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Hand movement functionality in institutionalised and non-institutionalised children

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Abstract

Background: The human hand exhibits remarkable versatility and utility, in its interactions with the surrounding environment. Inadequate hand strength and fine motor skills may lead to functional limitations. Limited information on hand strength and fine skill performance in institutionalised children motivated this study. We investigated hand function (hand-grip-pinch strength and dexterity in 50 institutionalised children (IG) (38 males, 12 females; mean age 11.28 ± 0.64 years) and compared them with 50 non-institutionalized children (CG) (40 males, 10 females; mean age 11.04 ± 0.72 years) being raised in their families.

Methods: In this cross-sectional study, all the one-hundred subjects, age 10-12 years, have completed hand grip test and three types of pinch tests (lateral, 3-point and 2-point) for strength and Purdue peg board task for fine manual dexterity. Grip and pinch strength were measured using Jamar dynamometer and Jamar pinch gauge respectively. In the Purdue Pegboard task, participants placed pins using the dominant, non-dominant, and both-hands respectively. Additionally, participants built assemblies using pins, washers, and collars with alternating hand movements. The student's independent t-test was used to analyse the differences.

Result: All the measures of grip strength, pinch strength and dexterity of IG were significantly inferior bilaterally to CG. The IG presented weaker hand-grip ($p < 0.001$) and pinch strengths ($p < 0.05$) and slower in dexterity skill performance ($p < 0.05$) than CG.

Conclusion: The institutionalized individuals showed weaker hand movement functionality than non-institutionalised individuals. Child Care Institutions must incorporate enriching play environments as a health promotive measure for optimal development of these children.

Keywords: hand function, grip strength, pinch strength, manual dexterity, institutionalism

Introduction

Family is considered to be the best environment for growth and development of a child. However, everyday across the world, families are disrupted due to parental death, abuse, neglect, and other unfavourable conditions.[1] COVID-19 has worsened the problem.[2,3] Countries like India are often overburdened with high numbers of orphans; and community-based or family care cannot be provided for all children in need.[4,5] Therefore, it is not surprising that the most common method of caring for children without parents is still through child care facilities like orphanages and children's homes.[5,6,7] Child Care Institutions (CCIs) may not be the last resort, but instead, the primary option for child care for diverse children.[8] Institutionalized children are individuals under the age of 18 placed in residential care facilities referred to as children homes, orphanages for care and protection.[9,10]

Although there are few children's institutions that are able to meet the needs of these vulnerable children, no institution in the world can ever fully replace the most vital institution of family.[11] Children raised in residential care institutions often have an unstable caregiving environment, negative experiences, and lack opportunity to explore and master their world.[12,13] Furthermore, transition of the child from family to an institution imposes a wide range of challenges which hinder the child's psychological adjustment.[14] There is evidence that children raised in institutions demonstrate poorer developmental outcomes across physical, cognitive, emotional, social, and behavioural domains when compared with children raised in families. In addition, it suggests that institutionalized children are consistently more vulnerable to suboptimal development.[15]

Children between the ages of 5 and 14 make up about one fifth of India's population, which includes primary and secondary school age groups.[16] School age is considered a dynamic period of growth and development due to physical, mental, emotional, and social changes children undergo during this sensitive period. During this stage of motor skill development, children learn to gain mastery of one's world through active exploration and manipulation of the surrounding environment through their hands.[17] The hand is the most functional part to communicate and carry out activities of everyday living and participate in diverse play and sport activities.[18] The human hand exhibits remarkable versatility and utility in its interactions with the environment.[19] The ability to move the arms and hands with precise coordination and optimal speed is necessary to perform various functions. It indicates a well-developed, neuromotor function.[19] Manual dexterity in childhood is essential for effective participation in a variety of daily self-care, play, and academic tasks progressively refined during development.[20] Current evidence supports steady improvement of dexterity skills during primary school years[20] and stabilizing during adolescence.[21] Poor motor dexterity has been linked to academic challenges, low self-esteem, and elevated anxiety.[20,22]

Grip strength and pinch strength are the basis for upper limb function. They represent the muscle strength of hand, forearm, and upper limbs.[23] These variables are important references in the evaluation of hand function, especially fine motor ability,[23] in grading the degree of disability, and level of physical capability.[24] Experimental and epidemiologic studies support grip strength (HGS) measurement as one of the most widely used functional parameters to measure overall strength in children.[25] Furthermore, dynamometer-based HGS evaluation is non-invasive, affordable, and extremely easy to administer.[24] A Pinch is a pattern of prehension used to manipulate objects using two or three fingers in coordination with thumb movements with no contact of the palm.[26] The three primary finger pinches include lateral pinch (LP), 3-point or tripod pinch (3PP) and 2-point pinch (2PP): LP, between pad of thumb and medio-lateral surface of index finger; 3PP, between pads of index, middle finger, and thumb; and 2PP, between pads of index finger and thumb.[27] Lateral pinch (also known as a key pinch) is mainly used while turning a

key.[28] 3-point pinch surrounds the object and is considered as a transitional strength of the fingers.[26] Most accurate and gentle pinches of all is 2-point pinch which is used to grasp small objects. Most common objective measurement to specifically measure pinch strength (PS) of the fingers can be achieved using Jamar® Hydraulic Pinch Gauge.[29]

Meanwhile, a decline in HGS and PS may result in significant functional restrictions that result in inefficient performance of daily activities impacting quality of life. Hand functionality is the prerequisite for most of the daily activities involving the upper limbs such as eating, writing, lifting & carrying objects, opening or closing doors, and so forth. Most sports require adequate grip and pinch strength to enhance performance.[30] Several factors influence HGS and PS which include age, gender, nutritional status, muscle strength, anthropometric parameters, and environmental conditions.[31]

Although institutional environments may provide children with basic food and shelter, these children may lag behind other children in physical and motor skill development.[32] Since grip and pinch strength and associated factors have become a major public health concern, particularly among children, the present study was undertaken to assess hand strength (HGS and PS) and dexterity as hand movement functionality and compare children living in orphanages with age-matched peers reared in their families. This may help to formulate effective interventions to improve motor skill and muscle strength of vulnerable children in future as a health promotive measure.

Method

Participants

One hundred children participated in this cross-sectional study. Institutionalized children were recruited from three institutions of North Chennai. Children who lived with families were recruited from three same schools as orphans. Both samples included boys and girls, with authorization to participate in the research as approved by legal guardian and signed assents obtained from participants. Orphanages for special needs children, children with a history of trauma, neurological or musculoskeletal disorders, congenital deformity, or cognitive impairment were excluded from both groups. According to the institutional, clinical psychologist report, two institutionalised children, one child with intellectual disability and the other with learning disability, were excluded. The study received institutional ethical approval, SRMIST-School of Public Health.

Procedure

Demographic information such as age, height, weight, dominant hand, and type of orphan were obtained. Body height was measured using stadiometer to the nearest centimetre and body weight was measured using a digital weight scale to the nearest kilogram. Hand dominance was assessed by asking each participant to pick up a pencil and draw a circle.[33]

Hand Strength measurements

The Jamar Hydraulic Hand Dynamometer for grip strength and Jamar Hydraulic Pinch Gauge (Baseline Hydraulic Fabrications Enterprises, White Plains, NY, USA) for pinch strength in kilograms of force (kg) were used to measure hand strength.[34] The Jamar dynamometer is the most widely used with established reliability and reproducibility.[35] The researcher held the dynamometer loosely at the bottom and the pinch gauge at the distal end around the readout dial to avoid dropping. All the children were permitted to practice using both handheld dynamometer and pinch gauge to allow them to be acquainted with the procedures. Each participant was then asked to apply maximum voluntary grip or pinch force thrice, and the highest reading was considered for analysis.[36] The measurements were alternated between the left and right hands to allow approximately 30 seconds between the readings.[37] Participants were encouraged with verbal instructions, to squeeze harder, harder, and relax as per the guidelines.[35] The contraction time was for less than 2 seconds.

HGS was tested first, followed by PS (lateral pinch, 3PP, and 2PP). Dominant hand followed by non-dominant hand.

The children were seated facing the evaluator with their shoulder adducted and neutrally rotated and elbow flexed at 90°.[34] According to the American Society of Hand Therapists (ASHT) recommendations, for all the participants, the handle of dynamometer was set to second position.[38] For measurement of palmar pinch, the pinch meter was grasped between the pads of the thumb, index finger, and middle finger. For measurement of lateral pinch, the pinch gauge was positioned between the pad of the thumb and the radial side of the middle phalanx of the index finger. LPP, was measured by placing the pinch gauge between pad of the thumb superiorly and medio-lateral surface of index finger inferiorly. 3PP was measured by grasping the pinch gauge between pads of index and middle fingers superiorly and pad of the thumb inferiorly and for 2PP measurement, pinch gauge was positioned between pad of index finger superiorly and pad of thumb inferiorly.[27]

Purdue Peg Board

Dexterity can be measured through observation of task performance.[39] The Purdue Pegboard test (PPT) measures speed and accuracy of hand-eye coordination, i.e., fine manual dexterity through a timed, peg-placing task.[40] The test consists of a rectangular board with two parallel rows of 25 holes. At the top of the board, metal bits such as pegs, collars, and tubes are placed in concave trays. After a brief practice, participants were asked to perform the tasks with dominant followed by non-dominant hand. A total of four, task scores were obtained: dominant hand, non-dominant hand, bimanual, and assembly. The dominant hand and non-dominant hand subtests required to place as many pegs as possible in the holes corresponding to the hand being tested within 30-seconds. Bimanual subtest required placement of the pegs in both rows with both the hands simultaneously in 30 seconds. The assembly task required making an assembly by placing pegs, washers, and collars using alternating hands in one minute.[41]

Statistical Analyses

SPSS software version 16.0 was used for statistical analysis. Descriptive statistics for categorical variables were expressed in percentages. Continuous variables were reported as mean, standard deviation (SD) for both the groups on dominant and non-dominant hands. The comparison of hand strength (GS & PS) and dexterity measurements between orphan and non-orphan children was performed using independent samples t-test. A significance level of $P < 0.05$ was considered for all statistical analyses.

Results

Demographic characteristics of the participants are presented in Table 1. The details are as follows (mean ± SD): age, 11.16 ± 0.69 years; weight, 32.94 ± 7.80 kg; height, 139.56 ± 8.64 cm; body mass index, 16.77 ± 2.8 kg/m^2. All the participants except one were right-handed (98%).

Table 1. Demographic information of the participants

Characteristics	Institutionalised children (N=50) Mean ± SD or f (%)	Non-institutionalised children (N=50) Mean ± SD or f (%)	Total (N=100) Mean ± SD or f (%)
Age (years)	11.28 ± 0.64	11.04 ± 0.72	11.16 ± 0.69
Height(cm)	138.53 ± 9.79	140.6 ± 7.27	139.56 ± 8.64
Weight(kg)	30.49 ± 6.97	35.39 ± 7.89	32.94 ± 7.80
BMI (kg/m^2)	15.74 ± 2.23	17.8 ± 3.03	16.77 ± 2.84
Gender			
Boy	38 (76.0)	40 (80.0)	78
Girl	12 (24.0)	10 (20.0)	22
Hand dominance			
Right	49 (98.0)	50 (100.0)	99
Left	1 (2.0)	0 (0)	1
Types of orphans			
Single	21 (42.0)	0 (0)	21
Double	17 (34.0)	0 (0)	17
Social	12 (24.0)	0 (0)	12
Duration of stay in children home/orphanage			
< 1	6 (12.0)	0 (0)	6
1-5	31 (62.0)	0 (0)	31
5-10	13 (26.0)	0 (0)	13

Table 2. Between-group comparison – Institutionalised children (IG) and Non Institutionalised Children(CG)

Variable	Hand dominance	Institutionalised children (N=50)	Non-Institutionalised children (N=50)	p-value
GS	D	16.60± 3.61	18.78±2.44	P < 0.001
	ND	14.22± 3.55	16.78 ±2.19	P < 0.001
LP	D	4.50 ± 0.95	4.88 ±0.95	P < 0.05
	ND	4.19 ±1.06	4.71 ±0.84	P < 0.001
3PP	D	4.10 ±1.17	4.60 ±0.83	P < 0.05
	ND	3.64 ± 1.08	4.15± 0.81	P < 0.05
2PP	D	3.10 ±0.71	3.38 ± 0.65	P < 0.05
	ND	2.77 ± 0.53	3.10 ±0.84	P < 0.05
PBB	D	13.42 ±1.38	14.0 ±1.38	P < 0.05
	ND	11.40 ±1.12	12.16±1.37	P < 0.05
	Both hands	17.08 ±2.22	18.0±1.69	P < 0.05
	Assembly	31.84 ± 7.27	37.52±5.82	P < 0.001

Notes. D Dominant hand, ND Non-Dominant hand; PPB Purdue Peg Board

The results showed that the BMI, HGS, PS exertions, and dexterity performance of institutionalised children were significantly lower than those exerted by the non-institutionalised children for all types of measurements.

The mean strength values were as follows (mean ± SD): grip strength (dominant hand, IC=16.60± 3.61 kg , CG = 18.78±2.44 kg; P < 0.001), (non-dominant hand, IG=14.22± 3.55 kg , CG = 16.78 ±2.19 kg; P < 0.001); lateral pinch strength (dominant hand, IG = 4.5 ± 0.95 kg, CG = 4.88 ±0.95; P < 0.05), (non-dominant hand, IG = 4.19 ±1.06 kg, CG = 4.71 ±0.84 kg; P < 0.001); three-point pinch strength (dominant hand, IG = 4.10 ±1.17kg, CG = 4.60 ±0.83 kg; P < 0.05), (non-dominant hand, IG = 3.64 ± 1.08 kg, CG = 4.15± 0.81 kg; P < 0.05); two-point pinch strength (dominant hand, IG = 3.1 ±0.71kg, CG = 3.38 ± 0.65 kg; P < 0.05), (non-dominant hand, IG = 2.77 ± 0.53 kg, CG = 3.10 ±0.84kg; P < 0.05); dexterity (dominant hand, IG = 13.42 ±1.38, CG = 14 ±1.38; P < 0.05), (non-dominant hand, IG = 11.4 ±1.12, CG = 12.16±1.37; P < 0.05), (both hands, IG = 17.08 ±2.22, CG = 18±1.69; P < 0.05); (assembly, IG = 7.96 ± 1.81, CG = 9.38±1.45; P < 0.001). Moreover, the mean values of dominant hand for all measures were higher than non-dominant hand measures in both groups.

Discussion

This study was interested in analysing the hand strength and dexterity of children institutionalised in orphanages/children's homes, and comparing it with individuals who live with their parents. Towards this end, hand grip strength, pinch strength, and dexterity were tested for 100 children. Results of the study were analysed by independent t test.

The study showed that there was a significant difference in hand strength measurements (GS & PS) and hand dexterity between children (Table 2). There were lower values among institutional care residents and higher values among non-institutional residents. In both dominant and non-dominant hands, orphaned children living in institutions had weaker hand strength (GS & PS) and slower dexterity performance as compared to non-orphaned children living with families.

One of the most important functions of the hand is the ability to grip objects and manipulate, and any decline in this capacity can make it more difficult to manage a broad spectrum of daily fundamental tasks such as self-care, eating, schoolwork, and sports.[42]

The muscular strength (GS & PS) differences between institutionalised and non-institutionalised children may be attributed to different factors. There are several hypothesized mechanisms linking the muscle strength to place of residence. In individuals who experience stress response, repeated activation of the hypothalamic-pituitary-adrenal pathway may have direct consequences on muscle strength.[43,44] Orphaned children living in institutional homes are more prone to develop various behavioural and mental illnesses like depression, anxiety, and post-traumatic stress disorder.[45,46] As per recent literature, the prevalence of behavioural and emotional problems of orphans in institutional homes in an Indian setting was found to be 56%.[47]

The motor dexterity performance of institutionalised children was significantly slower than non-institutionalised counterparts. Typically, institutional settings offer insufficient opportunities for motor skill activity.[48] The experiences in institutional environments often fall below what is needed to sustain optimal development of children.[49-51] Children (8-16 years) reared in institutions demonstrated delay in motor skills such as balance and bilateral coordination when compared to normal community samples.[52] Furthermore, longer institutional stays have been linked to difficulties in attention and memory,[53] sensory processing,[54] mental health, and limitations across physical, cognitive, and social domains.[55]

The socio-ecological model suggests multifaceted, contextual factors at different levels influence children's motor skills. These include environmental factors (e.g., availability and accessibility of physical activity equipment and play spaces in home, school,

and neighbourhood), family level factors (e.g., family socio-economic status, parental characteristics, and support) and individual level factors (e.g., Children's demographic, biological, psychological, and behavioural characteristics).[56]

The motor skills and physical activity of children are subjected to particular demands depending on the setting.[57] Newell's Model of Constraints emphasises the role of environment, including physical and social to master motor skill performance.[58] The physical environment refers to all physical elements of the setting in which a child grows and the social environment refers to all social relationships a child may encounter.[59] The environment in which a child is raised matters as motor development occurs in a particular social context. A child's living environment is inevitably the primary environment that influences different aspects of motor skill development. The availability of stimulating play materials,[60] having an access to explore in the outdoor play space with good potential for motor experiences, and spending time in physical activity play influences the development of motor skills competence.[61] The majority of home- raised children participate in after-school outdoor play on a regular basis on weekdays and on weekends have extended time for outdoor play. In contrast, orphaned children only on weekends participate in outdoor physical activity play due to safety concerns. On weekdays, they are engaged in their regular after-school activities which include academic instruction. Hence, the institutional care children of this study have insufficient daily physical activity time. Indian physical activity (PA) guidelines recommend 60 minutes daily of moderate intensity PA for school age children.[62] Both theories and empirical research suggest task quality and the amount of time spent on a task—including its frequency and duration—are reliable indicators of how well a motor skill develops and levels of physical activity.[63-65]

To our knowledge, this study is one of the first attempts to compare hand strength and hand dexterity measures of children being reared in institutional homes and to children being reared with families. However, there are a few limitations in this study. Firstly, these results need to be interpreted with caution as children's biological and psychological characteristics and physical activity, play characteristics at the school, and after-school were not included. Furthermore, participants were from three orphanages of the Northern zone of Chennai. Hence, findings may not be generalizable. Therefore, further studies considering other contributing factors across other zones of Chennai are recommended. This can provide valuable information on developmental domains of children residing in institutions for further health promotive measures. However, this study provides a snapshot of hand skills by place of residence.

Conclusion

The present study points out the need for attention to hand movement functionality of institutionalised children due to the observed performance differences in hand strength and hand dexterity performance with non-institutionalised children. For the optimal development of this group, a variety of stimuli must be provided, as an under stimulating environment may have an impact on their future progress. In an Indian context, with the large number of vulnerable children, services of CCIs are essential and will continue to be needed in the near future for the care and protection of children. This establishes the necessity to incorporate play activities that stimulate the development of children being reared in children's homes/orphanages to promote hand strength and hand skill performance. In conclusion, institutionalised children in this study showed weaker hand-grip and pinch strengths and slower performance in dexterity tasks that require fine and delicate movements of hand and fingers.

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