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Fine Motor Skills and its Growth Pattern in Variation to Age and Gender on Bengali (Indian) Primary School Children: A Cross Sectional Study

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ABSTRACT

Fine motor skill proficiency is an essential component of numerous daily living activities such as dressing, feeding or playing. Poor fine motor skills can lead to difficulties in academic achievement. The aims of the present study was to investigate the influence of age and gender on the development of fine motor skills and its pattern of growth on the primary school children of West Bengal. This cross-sectional study was conducted on 950 primary school going children from different districts of West Bengal state, India. Hand reaction times of the participants were evaluated by ruler dropping method and for the hand eye coordination Perdue pegboard test were applied. The results of the present study revealed that the scores of reaction time of children was significantly ($p<0.001$) and negatively correlated with the age of the children and the score of peg board test of the children were significantly and ($p<0.001$) positively correlated with age. It was found that the score of fine motor skills of girls were significantly greater than boys. Linear regression analysis demonstrated that age was significantly associated with the scores of fine motor skills of the children. Multiple regression analysis showed that even after controlling for the effect of the height, weight, BMI and SES,-, the age of the children had strong significant impact on fine motor skill. From the result it was concluded that the performance of fine motor skills of girls were better than boys. Age was the determining factor for the development of fine motor skills of the children.

Key words: Age, Gender, Cross Sectional Study, Reaction Time, Hand Eye Coordination.

INTRODUCTION

Motor development is the ongoing sequence of changes that occurs in nervous system by which coordination of the large muscles of the legs, trunk and arms and the smaller muscles of the hands take place sequentially. The two basic ingredients of motor development are changes of posture and movements. [1] Motor skill is nothing but a learned series of movements that combine to produce a smooth, efficient action. Neuromuscular development that starts in embryonic stage and it continues after birth. [1]

The constant biological and psychosocial changes that causes a major acquisitions in the motor, social-affective, and cognitive domains that occurs in first years of a child's life. [2] The constant changes of central nervous system such as myelination, synaptic organization reach the peak at 2 years of age that favouring the learning processes of the children. [2] However, the CNS is not the only factor responsible for motor development, it is also related to age, sex and the musculoskeletal development and cardio respiratory fitness, all are influenced by stimuli and environmental factors. [3]

Physical activities are vital and inseparable part of human life that plays a crucial role for the development of cognitive, social and motor skills was reported. [4-5] Thus, the main fundamentals of motor development, other than its biological basis are the fundamental motor skills (FMS) which involved the gross and fine motor skills. [6-7] It was established by the several researcher that preschool years (ages 3-6 years) are critical period for the development of motor skills. [6,8] It was demonstrated that the achievement of these skills are developmentally sequenced and are dependent in several internal and external factors. [8] Failure to develop and improvement of motor skills during the preschool and elementary school years often leads to deprivation and failure of the master skills during adulthood. [9] The poor performance in motor skills may lay on the line in future participation in academic, sport and physical activity. This problem also leads to decreased movement and mobility in children and increase the prevalence of overweight and obesity risks. [5,10-11]

Age and sex of the children had impact on the development of motor skills was established. [12] In several studies, it was noted that with the increment of age, children in catching and kicking skills were developed. [12-13] In a cross sectional study by Rodrigue et al. 2005; it was noted that age may an influencing factor for motor skills of the humans. [14] It was also reported that long-term retention of acquired skills declines with age; older adults still retain the ability to learn the skill. [14] Moreover, those who maintained a processing speed comparable with that of the younger participants evidenced no age-related performance decrements on the mirror-drawing task. [14]

Besides age, gender has also been found to affect children's developing motor skills, although relevant empirical data are often contradictory was established. Researchers either report gender differences in various motor tasks or they focus on the age in which boys and girls attain specific motor skills. [15-18] For instance, according to Denckla (1973), school-aged girls seem faster and better synchronized than boys; however these differences are not obvious during adolescence. [19] Additionally, it has been reported that boys' ball skills develop earlier than girls', while girls present manual dexterity skills earlier than boys. [20-21] Regarding balancing tasks, previous findings showed that girls outperform boys while other suggests small gender differences exist in between them. [21-24]

Majority of studies cited above have been conducted in abroad. Very little studies in this regard were carried on Indian children. Almost no study was found in the literature which has been conducted on Bengali population in India. In order to fulfill these lacunae, in the present investigation, some efforts have been given to evaluate the effect of age and sex on fine motor skills and its pattern of growth of primary school children of Bengali population in India.

MATERIALS AND METHODS

Selection of Site and Subjects:

A cross-sectional study was conducted on 950 school children of which 450 were boys and 500 were girls within the age group of 5-10 years from different districts of West Bengal state, India. The criteria for recruitment as a participants for the present study were children having age 5 to 10 years, should be apparently healthy, and not suffering from any kinds of psychiatric or neurological disturbances. Participants with background of acute or chronic diseases were excluded from the study. The participants who were taking psychotropic medicine for at least last one month were excluded in the present study. The protocol of the present study was explained verbally in local language (Bengali) and consent was taken from the parents. Ethical approval and prior permission were obtained from the institutional Ethics Committee before commencement of the study and the study was performed in accordance with the ethical standards of the committee and with the Helsinki Declaration.

Data collection procedure:

After obtaining consent form the parents and respective schools of the children. The children were introduced with the protocols for the experiments of fine motor skills. Prior to the actual data collection a pilot study was done on 50 children that were not included in the main study. The participants were divided into six groups according to the age of the children.

Methodology of motor ability test:

Reaction time test (ruler catching method) [25]

The reaction time was determined by measuring the time taken to catch a ruler dropped by an accomplice.

Determination of Reaction Time (RT):

Subject should hold the chosen hand and should extend the thumb and index finger so they were 8 cm apart. Investigator held a metric ruler with its end exactly level with the subject's extended thumb and index finger. The lowest numbers of vertically placed metric ruler should remain near the subject's hand. The ruler was dropped, and the subject was instructed to grasps it by the thumb and index finger.

Investigator had to record the number at the subject's fingertips, i.e. distance the ruler fell through the subject's fingers. Distance (d) fallen can be converted to time (t) passed with the following formula:

$d \text{ (in cm)} = (1/2)(980 \text{ cm/sec}^2)t^2$

$t^2 = d/(490 \text{ cm/sec}^2)$

$t = \sqrt{[d/(490 \text{ cm/sec}^2)]}$

[980 cm/sec^2 is the acceleration of a falling mass on Earth. Since we know how fast an object falls, we can figure out how long it took to fall a measured distance.]

The Purdue Peg Board Test [26]

The Purdue pegboard measures two types of activities such as gross movements of the hands, fingers and arms; and finger dexterity, that can be considered the ability to assimilate speed and exactness with finely controlled discrete movements of fingers. This apparatus is consist of wooden pegboard with four cups for pins, collars and washers at the top of the board, and two columns of 25 holes present at the centre of the board. The three tests was conducted using this equipment included a test with the right hand, a test with the left hand, a test and an assembly test.

For the preparation of Purdue pegboard test, participants were requested to sit comfortably at a normal table height. The pegboard was placed directly in front of the participants, with cups containing pins, collars and washers at the far end of the pegboard. It was ensured that cups which is present at the extreme right and extreme left of the centre that should contain 25 pins and the cups which is present in the right and left of the centre should contained 50 collars and 100 washers respectively. Participants were instructed about the goal of the experiment was to find out how many pegs, or assemblies for an assembly task, they could complete in 30 seconds. Participants were then instructed carefully, one step at a time, the tasks by the researchers, and were allowed time to practice each task until and unless they felt comfortable. The participants were also reminded that they should not worry about pins or other assembly components that drop, and should proceed with the experiment using components that were available on the pegboard. For tests, depending upon the dominant hand of participant, the dominant hand considered as the hand which is used most and the use of hand which is less compared to other is the non dominant hand. Participants were instructed to pick one pin at a time with their right hand from the right-hand cup for the right hand test. They were then instructed to place each pin in holes of the right-hand column of the pegboard, beginning from the top hole.

Participants were also instructed that to place as many pins as they could, working as rapidly as possible, until and unless the investigator requested them to stop at the end of 30 seconds. The number of pins placed in 30 seconds with the right hand was monitored by a stop watch that was recorded. For the left-hand test, participants were instructed to pick one pin at a time with their left hand from the left-hand cup then to place the pins in holes on the left-hand column of the pegboard beginning from the top hole. The number of pins placed in 30 seconds with the left hand was recorded.

For the Purdue pegboard assembly task, participants were instructed to pick up one pin from the right-hand cup with their right hand, and to place it in the top hole along the right-hand column of the board, then to pick up a washer with their left hand. After the pin was placed, they were then directed to drop the washer over the pin. While the washer was being placed, participants were instructed to pick up a collar with their right hand. Then to drop over the pin. Further they had to pick up another washer with their left hand and drop it over the collar. Participants were instructed that when the final washer for the first assembly was being placed with their left hand, they were to begin for the second assembly immediately by picking up another pin with their right hand, and continue placing it in the next hole. The total number of pieces assembled in 30s was recorded. Since each assembly consisted of four pieces, each completed assembly was counted four points.

Statistical Analysis:

Descriptive statistics of different variables of the participants were presented as means ± standard deviation and those were calculated for all the variables. To find out the significant difference of the variables, the t - test was performed. To test the association between two or more the variables Pearson’s correlation coefficient (r) was computed. One-way analysis of Variance (ANOVA) was computed to find the significance of difference among different groups. Post-hoc analysis (Bonferroni) was performed to test for differences in performances across the different groups. To address the potential for confounding, regression analyses was undertaken. Height, Weight, BMI, and Socioeconomic status were entered into the model as independent variables against the performances of the parameters of motor ability that were considered as dependent variables. P-value set at <0.05 level. Statistical analyses were performed using the statistical software IBM SPSS version 20.

RESULTS

Physical characteristics of the primary school children have been presented in the table 1. The results showed that mean height, weight and BMI of the children gradually increases as advancement of the age. Result of ANOVA indicated that there had a significance variation of physical characteristic of the children among different age group.

Table: 1 Mean±SD of physical characteristics by age of the children

Age(in yrs)	Height		Weight		BMI	
	Male	Female	Male	Female	Male	Female
5	108.07±4.48	106.14±7.29	17.34±2.71	16.87±3.38	14.90±2.72	14.84±1.68
6	110.96±6.55	109.72±5.90	18.65±3.31	18.99±3.50	15.14±2.38	15.72±2.34
7	117.55±5.26	113.84±6.33	21.32±4.25	20.44±3.10	15.34±2.29	15.80±2.28
8	117.84±5.69	119.19±6.47	21.82±4.08	22.61±3.98	15.63±2.05	15.93±2.46
9	124.02±6.61	122.18±7.43	25.62±5.58	24.64±4.01	16.53±2.71	16.50±2.16
10	129.38±6.58	130.06±6.28	29.29±5.76	28.19±4.60	17.35±2.38	16.69±2.75
F ratio	122.55***	137.77***	68.93***	90.63***	10.82***	6.11***

***p<0.001

The performance of motor ability of the primary school going boys and girls has been presented in Table 2 according to the age of the participants. The results of ANOVA showed a significant variation ($p<0.001$) of motor performances of the participants among different age groups.

Table 2: Scores (Mean ±SD) of different motor parameters of boys and girls of the age groups 5 -10 yrs

Age (yrs)	Reaction Time (Sec)		Peg board Score (No of pin inserted)					
			Dominant Hand		Nondominant Hand		Assemble task	
	Boy (n=450)	Girl (n=500)	Boy(n=450)	Girl(n=500)	Boy(n=450)	Girl(n=500)	Boy(n=450)	Girl(n=500)
5	0.299±0.080	0.261±0.077	6.14±2.19	7.41±2.06	6.21±1.57	7.16±2.15	4.96±2.61	5.77±3.05
6	0.264±0.067	0.245±0.058	7.07±2.36	8.37±2.50	6.73±2.20	8.02±2.29	5.35±2.46	7.04±3.21
7	0.259±0.068	0.242±0.060	7.40±2.29	9.08±2.64	7.15±1.91	8.74±2.33	5.75±2.70	7.24±3.07
8	0.229±0.055	0.218±0.054	8.60±2.79	10.06±2.41	8.23±2.51	9.42±2.27	7.75±2.79	8.19±2.58
9	0.221±0.051	0.204±0.055	9.45±2.92	11.43±2.18	8.97±2.28	10.24±1.99	8.51±2.52	9.56±2.73
10	0.200±0.048	0.195±0.054	11.34±1.86	12.40±2.72	10.60±2.26	11.29±2.07	9.44±2.76	10.62±2.68
F ratio	22.04***	13.91***	47.33***	40.79***	45.19***	31.51***	38.19***	26.45***
All age group	0.246±0.007	0.22±0.006 **	8.37± 2.97	9.67±2.93 ***	8.01±2.62	9.13±2.55 ***	6.98±3.14	8.04±3.23 ***

***p<0.001 [RT- Reaction time, DH- Dominant hand, NDH-Non-dominant hand]
* p<0.05, **p<0.01, ***p<0.001 with respect to boys; [RT- Reaction Time, DH- Dominant hand, NDH-Non-dominant hand]

From the results it was revealed that the performances of the scores of Pegboard test by dominant hand, non-dominant hand and assembled task by both hands were gradually increased from lower age group to higher age group. However, the score of reaction time (RT), represented by ruler dropping test, showed a gradual decrease of mean scores significantly ($p<0.001$) with the increment of age. The Bonferroni post hoc analysis showed that the score of participants belonging to the lower age group was significantly lower motor skill compared to rest of the age group.

Gender variation of motor ability parameters has been presented in the Table 2. The result showed that reaction time (ruler dropping test) of girls were significantly lesser ($p<0.05$) than that of boys. Thus it may be stated that girls had better reaction time in comparison to the boys. Results also showed that performances of hand eye co-ordination (Pardue peg board score) of dominant hand, non-dominant hand and assembled task of both hands of girls were significantly greater ($p<0.001$) than that of boys.

Correlation coefficient of motor performance parameters in respect to age were presented in Table 3. Correlation analysis demonstrated that the age was significantly ($P<0.001$) and positively correlated to the scores of Perdue pegboard test performed by dominant hand, non-dominant hand and assembled task by both hand.

Table 3: Correlation coefficient of motor parameters of studied children with age

Motor parameter	Boy	Girls
RT	-0.440***	-0.360***
Pegboard score -DH	0.572***	0.562***
Pegboard score -NDH	0.562***	0.514***
Assembled task -Both Hand	0.531***	0.475***

***p<0.001 [RT- Reaction time, DH- Dominant hand, NDH-Non-dominant hand]

On the contrary, the result also showed that the age had significant negative correlation ($P<0.001$) with the scores of ruler dropping test (reaction time). Linear regression analysis of age with different motor parameters such as reaction time (RT) and peg board scores (DH, NDH, Both Hand) was made and results showed that age had significant association with different motor parameters (Tables 4). Multiple regression analysis demonstrated that even after controlling for the effect of anthropometric parameters (height, weight, BMI) and socioeconomic status, the age had strong significant impact on all the motor parameters. Therefore, the age might be the best account for the variability of the motor performances.

Table 4: Regression analysis of motor parameters with age (Girls and Boys)

Variables	Unadjusted						Adjusted#			
(Girls)	B	SeB	B	R^2 change	F change	T	B	SeB	β	T
RT	-0.013	0.002	-0.347	0.120	62.59	-7.91 ***	0.008	0.002	-0.211	-3.78 ***
Pegboard score -DH	0.990	0.066	0.572	0.328	223.15	14.93***	0.815	0.107	0.472	7.65***
Pegboard score -NDH	0.0.857	0.059	0.563	0.317	212.26	14.56***	0.686	0.096	0.450	7.14***
Assembled task	0.970	0.072	0.532	0.283	180.34	13.42***	0.798	0.117	0.437	6.82***
Variables	Unadjusted						Adjusted#			
(Boys)	B	SeB	B	R^2 change	F change	T	B	SeB	β	T
RT	-0.019	0.002	-0.440	0.194	105.73	-10.28 ***	-0.015	0.002	-0.355	-7.75 ***
Pegboard score -DH	1.002	0.070	0.562	0.316	202.97	14.24***	0.835	0.094	0.469	8.86***
Pegboard score -NDH	0.796	0.063	0.515	0.256	157.90	12.56***	0.667	0.096	0.431	6.93***
Assembled task	0.932	0.082	0.475	0.226	127.98	11.31***	0.705	0.122	0.359	5.76***

***p<0.001 # adjusted Height, Weight, BMI, Socioeconomic scores

[RT- Reaction time, DH- Dominant hand, NDH-Non dominant hand]

Percentile growth of motor abilities of the primary school going children

The percentiles on a growth chart create a curve. As a child grows, plotting the weights and heights on the chart will indicate whether a child is following a curve, which means that the child is remaining near or at the same percentile. Like the physical growth the motor growth can be plotted in percentile curves. Following a curve indicates a pattern of healthy growth. Even a 5th percentile can be appropriate for a child if the child follows this percentile curve consistently. The same is true for a child following the 90th percentile. A child at the 5th percentile is just smaller than average, and a child at the 90th percentile is just larger. If a child's growth pattern suddenly changes and weight drops or increases significantly in the percentiles, a careful look may be given for reasons behind the shift.

Figure 1 & 2 showed comparison between different percentile curves of reaction time of boys and girls. From the figure it was noted that the reaction time (RT) below 15th percentile indicated lower scores. As it was a time parameter score the growth of reaction time might be treated as good. Due to the same reason the growth curve of 90th percentile curve of reaction time indicated poor development of reaction time. [27] In this present studies the no of student belonging to above 90 percentile and below 15 percentile has been presented in fig 1 and 2.

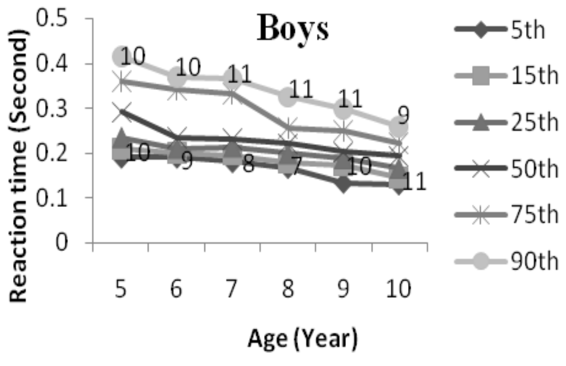

Fig-1: Comparison between different percentile values of reaction time for age.

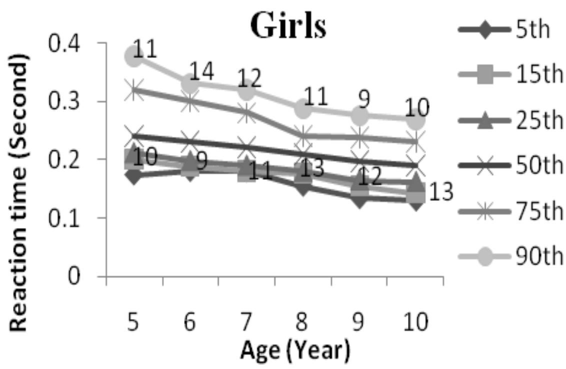

Fig-2: Comparison between different percentile values of reaction time for age.

Figures 3 to 6 showed percentile growth curves of hand eye coordination such as pegboard test by dominant hand non dominant hand of boys and girls. Performances of motor ability below 15 percentile were considered as poor development of motor skill. Performances above 90th percentile were considered as very good development in motor ability of the children. The fig 3-6 also indicates the number of participants belongs to above and below 90 percentiles and 10 percentiles.

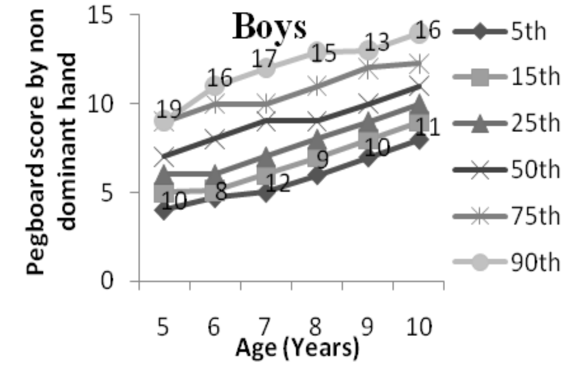

Fig-3: Comparison between different percentile values of pegboard score by nondominant hand for age.

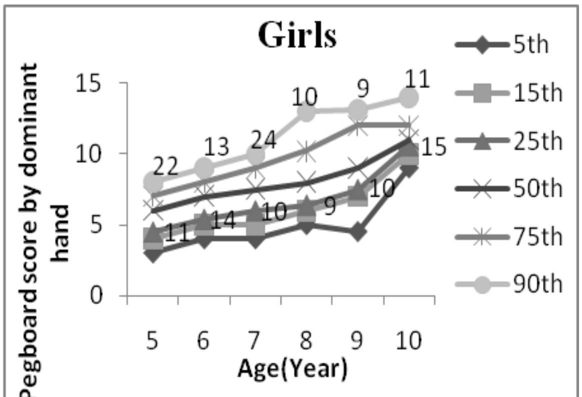

Fig-4: Comparison between different percentile values of pegboard score by dominant hand for age.

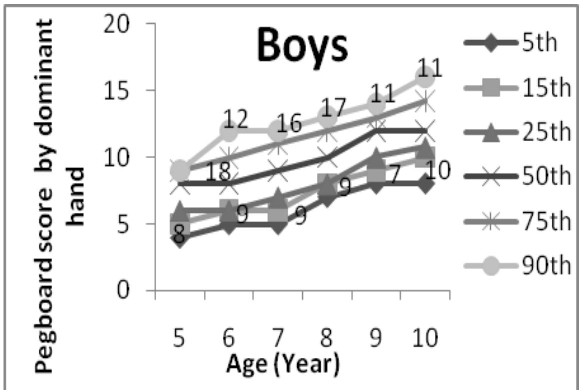

Fig-5: Comparison between different percentile values of pegboard score by dominant hand for age.

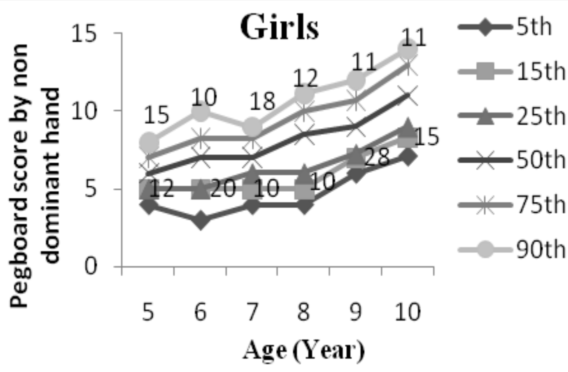

Fig-6: Comparison between different percentile values of pegboard score by nondominant hand for age.

DISCUSSION

Motor competence constitutes a significant developmental challenge during preschool years. The present study was designed to investigate the effect of age and gender on motor skills of preschool children. The results showed an improvement in reaction time with the increase of age. The fine motor activity (scores of peg board test) was also enhanced with the advancement of age among boys and girls. Thus the older children presented better scores than that of younger ones. Other investigators reported age-related improvement in visual motor [28] and balance skills during preschool years. [24]

The gradual improvement of motor activity from the age 5–10 years suggested an underlying maturational process of the cortex and corticospinal tracts of the nervous system. By using Magnetic Resonance Imaging (MRI) technique Paus et al. (2001) found that the age related improvement of children was due to continuous growth of corpus callosum from childhood to adulthood. [29] In another study it was demonstrated that the corticospinal and thalamocortical tracts that support motor functions also showed age-related maturation. [30]

As far as gender difference in motor ability was concerned, the results of the present study showed that the reaction time was significantly better in the girls compared to that of boys. The results also revealed that the dexterity and hand–eye coordination of the girls were better than that of the boys. It was noted that the pegboard scores of dominant hand, non-dominant hand, and assembled task of both hand of the girls were superior to boys. The findings of our study were similar to that of some previous studies it was also reported that performances of pegboard activity of girls were better than boys. [21,31] Gender differences in motor development and reported that girls were faster and better coordinated than boys early in the elementary school years, but these differences might disappear by adolescence was reported. [19,32] It was explained that girls tend to display fewer and less pronounced overflow movements throughout childhood. [31] Giedd et al. (1999), by anatomical MRI studies, showed that systems underlying motor development (i.e., frontal and parietal gray matter) reach maximum size one year earlier in girls than in boys. [33] Girls and boys show increase in white matter and corpus callosum volume from 6 years to17 years of age; however, girls show these developmental changes gradually over this age range, while boys show a dramatic increase over a shorter time period, with greater volumetric changes than the girls between ages 10–14 years. [34]

The neural pathways were the important factors for motor systems that underlie patterned movement may mature differently in girls than in boys and it was reported that the left hemisphere was more involved in the timing of complex sequences than the right hemisphere. [35] Similar findings were reported by Grafton et al. (2002) and concluded that in time related task involvement of the left hemisphere was greater than right hemisphere. [36] Other studies reported that development of left hemisphere in girls was faster than boys. [36-38] This might be the reason for gender differentiation motor performances of children. It might also be reason for the different rates of brain maturation and the age-increased myelination of the central nervous system which promotes development of children's fine motor skills. This interpretation was also supported by the coordinated emergence of neurological functions, [39-40] motor and cognitive advances during human development. [41] Gender differences in motor development have also been attributed to biological factors and more precisely to the differentiated neurological maturation of girls and boys. [42] Within this context, girls' predominance on both visual motor and hand–eye coordination (pegboard test) could partially be explained by more rapid development of young girls' left hemisphere. [43]

These different gender-specific rhythms in brain maturation, could suggest that a 5 to 6-year-old boy need a longer period of time to build up fine motor (small muscle and nerve) skills, which are required for detailed hand work while executing peg board task and reaction time and visual motor tasks.

CONCLUSION

In the present study it was noted that the motor ability of the primary school children was gradually increased with the advancement of age. It was also observed that the motor ability of the girls were significantly better than boys. Gradual improvement of cortex and cortico-spinal tract along with continued growth of corpus calosum and thalamo-cortical tracts and myelination of different areas of central nervous system might be possible cause of age specific motor development of the children. In present investigation normative data for cognitive skills and motor ability parameters of the Bengali population have been formed. The parameters of the norms for motor ability that help to determine the measures of the developmental progress of children such as reflexes, and responses. Such graded norms will be helpful for categorizing each of children according to their motor performance. Graded norms, especially of motor skill parameters, will be a guide for selecting the students for different indoor and outdoor sports events. On the other hand, according to the grading of motor parameters, the children with poor or lower score may be identified and special emphasis may be given on them. Some suitable training may be arranged for betterment of their skills.

Study Limitations

The selected subjects of the present study were limited to Bengali population from three different districts in West Bengal. In this present study parameters related to anatomical and volumetric changes in the children as a function of age, sex, has not been studied. The neuroanatomical and neurophysiological studies for supporting the results could not be performed. The findings of other investigation available in the literature were used for explaining the results. In the present study a cross sectional design was used to investigate developmental differences of the children.

Conflict of Interests

The authors declare that there is no conflict of interests.

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List of abbreviations

CNS- Central Nervous System
RT- Reaction Time
ANOVA- Analysis Of Variance
BMI- Body Mass Index
DH- Dominant Hand
NDH- Non Dominant Hand
SeB- Standard Error of Beta
MRI- Magnetic Resonance Imaging

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