the cart that were most appreciated by both the parents and the children were the increased independence and mobility it provided. The main objection voiced by the parents was the weight of the cart. Table 3 lists the features the children and parents liked best and least about the cart.

OPERATIONAL SKILLS

As seen in table 4, most of the children learned to control the cart with relative ease. The average training time was 5 1/2 hours. The oldest child (14 years) learned to operate the cart in 1/2 hour, while the

TABLE 3. FEATURES OF CAPP CART LIKED BEST AND LEAST BY CHILDREN AND PARENTS

Features	Number	
	Children	Parents
Liked Best		
Increased independence	6	10
Adjustable seat	3	6
Increased speed	3	—
Appearance	1	2
Ease of operation	1	—
Reduction of fatigue	1	—
Less lifting and pushing	—	1
Liked Least		
Weight	—	9
Lack of "on-off" control	2	3
Slow speed	3	1
Frequent mechanical breakdowns	2	2
Insufficient ground clearance	—	3
Difficulty driving over uneven terrain	2	—
Chin control not centered	2	—
Use of prosthesis impeded by control arm	1	—
Cart "drift" toward the left	—	1
Lack of sufficient wheel traction	—	1
Erratic turning	—	1
Noise during seat elevation	—	1

youngest (6 years) required 14 hours of instruction.

Training items were divided into ' 'starting and stopping," "driving," and "turning". The children were asked to start and stop smoothly while driving forward and backward. Most of the children learned this with little difficulty; four learned with no formal training.

The driving test consisted of moving forward and backward in a straight line and on a diagonal, crossing doorsills, and changing direction on command. The children learned to ascend and descend inclines of 10 degrees, to avoid obstacles, and to drive through a "slalom" course.

Finally, the children were taught to turn the cart on its base, using a rear wheel as a pivot, 90 degrees forward and backward. Three children required no training to perform these tasks, and all of the children learned to perform all activities independently.

Two of the younger children began training programs using cars with six-volt batteries because the speed of the cart with the larger battery frightened them at first. After training, they found the cart too slow, and the original twelve-volt batteries were reinstalled.

Seven children considered driving backward the most difficult operation to learn. Other areas of difficulty mentioned by the subjects were the delicate control required in confined areas, and turning.

Three children lost their balance while learning to operate the cart. One child lost his balance while turning and driving backwards and two, when they changed directions rapidly on a level surface. However, none of them lost sufficient balance to fall from the cart during the training period.

Six children damaged property while learning to drive the cart: scraping walls, door frames, or furniture. One child scratched the family car; another, through continued reckless driving, endangered other persons who were in his way.

SAFETY

Five children wore safety belts while driving the cart.

One child fell from the cart while at school. She was not wearing a safety belt,

TABLE 4. MOST DIFFICULT MANEUVER AND TIME REQUIRED IN TRAINING

Child	Age (*yr*)	Training Time (*hr*)	Most Difficult Maneuver
P. V. G.	8	1	
V. R.	7	3½	Approaching object; driving through doorway
C. N.	12	6½	Driving on incline
T. C.	8	4	Backing
S. A. M.	14	½	Backing
M. O.	7	5	Approaching table; backing
T. B.	10	8	Turning
L. A.	7	5	Backing
J. S.	12	2	
A. R.	6	14	Backing
M. E.	7	3	Backing

TABLE 5. CAPP CART USAGE

Child	Age	Average School Day (%)	Average Nonschool Day (%)
P. V. G.	8	100	75
V. R.	7	0	10
C. N.	12	70	30
T. C.	8	100	100
S. A. M.	14	10	10
M. O.	7	50	0
T. B.	10	40	15
L. A.	7	2	2
J. S.	12	—	75
A. R.	6	80	—
M. E.	7	75	25

because it restricted her movements while in, and transferring in and out of, the cart. She had swung the control arm away while leaving the battery connected to the motor, and a classmate accidently touched the drive control, which sent the cart forward and caused the child to fall from the cart. Although the child was not injured, the episode dramatized the need for additional safety features.

EXTENT OF USE

Table 5 shows the extent of cart usage. On the average school day, four children were in the cart at least 75% of their waking hours, three children utilized it between 40 and 70% of the day, and four children less than 10% of the time.

On weekends, two children used the cart more than 75% of the time; two children, 25 to 30%; and seven children, less than 25% of the day.

In considering where the cart was used primarily, we found that four children used it both at home and at school; five, only in the home; and two, only at school. The principle reason for using the cart in only one location was its excessive weight, which made transportation difficult. Nine people commented on this problem. Those who used the cart only at home considered the danger of driving a cart with such sensitive controls too great to permit unsupervised use. Two clinics stated they were unable to rely on school personnel to provide daily care for the cart, such as charging and filling the battery and reporting breakdowns.

As shown in table 6, most children were independent in such activities as driving through a 24-inch doorway, entering and leaving an elevator, approaching objects, and adjusting the seat height. The children with upper-extremity amelia and phocomelia continued to require assistance for activities involving reaching, such as pushing elevator buttons and opening and closing cupboards and drawers.

The majority of the children were independent in transfer activities (table 7),

TABLE 6. PERFORMANCE OF CHILDREN ($N = 11$)

	Independent without Cart	Need Less Help in Cart	Independent in Cart	Totally Dependent
Drive through 24-in. doorway	3	1	7	0
Push elevator call button	1	2	4	4
Enter, turn in, leave automatic elevator[a]	2	2	5	1
Push button in elevator[a]	1	1	4	4
Approach table; adjust seat ht.	0	2	9	0
Play, write, eat at table	3	1	4	3
Approach toilet, sink, bathtub	1	2	5	3
Open cupboard; obtain object	0	1	4	6
Close cupboard	0	2	4	5
Open and close drawer	1	2	4	4
Get item from drawer	1	1	4	5

[a] One child not tested.

TABLE 7. EASE OF TRANSFER

	Children Independent with Cart	Easier for Assistant without Cart	Easier for Assistant with Cart	Not Tested
Cart to bed	6	0	4	1
To/from cart and toilet	4	3	3	1
Cart to car	3	4	3	1
Cart to schoolroom chair	4	2	4	1
Bed to cart	6	1	3	1
Car to cart	3	3	4	1
Schoolroom chair to cart	4	1	4	2

TABLE 8. ADVANTAGES AND DISADVANTAGES OF CAPP CART

Advantages	Clinics Reporting	Disadvantages	Clinics Reporting
Adjustable seat	7	Lack of "on-off" switch	5
Increased mobility	7	Insufficient ground clearance	4
Easy control	4	Nonmaneuverability in confined areas	2
Maneuverability	3	Inability to use prosthesis on same side as control arm	1
Movable control arm	2		
Stability	1		

e.g., cart to bed, toilet, or chair. The most troublesome transfer activities involved the toilet; presumably, these difficulties arose because of the narrowness of many bathroom doors and the lack of removable armrests on the cart.

After three months of use, most reporters noted a general improvement in driving and maneuvering skills.

ADVANTAGES AND DISADVANTAGES

Seven clinics reported that the greatest functional advantage of the cart was the adjustable seat (table 8). Other assets reported were the increased maneuverability, easy control, the movable control arm that facilitated transfers, and the stability of the cart. The greatest disadvantages were the lack of an "on-off" switch, and insufficient ground clearance.

Six children depended less on adult help while in the CAPP cart; four reported no change in the amount of adult help required; no information was available for the eleventh child. Nine parents reported that their children required less lifting; however, one child required more lifting. Before the arrival of the cart, this girl spent most of her time on the floor, where things had been built to accommodate her. Since she was unable to transfer in and out of the cart from the floor, she had to be lifted each time.

One child was unable to use his prosthesis while in the cart, because the control arm was on the same side and interfered with its use. Most of the children felt that the chin control was not the optimal control site, and they preferred to use their arm stumps. Two therapists suggested that, if the control arm were placed to the side, a child could control the cart more efficiently with his stump. One therapist objected to the chin control because she feared damage to the child's lower jaw while driving the cart over rough terrain, although there was no report that this occurred. It was suggested that, if the control arm were relocated, a child could maintain a more normal sitting posture and turn his head for driving, and the control arm would not hinder activities at a desk.

CART MAINTENANCE

The twelve-volt battery required recharging every 24 hours. The batteries normally were charged overnight, and none needed replacement during the test period. Filling the battery with water was a considerable problem for parents because of the small storage space in the cart, which made battery-removal difficult.

Most maintenance problems concerned the rear wheels and switches; five carts required wheel replacements. The rear wheels attach to the gear box and receive the power to drive the cart. Since they do not swivel as the front wheels do when the cart turns, a torque is applied. These wheels, which were commercially available as wheelchair casters, were not designed for this amount of force and broke as a consequence of the torque overload.

All the carts required replacement of the switches in the control mechanism. The original switches were not the model ordered, but, for reasons of expediency (low cost and commercial availability), they were installed in the carts. When it became apparent that these were unsatisfactory, they were replaced with the model originally ordered, and the problems were eliminated.

CONCLUSIONS

With one exception, all the children and their parents were very enthusiastic about the CAPP cart and preferred it to other modes of transportation. It provided increased independence to ten of eleven children with quadrimembral deficiencies.

Training did not present a problem, even for the youngest child; however, consideration should be given to introducing the very young or apprehensive child to the cart with a six-volt battery. Since the cart is very stable, most driving hazards arose because of recklessness or poor driving skills. Perhaps greater care should be directed toward predriving instructions, and the children should be given more opportunity to practice driving skills under supervision. It must be remembered, however, that children tend to be less responsible and less coordinated than adults, and more accidents are to be expected from them.

The CAPP cart afforded the children more independence in terms of mobility and endurance. Hemimelic children were able to perform many activities, such as opening and closing cupboards and drawers, as a result of the adjustable seat, which allowed them to approach objects more closely and normally.

DESIGN CONSIDERATIONS

Although a number of clinics suggested the inclusion of a seat belt, this would tend to restrict a child's independence if he were able to transfer in and out of the cart without assistance, since most arm amputees would be unable to manipulate the belt independently. Seat belts are readily available or easily devised, and the application of a belt might best be left to the discretion of the clinic or the child's parents. Another suggestion was the incorporation of an "on-off" switch that could be controlled by the child, or a switch that would automatically cut the power when the control arm is swung to the side.

Although the present velocity of the cart is satisfactory for forward maneuvers, it is clearly too fast for driving backwards or for delicate control. Consequently, consideration should be given to including a variable speed-control mechanism.

Although wheelchair casters are commercially available and relatively inexpensive, they are not designed to absorb the high torque forces that are applied to the rear wheels of the CAPP cart. Stronger drive wheels would probably have prevented many of the mechanical breakdowns that occurred. Consideration should also be given to including pneumatic tires, which provide greater traction and more comfort.

Since most of the children preferred to control the cart with their arm stumps, consideration should be given to placing the control arm to one side, close to the shoulder or stump. This would also avoid interference with use of an upper-limb prosthesis. A second possibility, particularly for the upper-limb amelic child, is to lower the control arm to the level of the chair seat, which would allow the child to control the cart with his foot or leg stump while enabling him to sit straight and to turn his head freely.

Note: As a result of the findings of the evaluation study, a new control box was developed that incorporates a variable-speed mechanism, and an "on-off" switch that can be controlled by the child. All carts have been recalled to UCLA, where a detailed analysis is also being conducted of the effect of use on the mechanical segments of the cart. The new control mechanism and a set of stronger wheels have been installed, and the carts were returned to the children for continued use. Each clinic will provide any further training required to operate the cart with the new control system. After six to eight weeks of additional use by the child, the clinic and the children will be asked to record their reactions to the modified cart.

RECOMMENDATION

On the basis of the results of the clinical evaluation of this item, and the design modifications implemented by the developer, it is recommended that the C APP cart be made available to all limb-deficient children for whom conventional methods of transportation are unsatisfactory.

APPENDIX

J. T. was an eight-year-old girl with bilateral upper-limb amelia and lower-limb terminal-transverse hemimelia (A/K type). Initially, the control arm on the cart was lowered to the seat level to allow her to operate it with her leg stump. She did not wear lower-extremity prostheses while she was in the cart.

This child learned to operate the cart in approximately 2 1/2 hours; driving backwards and turning were the most difficult tasks for her to learn. As with the other amelic children, she was able to move about independently, but she continued to be totally dependent in activities involving the arms.

She used the cart for the entire school day, but she did not use it at home because her parents found that its weight made transporting the cart very difficult.

Both the child and her parents found that the cart was too slow for her to keep up with the other children. The child's other reactions were similar to those of the other children; that is, she liked the adjustable seat and the increased independence, but disliked the lack of an "on-off" switch and of sufficient ground clearance. Her teacher reported that the cart often became stuck in the school yard because of insufficient clearance.