The effect of upper extremity weight bearing on upper extremity function in children with hemiplegic type of cerebral palsy

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ABSTRACT: *The main objective of this study was to quantify the effects of weight bearing on upper limb function in children with hemiplegic cerebral palsy. This study also sought to monitor the change in spasticity immediately following weight bearing exercises. A quasi-experimental, one group pre-test, post-test design was used. Eleven children with hemiplegic type of cerebral palsy from a special school in KwaZulu Natal participated after fully informed consent of the caretaking guardian. The intervention consisted of a standardized program of weight bearing. The Melbourne Assessment of Upper Extremity function was used to quantify upper extremity function of reach, grasp and manipulation and the modified Ashworth grading of spasticity was used to grade and monitor spasticity. The data was analysed using the Wilcoxon signed rank test. A significant decrease in spasticity during elbow extension (p= 0,004), wrist flexion (p=0,026) and extension (p=0,004) was noted. Statistically significant improvement in function, reach (p=0, 00), grasp (p=0, 02) manipulation (p=0, 05) and overall quality of function (p= 0,003) was also found. An overall significant effect of weight bearing exercises on upper extremity function was noted providing evidence for practice.*

KEYWORDS: CEREBRAL PALSY, REACH, GRASP, MANIPULATION, MELBOURNE ASSESSMENT.

INTRODUCTION

Weight bearing exercises have been used as a part of neurodevelopmental therapy (Chad et al 1999) and constraint induced movement therapy (De Luca et al 2003) to retrain upper extremity function in children and adults with neurological dysfunction. Erhardt (1974), Irwin-Carruthers (1982), and Boehme (1988) described extensively the significant role of weight bearing in developing upper extremity function and fine hand control. However, the evidence for the effectiveness of weight bearing exercises on the quality of upper limb motor function is to a large extent anecdotal rather than empirical. This is largely due to the fact that available tools such as the Bayley Motor Scales, the Jebsen-Taylor Test of Hand Function (Taylor et al 1973) and the Peabody Fine Motor Scale (Folio and Fewell 1983) are either not standardized for the cerebral palsy population or do not quantify quality of movement. The Erhardt Developmental Prehension Assessment is also not quantifiable (Johnson et al 1994).

Although Chakerian and Larson (1993) quantified the effectiveness of weight bearing exercises on upper limb function, they did not focus on quantifying the quality of the function. Smelt (1989) and Kinghorn and Roberts (1996) investigated the effects of weight bearing splints on hand function. A reduction in tone and improvement in upper extremity function were observed but not quantified. Therefore, there is insufficient evidence that clinicians can readily use in day-to-day therapy. The purpose of this study was to quantify the effects of upper extremity weight bearing exercises on the quality of upper extremity function, namely reach, grasp and manipulation in children with hemiplegic cerebral palsy. In addition spasticity was also monitored due to its effects on function.

METHODS

Prior to data collection ethical approval was obtained from the Ethics committee of the University of KwaZulu Natal and the study was undertaken at a special school in Ethekweni, South Africa.

To control as many variables as possible, the population was restricted to children with hemiplegic cerebral palsy between the ages of 5 and 15. The children were selected based on cerebral palsy presentation (hemiplegic), age, the ability to follow instructions and willingness to participate in the study. Children were excluded if they were due to undergo any surgical intervention during the study period or underwent any surgical intervention a month prior to the study, due to receive Botox injection during or prior to the study, had uncontrolled epilepsy, began any medication that had an effect on the central nervous system, had any non-neural contractures or deformities in the upper extremity, had associated Attention Deficit hyperactive syndrome or had total cortico-visual impairment. To obtain

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a sufficiently large population who met the criteria, a list of all special schools catering for children with cerebral palsy in the province of KwaZulu Natal was obtained from the KwaZulu Natal Department of Education. Telephonic enquires with the principals of the schools led to the convenient choice of one school for the pilot study and one for the main study. The schools were chosen based on the availability of sufficient numbers of children who met the criteria for inclusion into the study. Convenient sampling was then used.

Eleven Black African (9 males and 2 females) children aged 8 to 15 years (mean =12.66 years) who met the inclusion criteria participated in the study with fully informed consent from the caretaker guardian, the principal of the school. The right side was affected in 9 children and the left side in 3 children. Five children presented with mild, three with moderate and four with severe afflictions (Bohannon and Smith 1987).

To quantify upper extremity function, the Melbourne Assessment of Unilateral Upper Extremity Skill Test ('Melbourne Assessment') was used (Randall et al 1999). The validity, inter- and intra-rater reliability of the Melbourne Assessment were confirmed by Johnson et al (1994) and Randall et al (2001). Prior to using the tool in South Africa a pilot study undertaken by the first author (Jayaraman and Puckree 2009) to determine the reliability showed a substantial inter-rater agreement and for the test-retest reliability the Kappa values of 0.82 signified an almost perfect agreement. The Modified Ashworth Scale was used to grade spasticity. Bohannon and Smith (1987) and Jan et al (2005) reported that the tool had a moderate to good reliability.

Intervention:

A program of weight bearing exercises was undertaken by each child 3 times a week, for 15 minutes each, for 12 weeks under the supervision of the researcher. The Melbourne assessment was applied pretest, during the intervention at intervals of 14 days and posttest after 12 weeks of the intervention. The Modified Ashworth grading of spasticity was done post intervention. To ensure reliability of the findings all the assessments were conducted by the researcher with the exception of the grading of spasticity, which was done by the Head physiotherapist. For the Melbourne assessments, each child was seated on a chair appropriate to his/her size to ensure that the feet rested on the ground. The tools for the subtests were placed on a marked position at a comfortable forearm distance from the midline, on a table adjusted to the chest level (below the nipple line) of each child to ensure easy access. The assessments were videotaped, according to guidelines in the instructional manual of the Melbourne Assessment (Randall et al 1999). Instructions were given to the child in English by the researcher and in Zulu with the help of an assistant. Each child was allowed a few test trials before each task was performed.

The program of weight bearing included prone lying and weight bearing on forearms over a prone wedge, on hands over a prone wedge, on forearms over a bolster, on hands over a bolster, on hands over a foam block, on hands when lying on an inclined plane and over a physiotherapy ball. The other weight bearing positions used in the intervention included quadruped, quadruped with one hand resting on a foam block and side sitting with weight bearing on one hand. Each position was demonstrated to each child and followed up with instructions and explanations, which were standardized. Each child had to maintain each position for 30 seconds. Data was analyzed with the help of a statistician and each child's pre-test measurements served as a control. The normalized data were pooled and subjected to descriptive and statistical analysis. The Wilcoxon Rank sum test was used to compare pre-test values with post-test values. The raw scores from the Melbourne assessment were converted to percentage scores, which were normalized (pretest values served as a control). Normalization was necessary to reduce variability, which is often large in this kind of patient population. The sum of the scores in the sub skills was calculated and taken to represent the quality of performance in each of the components of reach, grasp and manipulation. A two-tailed t-test was used to compare pre-test 1 values with pre-test 2 values.

RESULTS:

11 children completed the program. The demographic details of the participants are included in Table 1. The children ranged in age from 8 to 15 years, included 2 females and the majority suffered from mild hemiplegic cerebral palsy. Spasticity decreased significantly post-test compared to pre-test during elbow extension ($p=0.004$) and wrist flexion and extension ($p= 0.026$ and 0.004) respectively.

Table 1: Demographic details of the participants.

Child	Gender	Side Affected	Age	Severity of condition
A	Male	Right	14 yrs	Mild
B	Male	Right	12 yrs	Mild
C	Female	Right	14yrs	Mild
D	Female	Left	14yrs	Mild
E	Male	Right	13 yrs	Mild
F	Male	Left	9 yrs	Moderate
G	Male	Right	12yrs	Moderate
H	Male	Right	12 yrs	Moderate
I	Male	Right	12 yrs	Severe
J	Male	Right	15 yrs	Severe
K	Male	Left	15 yrs	Severe

Overall quality of upper limb movement: The percentage scores and the normalized data (with pretest 1 as the reference) of the overall quality of upper extremity function as measured by the Melbourne Assessment are given in Table 2. A comparison of pretest 1 values with assessment 7 shows that the quality of upper limb movement changed in all eleven children. A maximum change of 17% with a range of 2- 17% is noted. The post-test values in 10 children were better than that of the pre-test 1. The maximum change in function occurred after eight treatment sessions in one child, twenty treatment sessions in three children, twenty six treatment sessions in four children and after thirty three sessions in three children. The mean change in the quality of post-test upper extremity movement was significantly better than the pre-test values (8%); p= 0,003.

Reach

Table 3 gives the raw and normalized values for reach, as measured by the Melbourne assessment for each child. Maximum change in reach function was seen in child G who also showed the

Table 2: Overall quality of upper extremity function as per Melbourne Assessment. Normalized values in % (with pre-test 1 as reference; raw values in brackets) (n=11)

Child	Pr1	Pr2	As1	As2	As3	As4	As5	As6	As7	Po1
A	100 (75)	100 (75)	100 (75)	100 (75)	100 (75)	101 (76)	101 (76)	100 (75)	101 (76)	101 (76)
B	100 (78)	100 (78)	100(78)	100 (78)	100(78)	100 (78)	100 (78)	101(79)	101(79)	100 (78)
C	100(74)	101(75)	101(75)	102 (76)	101(75)	102 (76)	102 (76)	104 (77)	104 (77)	102(76)
D	100 (74)	101 (75)	100 (74)	101(75)	104 (77)	105 (78)	105 (78)	104 (77)	104 (77)	104 (77)
E	100(57)	91 (52)	103 (59)	105 (60)	110 (64)	107 (61)	108 (62)	108 (62)	108 (62)	108 (62)
F	100 (59)	100 (59)	106 (63)	108 (64)	108 (64)	111 (66)	115 (68)	113 (67)	115 (68)	115 (68)
G	100 (58)	98 (57)	113(66)	117 (68)	103 (60)	113 (66)	117 (68)	117 (68)	117 (68)	117 (68)
H	100 (61)	100 (61)	100 (61)	103 (63)	101 (62)	108 (66)	113(69)	113 (69)	109 (67)	113(69)
I	100 (49)	97 (48)	97(48)	100 (49)	102 (50)	102 (50)	102 (50)	104 (51)	104 (51)	104 (51)
J	100 (51)	100(51)	101(52)	111 (57)	111 (57)	111(57)	113 (58)	113 (58)	111 (57)	111 (57)
K	100 (50)	106(53)	108 (54)	112 (56)	110 (55)	110 (55)	110 (55)	112 (56)	112 (56)	112 (56)
Mean ± Sd	100±0	99,45 ±3,42	102,6 ±4,39	105,36 ±5,56	104,54 ±4,14	106,36 ±4,39	107,81 ±5,85	108,09 ±5,50	107,82 ±5,23	107,91 ±572
Cond Mean	99,7		106,00							107,91

Pr=pretest, As= measurements at 14 day intervals during intervention, Po=Posttest; Sd=standard deviation

Table 3: Quality of reach as per Melbourne Assessment. Normalized values in % (With pre-test 1 as reference; raw values in brackets)(n=11)

Child	Pr1	Pr2	As1	As2	As3	As4	As5	As6	As7	Po1
A	100 (33)	100(33)	100(33)	100(33)	100(33)	100(33)	100(33)	100(33)	103(34)	103(34)
B	100(33)	100(33)	100(33)	100(33)	100(33)	100(33)	100(33)	100(33)	100(33)	100(33)
C	100(31)	100 (31)	100(31)	103(32)	103(32)	103(32)	103(32)	103(32)	103(32)	103(32)
D	100(30)	97(29)	97(29)	97(29)	110(33)	110(33)	110(33)	110(33)	110(33)	110(33)
E	100(27)	96(26)	100(27)	100(27)	100(27)	96(26)	96(26)	96(26)	96(26)	96(26)
F	100(24)	100(24)	100(24)	95(23)	95(23)	104(25)	112(27)	108(26)	112(27)	112(27)
G	100(28)	100(28)	110(31)	114(32)	100(28)	103(29)	114(32)	114(32)	114(32)	114(32)
H	100 (29)	100(29)	100(29)	100(29)	100(29)	103(30)	106(31)	110(32)	110(32)	110(32)
I	100 (24)	100(24)	100(24)	100(24)	100(24)	100(24)	100(24)	104(25)	104(25)	104(25)
J	100(25)	100(25)	100(25)	100(25)	100(25)	100(25)	104(26)	104(26)	100(25)	100(25)
K	100(24)	100(24)	100(24)	104(25)	100(24)	100(24)	100(24)	104(25)	100(24)	100(24)
Mean ± Sd	100,00 ±0,00	99,273 ±1,54	100,55 ±3,20	101,.09 ±4,76	100,73 ±3,41	101,73 ±3,39	104,09 ±5,50	104,82 ±5,02	104,73 ±5,59	104,73 ±5,59
Cond mean	99,64						102,125			104,73

Pr=pretest, As= measurements at 14 day intervals during intervention, Po=Posttest; Sd=standard deviation

most change in the overall quality of upper limb movement. Three children had less than 5% change and the quality of reach improved by 10% or more in four children. Maximum change occurred after assessment 6, which was maintained up to the posttest. Post-test means were significantly greater than the pretest values (p= 0, 03).

Grasp

Table 4 shows that 6 children improved their ability to grasp. Child H had the maximum change in grasp followed by child F. Twenty five percent change in function was seen in one child and 50% change was seen in two children. A significant increase in grasp (29%) from baseline to post test (p= 0, 02) was noted.

Manipulation

The quality of manipulation changed in 5 children as shown in Table 5. The post- test mean was significantly higher than the pre test values (p=0, 05).

On an observational note, the accuracy with which the majority of the children released objects (crayon, pellet) improved. Target accuracy also improved

Table 4: Quality of grasp as measured by the Melbourne assessment: Normalized values in % (with pretest 1 as reference; and raw values in brackets) (n=11).

Child	Pr1	Pr2	As1	As2	As3	As4	As5	As6	As7	Po1
A	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)
B	100(5)	100(5)	100(5)	100(5)	120(6)	120(6)	100(5)	120(6)	120(6)	120(6)
C	100(4)	100(4)	100(4)	125(5)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)
D	100(5)	120(6)	100(5)	120(6)	120(6	120(6)	100(5)	100(5)	100(5)	100(5)
E	100(4)	50(2)	100(4)	125(5)	125(5)	125(5)	125(5)	125(5)	125(5)	125(5)
F	100(3)	100(3)	100(3)	166(5)	166(5)	166(5)	166(5)	166(5)	166(5)	166(5)
G	100(2)	100(2)	100(2)	150(3)	150(3)	100(2)	150(3)	150(3)	150(3)	150(3)
H	100(2)	100(2)	100(2)	200(4)	100(2)	150(3)	250(5)	250(5)	150(3)	250(5)
I	0(0)	0(0)	0(0)	0(0)	100(1)	100(1)	100(1)	100(1)	100(1)	100(1)
J	100(2)	100(2)	100(2)	150(3)	150(3)	150(3)	100(2)	100(2)	100(2)	100(2)
K	100(2)	100(2)	150(3)	100(2)	100(2)	100(2)	150(3)	100(2)	150(3)	150(3)
Mean ± Sd	100,00 ±28,74	97,00 ±32,14	105,00 ±33,40	133,60 ±48,50	121,00 ±23,21	117,36 ±26,05	129,18 ±46,23	124,.64 ±46,4	120,09 ±27,7	129,18 ±46,23
Cond mean	89,54						114,67			129,18

Pr=pretest, As= measurements at 14 day intervals during intervention, Po=Posttest; Sd=standard deviation

Table 5: Quality of manipulation as measured by the Melbourne assessment: Normalized values in % (with pretest 1 as reference and raw values in brackets) (n=11).

Child	Pr1	Pr2	As1	As2	As3	As4	As5	As6	As7	Po1
A	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)
B	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)
C	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)
D	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)	100(4)
E	100(1)	100(1)	100(1)	100(1)	100(1)	100(1)	100(1)	100(1)	100 (1)	100(1)
F	100(2)	100(2)	150(3)	150(3)	150(3)	200(4)	200(4)	200(4)	200(4)	200(4)
G	100(1)	100(1)	200(2)	200(2)	100(1)	200(2)	200(2)	200(2)	200(2)	200(2)
H	100(2)	100(2)	100(2)	100(2)	100(2)	100(2)	100(2)	100(2)	100(2)	100(2)
I	100(1)	100(1)	100(1)	100(1)	100(1)	100(1)	100(1)	100(1)	100(1)	100(1)
J	100(1)	100(1)	100(1)	100(1)	100(1)	100(1)	200(2)	200(2)	200(2)	200(2)
K	100(1)	100(1)	100(1)	200(2)	200(2)	200(2)	200(2)	200(2)	200(2)	200(2)
Mean ±Sd	100,00 ±0,00	100,00 ±0,00	113,64 ±30,82	122,73 ±39,10	113,64 ±30,89	127,27 ±44,53	136,36 ±48,10	136,36 ±48,10	136,36 ±48,10	136,36 ±48,10
Cond. mean	100,00		126,62							136,36

Pr=pretest, As= measurements at 14 day intervals during intervention, Po=Posttest; Sd=standard deviation

in the 'hand to mouth' and 'reaching to opposite shoulder' tasks. In addition there was reduced compensatory movements, increased thumb involvement when grasping, reduced flexion at the wrist and better fluency of movement. Increased ranges of motion in tasks like reaching to brush the forehead, reaching to the opposite shoulder and hand to mouth was also observed despite the fact that the supination and pronation components did not improve. The most significant clinical outcome was that two children who were initially unable to grasp a crayon/pellet were able to grasp it after the intervention.

Association between spasticity and quality of movement

A reduction in spasticity post-test compared to pre-test during wrist flexion and extension and elbow extension was observed in 3 children. An average improvement in quality of movement of 1% was observed in these children. In one child the tone decreased during extension of the elbow and wrist, and during elbow flexion and the quality of movement improved by 16%. In two children the spasticity decreased during wrist extension and the quality of movement improved by over 15%.

DISCUSSION

The results show that the quality of upper limb movement as quantified by the Melbourne assessment changed in ten children and this change (measured one week later) was retained even after cessation of the program of weight bearing treatment in eight children. An average of twenty one treatment sessions was necessary before maximal change in function could be seen. Reach, grasp and manipulation significantly improved post-test. The improvement in the quality of movement, reach, grasp and manipulation did not deteriorate upon cessation of treatment.

The Melbourne manual states that only a raw score change that is greater than or equal to 14 points, and a percentage score change that is greater than or equal to 12% can be considered a true change. According to this criterion there were no 'true changes' in functional tasks assessed in any of the children in the study. Statistically however, there was significant improvement in the quality of movement in all of the children. Reach, grasp and manipulation scores increased significantly when compared to the baseline. This finding is supported in reports by Corn et al (2003) who also found statistically significant and clinically observable results in their studies but the children did not improve as per the Melbourne criteria. They concluded that if the measurement error that may arise as a result of multiple untrained raters was reduced then 'smaller changes' in the Melbourne values could be regarded as significant. Therefore the responsiveness of the tool requires further research in clinical trials to quantify the "smaller change" necessary for significant improvement as per the assessment protocol.

Despite the possible influences of other uncontrollable sensory effects, the weight bearing program produced a statistically significant change in reach and this may attest to its value as a powerful tool in therapy. These results are supported by Chakerian and Larson (1993) who also reported significant improvement in reach with elbow extended and grasp.

Schieber and Santello (2004) reported that weight bearing improved the musculoskeletal components required for reach, grasp and manipulation namely, flexion of the shoulder, extension of the elbow, and extension of the wrist beyond neutral. Postural support and spinal extension, which are also necessary, are activated during weight bearing (Shumway-Cook and Wollacott 2001; Boehme 1988). A stable trunk provides a basis for effective limb movements. The effects seen in this study could have occurred in the trunk which when it was more stable, allowed for more effective upper extremity functions. The improvements in reach, grasp and manipulation following a program of weight bearing that were observed in the present study cannot be compared directly with other studies, since none exist. The physiological basis for normal development and movement can be used to understand the findings (Irwin-Carruthers 1982; Stockmeyer 1980); Erhardt 1974). In normal development proximal stability is the basis for distal mobility. Weight bearing through the developmental sequence systematically develops proximal stability.

Similar to the report by Chakerian and Larson (1993), who found no significant change during reach with supination, we observed that the components of supination and pronation did not improve in tasks that required the child to reach to brush the forehead, or take the palm to the "bottom". The improvement in release of an object in our study is supported by Kinghorn and Roberts (1996) who noted significant temporary improvement in release, and Smelt (1989) who reported qualitative changes in volitional release. Corn et al (2003) suggest that this probably was the result of an improvement in proximal stabilization. Weiss and Jeannerod (1998) state that improved sensory feedback ensures accuracy during the final components of the movement. Weight-bearing increases stimulation of proprioceptors and mechanoreceptors which could have contributed to the improvement in function observed. However electromyography will be able to confirm the actual changes occurring in the muscles (Smelt 1989).

The improved target accuracy when taking the hand to mouth or the opposite shoulder could have been due to an increase in the range of motion at the shoulder girdle. Smelt (1989) also found an increase in shoulder range of motion. Children who had been classified as moderately and severely affected, improved the most in terms of the overall quality of upper limb movement and reach, grasp and manipulation.

The availability of children who met the criteria, their willingness to participate in a controlled study as well as the school classroom and term schedule affected the duration of the study and the number of pre and post-tests that could be included in the design. A larger sample and/or a control group would have strengthened the study. In a study of this nature, history, maturation and learning effects may have threatened the internal validity. To protect against this, extraneous variables like what the child did during physiotherapy and occupational therapy was regulated. However, it was not possible to control exposure to any other outside events like what the child did at home or in the class. In addition, learning and maturation (mean age of children =12, 6) is a part of normal development and if it occurred is likely to have occurred in all the children but probably in varying degrees.

A double blinded study would have totally eliminated experimenter bias but it was not possible due to logistical constraints. Finally it will not be possible to generalize the results of this study to a wider population due to the fact that the sample size was small, and the subjects were not chosen randomly.

CONCLUSION

Weight bearing exercises in the form of sustained positions improved reach, grasp, manipulation and the overall quality of movement in children with hemiplegic cerebral palsy under the conditions of this study. This study provides some evidence for the effectiveness of weight bearing in improving upper extremity function in children with cerebral palsy.

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