Synopsis of the thesis

EVALUATION OF HEALTH HAZARDS DURING CLASSROOM ACTIVITIES AND AN ERGONOMIC APPROACH FOR DESIGNING A WRITING DESK FOR THE CHILDREN OF RURAL PRIMARY SCHOOL

By

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2014

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Introduction:

A school is a second home for the children. They are required to spend a considerable time in the classroom. Children have to spend about 80% of their school time in the classroom performing various activities like reading, writing, drawing and other related activities, which requires them to sit continuously for long hours. The sitting position has been found to be the most troublesome situation in connection with low back pain. Mismatches between the dimensions of school furniture and body dimensions might be the reason for the occurrence of discomfort/problems in various body parts of school children. Most of the furniture found in classrooms is not designed or suited to the anthropometric dimensions of the students. It is easy to imagine that pain and discomfort have an impact on the ability of students to focus on learning. Various studies have shown that the ill fitted design of classroom furniture have contributed to the high incidence of musculoskeletal disorders among schoolchildren. Back pain is a significant burden of primary school children. Some studies have highlighted the high prevalence of back pain that exists among school children including bad sitting posture. These exposures may be present in schools due to prolonged flexed postures caused by mismatch between children and school furniture. A greater understanding of the risk factors associated with the onset of spinal pain is important before well targeted preventative action can be taken with the aim of controlling and/or reducing back pain amongst children.

In a large number of rural primary schools of West Bengal state (also in other states of India), students are not provided with bench and desk. They sit on the floor for attending the class. They sit on a typical Indian traditional sitting posture, i.e., sitting on the floor with folded legs. Sometimes the children stretch their legs while sitting on the floor. However, in some other schools students use a unit of bench and desk for reading / writing purpose. Children observed sitting in static postures during lessons showed increased levels of upper back pain and neck pain. Sitting in the same posture for a long time causes an extremely undesirable physiological strain and the muscles, the ligaments, and the disc and that the situation is related to pain.

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When the children sat on the floor there was no question of fitting the furniture with body dimension of the user. They can sit freely on the floor. It gives the body a stable posture. Slightly forward or reclined sitting posture relieves the strain on the back muscles and makes sitting more comfortable. Slightly forward bent trunk holds body weight in balance. But, during performing their activities, the students have to adopt sharp forward bent posture. The backward rotation of the pelvis puts the spine into a state of more kyphotic and increases the pressure within the discs. Sitting in the same posture in a forward bending position for a long time puts an extremely undesirable physiological strain on the muscles, ligaments and in particular on the discs. The children may feel discomfort/pain in different parts of the body especially at neck, thigh and lumber region and muscle fatigue also occurs.

In the present study efforts have been made to evaluate postural pattern and posture related disorders of schoolboys during class work. Keeping these facts in mind, only a desk may be placed in front of the student for writing and reading.

School furniture design should be made on the basis of body dimension of the user population. Therefore, the design criteria of school furniture should be fixed by considering anthropometric dimensions of the school children. It is well known fact that the body dimension depends on nutritional status and the nutritional status influences the growth of the children. It has also been shown that the nature of the children's growth depends upon nutritional status and environmental condition, which interacts with other socio-economic, bio-physiological, and physical environmental factors. Socio-economic status plays a dominant role in the growth and physical development of the children. In view of the above mentioned aspects, the present investigation was carried out on Bengalee rural children, which included collection of data on demographic and socioeconomic particulars of the households, nutritional anthropometry, and dietary assessment of rural primary school children.

In the present study, emphasis has been given on to assess the food and nutrient intakes as well as the nutritional status of the individuals in the rural areas to provide baseline information on the growth and development of normal rural Bengalee primary school children.

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Physical growth and development was considered for designing the school furniture of the primary school children. The dimensions of the writing desk should be suitable for the users. The height of the desk should be appropriate because too high desk will impose poor posture especially in the neck as students tend to flex head and neck. A desk that is too low encourages slouching. Problems arise when the distance between the children and desk is more. The gap prevents them for getting close to the desk, thereby encouraging more bending forward. Another important consideration is the angle of the writing surface. The slope providing the writing surface may reduce the distance between the child's eyesight and the working surface. The flat surface encourages the children to bend forward.

The present study has been carried out in the schools of rural areas of West Bengal state (India). Two types of seating arrangements are noted in the primary schools, viz., school children using bench and desk units and school children do not use bench and desk unit. In the second category schools students are found to sit on the floor of classrooms.

As traditional sitting is a practice among a section of students. However, it is required to evaluate its suitability from the view points of ergonomics. A comparative study may be done with that of sitting on the bench or chair. Moreover, the traditional sitting in the classroom may be made relatively comfortable if the children can keep their back straight during reading and writing. The problem may be solved by providing a desk in front of the children while sitting on the floor of a classroom. However, the provided desk must be compatible to the children while adopting sitting posture in the classroom. So, it can be said that there is a need to design school furniture and also proper layout of those furniture based on the anthropometric measurements of the school children, which will provide a better sitting posture to them and relieving them from various bodily discomfort.

In the present investigation, the schools where both boys and girls (co-education) were studied and usually adopted Indian traditional sitting posture (sit on the floor) for attending the class, were taken into consideration. The problems of this posture were identified and an effort has been made to design a writing desk for the students while sitting on the floor.

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Aims and Objectives:

The present investigation was aimed to design a writing desk from the view points of ergonomics for the rural primary school children. The objectives of the present study are as follows:

a) To assess the pattern of food intakes as well as the growth and nutritional status of the rural primary school children to provide baseline information on the growth and development of the school students in the rural areas of West Bengal.

b) To form an anthropometric database of the rural primary school children; this may be used for designing school furniture.

c) To assess the suitability of traditional sitting posture for class room activities by subjective evaluation and EMG studies.

d) To evaluate postural variations during classroom activities.

e) To assess the musculoskeletal problems of sitting on the floor in the classroom

f) To design a writing desk, suitable for traditional sitting posture, for the rural primary school children from the viewpoint of ergonomics.

g) To evaluate the newly designed writing desk by subjective and biomechanical parameters.

Methodology:

The study was carried out in the 34 rural primary schools located at remote areas under Midnapore Sadar in West Midnapore district, West Bengal. For the study 810 (boys-410, girls-400) primary school students having age range 6 to 9 years were selected at random from 25 primary schools where the children were used to sit on the floor Another 440 children (boys-240, girls-200) were randomly selected from rest 4 primary schools where the children were provided unit of bench and desk for sitting in the classroom.

All the subjects (primary school children) were volunteered for the present investigation. Informed consents from the parents of the children were taken before performing the experiments. Anthropometric study was done on 1250 subjects. Some of

the measurements viz., body joint angle, center of gravity, electromyogram and base contact area were studied on lesser number of children who were randomly selected.

The socioeconomic status of the family of the school children was assessed by using modified Kupaswami scale with an update of income range of the year 2012.

The nutritional status of primary school students was evaluated by weighing raw foods and cooked food material. At first 1250 children (age 6-9 years) were randomly selected for dietary assessment. The respective House Holds were visited by the investigator. According the 24 hours recall and one day food record was investigated and assessed five times in each house hold. Volumes and portion sizes for the 24-hour recalls were estimated using measuring cups and spoons. For the one-day-food record individual digital kitchen scales were used. From the recorded quantity of the food, the amounts of energy, carbohydrate, protein, and fat consumed by the children were calculated by using McGraw-Hill, Food Composition Table, 2009. The daily intakes of various nutrients were computed and compared with 'Recommended Dietary Allowances for Indians' (RDI) suggested by the NNMB [NNMB. Technical Report No.21, 2002.].

Different anthropometric dimensions of the subjects were taken by means of anthropometer (Holtain), sliding caliper and steel tape by adopting proper landmark definition and standard measuring techniques.The all data were taken with the mean of three consecutive trials. The following anthropometric measurements were taken:

Weight, height and mid upper arm circumference

BMI was calculated by the following equation:

Body mass index (B.M.I.) = Weight (Kg) / Height (meter) ^{2}

The individuals of different age groups were categorized according to their protein/calorie adequacy status. The Expert Committee of Indian Council of Medical Research (ICMR) has suggested requirements for energy as the recommended allowances.

The Protein-Energy ratio was used to determine what percent of their energy value is supplied by their protein content. The following formula was used:

Protein-Energy ratio= (Energy from protein/ Total energy in diet) ×100

The musculoskeletal disorders (MSD) caused during adopting different sitting posture were evaluated by the modified Nordic questionnaire technique

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To evaluate the segmental pain, the subjective assessment was employed. A 10-point scale was used for this purpose, which was graded from no discomfort at all to maximum discomfort.

The EMG of the children was recorded by a BIOPAC System (USA) [Fig.-5.3]. For the EMG study two muscles, viz., back muscle (Latissimus dorsi) and shoulder muscle (Upper Trapezius) of the children during adopting sitting postures in the classroom. The EMG was also recorded in normal erect posture, which was taken as reference posture. The purpose of the study was to compare muscular activity levels of different selected postures displayed by 16 children (two children from each Grade and each sex).

The base contact area of the body of the students with bench or floor was determined with a planimeter in different postures, viz., standing, and sitting on bench, sitting on the floor with folded knee, and sitting on the floor with stretched leg.

The whole body centers of gravity (CG) of the students were determined in different working postures by segmental method under reference position (normal erect posture) and during adopting different sitting postures. The percentage of location of whole body CG will be determined by the length of the CG from the ground and total length (maximum) of the body in the photograph. The following equation was used:

Percentage (%) of location of CG = (Length of the CG from the ground /Total length of the body) x 100

The joint angles of the body were measured by a goniometer (Lafette, USA, Model No.- APM-I). The angles were measured in normal erect posture as well as different sitting postures in the classroom. The different joint angles e.g., neck flexion, shoulder, elbow, wrist, hip and knee were measured. The joint angles were measured in both sides of the body.

Different anthropometric measures of the school children were taken by adopting proper landmark definitions and standard measuring.

The following body dimensions were measured under traditional sitting:

a) height, b) buttock - Knee length c) knee height from floor, d) elbow height from floor, e) elbow to elbow length in writing position, f) arm reach, g) span of arms flexed at the elbows *(Spine Akimbo)..*

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The following anthropometric dimensions were taken during sitting position on the bench of the children:

> a) popliteal height, sitting, b) buttock-popliteal length, sitting c) thigh clearance height from seat d) elbow height from the seat, sitting, f) hip breadth

For the assessment of the mismatch of the bench and desk with the user children, the following measures were taken from the furniture (unit of bench and desk) which was provided by the school authority:

> i) Seat Height, ii) Seat Depth, iii) Seat width, iv) Seat to Desk Height, v) Seat to desk clearance

For the study of working postures 52 children (boys=28, girls=24; taking 13 children from each of the four Grades) were selected at random from the previously selected 840 students of different schools. The posture of each subject was recorded using a video camera (Sony Handicam). The camera leveled on a tripod, was located approximately 2 meter from the subject and positioned perpendicular to the plane of motion to decrease errors of perspective. Postural changes of the children were video recorded during class work. Afterwards, the video records were transferred to a computer and the postural changes were analyzed after setting time in it. The following major postures were studied:

> a) Sitting erect with folded legs, b) Slight trunk bend forward (Trunk flexion$>20^0$),
>
> c) Greater bending of trunk forward (Trunk flexion>45), d) Stretching legs forward.

The average interval of changing any major posture was also calculated from the recorded data. The duration of different postures in school children during attending classes was also calculated from the recorded data.

The work-rest cycle of primary school children was studied while the children spent scheduled school hour (about 5 hours). The whole day school hour was categorized into performance time during attending the class and rest period. The rest period was again subdivided into work related rest and prescribed rest (i.e. rest for tiffin break). The work related rest was considered as rest pause taken by the children during attending the class which was recorded by video graphic method.

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Work related musculo-skeletal disorder was assessed by Quick Exposure Check (QEC) method The method includes the assessment of the back, shoulder/upper arm, wrist/hand and neck, with respect to their postures and repetitive movement. The QEC checklist/assessment sheets were filled to quantify the exposure risk for the four main areas of the body (back, shoulder /arm, wrist, and neck) of the rural primary school children.

Different design concepts were developed with different new characteristics of the furniture (writing desk) on the basis of the needs of the present situation.

On the basis of characteristics of the developed design concept some prototype models of the furniture were made. An anthropometric database of the primary school children were used to develop prototype of the design of the school furniture (desk). For fabricating the desk, the wooden pieces were used.

The prototypes were given for trials to the user population to assess the suitability of the design and compatibility of the product with physical characteristics of the primary school children. This was done by direct observation as well as taking user's feedback.

The psychophysical response of the workers during using different models of newly developed furniture (desks) was studied by paired comparison tests. The paired comparison test was performed by using10-point scale (-5 to +5) to evaluate the psychophysical response of the students.

To evaluate which prototype of the newly designed desk was more suitable and comfortable, the electromyography study was done by placing the electrodes on the back muscle (viz., latissimus dorsi) and on the shoulder muscle (viz., upper trapezius) as well as different joint angles were measured and compared with that measured under traditional sitting pose.

Finally, the design was made by analyzing the behavioral pattern and preference scores of the students during attending class considering the body dimensions and other necessary parameters of the users.

The subjective evaluation was made by questionnaire method to evaluate the comparison with that of existing system and other prototypes of newly designed writing desk during attending the class. Cost analysis of the product was made by standard method.

Results and Discussions:

General demographic data of the primary school children showed that about half of the households had "kutcha" houses, and agriculture was the major occupation of the respondent's family. The socio-economic status of 1250 House Holds according to the modified Kuppuswamy Scale (Kumar et al, 2012) represented that 21% of the head of the families (males) were illiterate. Most of the earning members of those families earned Rs.2350-6550 per month approximately. The average per capita monthly income was Rs.4657. The lower socioeconomic status of the families might be related to the paucity of income sources, low wage rate, poor communication system, fewer numbers of schools etc.

From the results, it was observed that the amount of consumption of cereal product was found to be higher in boys of Grade-I and Grade-II than that of the girls of same groups but the girls of Grade-III and Grade-IV consumed higher amounts than that of the boys. The intake of pulses was very low for both boys and girls in the studied age groups. The mean intake of pulses among the boys and girls of Grade-IV was higher than that of the other grades.

When the daily food intake of the children had been compared with that of NNMB (2002) recommended values for primary school children of 6-9 yrs of age (Grade-I to Grade-IV), it was observed from the results that the amount of cereals, pulses, leafy vegetables, other vegetables, milk and oil consumed by the children of Grade-I and Grade-II were lesser (5.3%, 29.7%, 14.4%, 4%, 66.9% and 54.8% respectively) than that of the recommended values of NNMB (2002) but they took 34% and 15.8% higher amount of roots and tuber, and sugar in comparison to the recommended amount. On the other hand, the intake of cereals, pulses and vegetables by the children of Grade-III and Grade-IV were more or less the same with the recommended values of NNMB. But the intake of milk and oil, in this group, was notably lower than the recommended amounts. The proportions of cereal to pulse were 10:1 and 8.6:1 respectively for both Grade-III and Grade-IV as against 9:1 ratio suggested by Indian Council of Medical Research (1996). The energy consumption of children of the Grade-I and Grade-II was 79.8% and 74.2% of RDA respectively. The intake of energy of the children of Grade-III and Grade-IV were 22.61%

and 8.41% lower than RDA values recommended by NNMB (2002) . It was found that only 10.2% of the studied children consumed adequate amounts of both the components, i.e., protein and energy, while about 53.17% of the children consumed diets deficient in protein and energy both. About 29.9% of the children had adequate amounts of protein but inadequate amounts of calories. Thus, it was observed that the diets were predominantly more deficient in calories than the protein, with about 84% of the children consuming inadequate amounts of calories. In the present study the protein energy ratio of the boys was 10.14%, 4.88%, and 6.41% lower for the Grade-I, Grade-II and Grade-III respectively of ICMR recommended values of the corresponding age groups and in girls it was 14.5%, 2.9% and 15.8% for Grade-I, Grade-III and Grade-IV respectively of ICMR values. The protein energy ratio was slightly higher than ICMR recommended value in case of Grade-III for the boys and Grade-IV for girls. In 4.5% of boys and 10.5% of girls the protein energy ratio was lesser than 4%; the subjects were referred as unable to eat enough to satisfy protein requirements. The results showed that the height of boys of seven and eight years increased slightly better than that of the girls. But the increment of height of girls at Grade-IV was better than the boys of the same age group.

It was fount that between Grade-I, there is very little, if any, difference between boys and girls in terms of height. The average weight of boys at Grade-I was 15.43 kg and it was 21.12 kg at the Grade-IV. In case of girls, the mean value of weight was 14.14 kg and 18.63 kg at the Grade-I and Grade-IV respectively. The analysis revealed that from Grade-I onwards, the average weight was found to be lower than the respective standard weight (NNMB-2002) for both the sexes and the differences were significant (P<0.001). These differences might be due to the variation of economic condition and food habits in the children between the groups. Results showed comparison of mean weight of boys and girls with NNMB standard. When compared with NNMB standard, the mid-upper arm circumference of children of different grades, showed significantly lower (p<0.001) values in both the genders. It had been observed that about 69.5% boys and 68.5% girls of primary school had satisfactory nutritional status whereas 12.5% and 17.5% of them remained in severe malnutrition zone respectively in terms of mid-upper arm circumference. The height, weight, and BMI of Bengalee primary school children (both boys and girls were taken together for each grade) were compared with the Indian,

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Malaysian and African rural primary school children in this study. From the results it was observed that standing height and weight was higher in rural Bengalee children than that of the Indian average rural children. Bengalee children had 3.1%- 6.8% higher values in height than the NNMB values of Indian rural children of the same age groups. But the BMI was lower (3.5-5.8%) in Bengalee school children than that of the Indian children of the Grade-I – Grade-IV (6-9 years).

From the results, it was observed that most of the children (76.8%) had normal body weight and only a little number of children was overweight (7.8%) or underweight (10.7%). It was further observed that the highest percentages (about 20.19%) of underweight children were found in the Grade-III. It had been observed that correlations between carbohydrate intake and anthropometric measures were positive and significant in all grades excepting correlation between carbohydrate intake and BMI for the age groups of Grade-I and Grade-III. Protein and fat intake were significantly correlated (P<0.001) with height, weight, arm circumference, and body mass index of all age groups. The association between fat intake and anthropometric dimensions indicates the influence of fat on growth. Energy intake was significantly correlated (P<0.001) with height and BMI of the all age groups. Energy is a prime requisite for body function and growth. The body dimensions increase as the body growth takes place. The positive correlation between energy intake and body dimension supports the relationship.

From the study it appears that a large number of boys and girls of rural Bengalee children of suffer from malnutrition. The nutritional status of children is lower than the NNMB standard in terms of height, weight, BMI and MUAC (Mid-upper arm circumference). Body dimensions may temporally differ by changes in nutritional status, socioeconomic situation, as well students' weight and height changed. Hence it was essential for make a focus on the health and nutritional status of Bengalee primary school children for designing the classroom furniture for those children.

It has been pointed out earlier that in a large number of primary schools in rural areas of West Bengal state students are used to sit in the floor during attending the class. However, in some of the rural schools conventional bench-desk units are used. The discomfort of the student during attending the class was assessed for different postures adopted by the students. It was noted from the results that the problems in the thigh, knee

and lower back regions were the most prevalent among the children. A low percentage of students experienced right and left shoulder discomfort (7.41% and 7.78% respectively). Overall, most of the children reported neck discomfort (13.6-25.8%). It was found that the lower back pain was more prevalent for the Grade-IV children (boys=32.7%, girls=38.8%) than the other grades. The area of most discomfort reported by the children was the thigh. A higher percentages of children reported discomfort in the thigh region during sitting on the floor with folded legs and it was also found that the occurrence of problems was greater in Grade-IV children (Boys=77.9%, Girls=82.4%) than that of the other grades. The second most reported area of discomfort was knee area. A higher percentage of knee discomfort was found both in Grade-III (Boys=39.8%, Girls=47.6%) and Grade-IV (Boys=50.0%, Girls=43.5%) children respectively than that of the children of other graders. This might be because of compression of thigh muscle with the floor as well as due to folding of upper and lower leg at knee joint. A larger percentage of girl students reported low back pain (34%) than boy students (26.6%). Girls also had higher reports on thigh discomfort (70%) than that of boys (59%). It was noted that the frequency of occurrence of pain / discomfort was significantly higher in the children (p<0.05 or lower) while sitting on the bench than that in sitting on the floor. From the comparison of MSD (musculo-skeletal disorder) between boys and girls, it had been revealed that the girls had significantly higher incidence of MSD in different segments of the body excepting shoulder. When the children sat on the floor there was no question of fitting the furniture with body parts of the user. In other words they were not required to adjust their body with the bench and / or desk. They can sit freely on the floor. These were the probable reasons for low occurrence of discomfort or pain among the students when they sat on the floor. A lesser number of students reported thigh and knee problems during sitting on the floor with stretched leg than that of sitting on the bench.

From the study of mismatch between classroom furniture and anthropometric measures, it was revealed from the results that the sitters using bench–desk unit were more sufferer, from the view points of discomfort, than that of the children sitting on the floor. The striking reason for this might be the mismatch between furniture dimensions and users' body dimensions. Seating height (96-100%) and seat to Desk Height (95-97%) showed higher mismatch from studied schools. In the case of the higher sitting height of

seat surface, most of the students will not be able to support their feet in the floor, generating increase tissue pressure on the posterior surface of the knee.

It was revealed that during sitting on the bench the PRD was comparatively higher than that of during sitting on the floor. From this result, it was also revealed that the primary school children reported higher degree of pain/discomfort ($p<0.001$) at neck, shoulder, right upper arm, lower arm, lower back, buttock and leg for both boys and girls when they sat on the bench than that of the students sitting on the floor with folded legs. The mean value of scores (PRD) of all segments was taken as the overall discomfort rating of the students. The overall PRD was significantly higher in both boys ($p<0.01$) and girls ($p<0.05$) when they were sitting on the bench than that of sitting on the floor. The PRD score was the highest in low back segment of the body when they used bench and desk in the classroom. This might be due to ill-fitted furniture to the children.

It was observed from the results of ANOVA that the center of gravity differed significantly ($p<0.01$) due to change of the different sitting postures. The deviation of CG of different sitting postures from the reference standing erect was also differed significantly ($p<0.001$).

Lowering of CG increases the stability of the body. The shifting of CG towards upper side of body makes the body unstable and leads to impose postural load. But when the children sat on the floor by adopting two sitting pose, viz., sitting on the floor with folded legs and sitting on the floor with stretched legs, the location of CG became lowered indicating higher stability of the body. So from the above observation, sitting on the floor is better than sitting on bench from the standpoint of equilibrium of the body.

From the results, it was revealed that the EMG voltages and their RMS values from the back muscles (latissimus dorsi) and the shoulder muscles (upper trapezius) were found to vary significantly ($p<0.01$) with the change of posture. It was reduced gradually in the following sequence of postures – standing > sitting on the bench > sitting on the floor with folded legs > sitting on the floor with stretched legs.

From the study, it was observed that the positive correlation between CG and the EMG voltage indicated that the electrical response of muscles was decreased with lowered values of Center of Gravity.

The largest body contact area was found in case of the students sitting with folded legs). It was about 68.6% and 59.3% higher than that of sitting on the bench in case of boys and girls respectively. Increased body contact area in sitting on the floor yielded greater stability of the body in comparison to the sitting on the bench. There was a significant negative correlation between the body contact area and the EMG voltage of the students indicated that the electrical response of muscles is increased if the body contact area is decreased. There was a significant negative correlation between the body contact area and the percentage of location of whole body CG of the students. Thus in case of sitting with folded legs the body contact area was the higher and the CG values was lower than in case of sitting on the bench indicating greater stability of the body in the former posture.

The children sat on the floor in the class room generally by adopting four different sitting postures, viz., sitting erect, sitting with lesser forward bend, sitting with greater forward bend, sitting with stretching legs. It had been noted that the work related rest was higher in case of girls of Grade-IV and boys of Grade-III than their counterpart. The result also showed that the boys took significantly ($p<0.05$) lesser amount of work related rest than girls. This might be due to onset of earlier fatigue in girls than that of boys. This was probably due to consumption of lesser amount of food than the boys and suffered from energy deficiency. It was observed that during sitting on the floor, both boys and girls spent greater duration of time by sitting with greater forward bend (42.3% and 50.7% respectively) than that of the other postures). The duration of time spending for classroom performance were significantly ($p<0.01$) different between all of the adopted sitting postures.

It was revealed that during sitting with greater forward bend, the QEC scores were comparatively higher than that of during sitting on the floor with other sitting poses. Among the children who sat on the floor with greater forward bend, the QEC score of back was high among both boys and girls (23-29) and it was moderate in shoulder and arm (21-30) as well as wrist and hand (21-30) and high in neck (12-14) for both boys and girls. Very high degree of stress was reported by both the boys and girls while sitting on the floor with greater forward bend.

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The lumber spinal angle was found to be deviated in sitting with forward bend posture from that sitting with erect posture. The deviation of spinal angle was found higher when primary school children adopted greater bending forward during their class performances. This may create extra pressure on intravertebral disc zone of lumber segment. As a result pain was often complained by the children.

It was found that the joint angles of the children were deviated in different sitting postures from that of reference i.e., normal erect posture. From the result, it was revealed that the change of the neck flexion angle (^{o}) of sitting postures from the sitting erect differed significantly ($p<0.001$) for each grade of both boys and girls. From the results, it was revealed that the shoulder angle showed more abduction during adapting forward bend posture than that in erect sitting posture. From the results, both Grade-III and Grade-IV children, the hip angles vary significantly ($p<0.01$) with the change of the different sitting.

The absolute EMG voltages and RMS values of the back muscle (Latissimus Dorsi) and shoulder muscle (Upper Trapezius) were found to vary significantly ($p<0.01$) with the different sitting postures. It was increased gradually in the following sequence of postures – sitting erect > sitting with stretched legs > sitting with lesser forward bend > sitting with greater forward bend.

From the above study, it was found that the myoelectical values of both muscles during adopting sitting with greater forward bending were significantly higher ($p<0.001$) than the other sitting postures of both boys and girls. It can be concluded that the disadvantage of bending sitting posture is indeed the fundamental cause of backache.

The school furniture should be made on the basis of the anthropometric dimensions of the user population (school children). Results reflected that no significant variations in body dimensions were found between the boys and girls of Grade-I to Grade-III except the arm reach and spine akimbo of boys with girls of Grade-III ($p<0.001$). However, most of the anthropometric dimensions of the schoolboys differ significantly ($p<0.05$ or less) from girls of Grade-IV.

Various percentile values (5th, 50th and 95th) of different anthropometric dimensions of the schoolchildren of different grades were computed for the purpose of designing school furniture and layout of the classroom. It was found that differences between mean values of various anthropometric dimensions of grade I and grade II were not vary much for both boys

(0.1% to 8.9%) and girls (1.0% to 8.4%). The mean differences (%) of different anthropometric dimensions of the children between grade III and grade IV were not appreciably large (2.8% to 10.3% for boys; 1.3% to 9.5%).

There are many variations in body size among primary school children. Provision of adjustable benches and desks might appear a suitable solution, but especially young children might have great difficulties in adjusting that furniture to their size and liking. Moreover, adjustable seats and desks are costlier than the ordinary one. Therefore, it will be suitable to make fixed design of school furniture considering the anthropometric data of primary school children.

The seating furniture adapted to body dimensions increased the learning effectiveness. While all the components of classroom environment are important, furniture for seating require special attention as it facilitates the functioning of students in a classroom. Common locations for discomfort whilst reading from paper included eyes, neck, mid back, and head. Keeping above all facts in mind, if a suitable desk is placed in front of the student for writing and reading, they may overcome musculoskeletal stresses. As the elbows get support on the writing desk, the work surface come closer to the children, the lumbar backbone move less forward in order to balance the force. As a result, backbone is about to drawn straight and the body will naturally sit up correctly. Thus, this kind of sitting posture is naturally popping up vertebral column, raising head and straightening chest, keeping a safe distance between eye and work surface. Hence there may be the chances of improving posture and reducing the stresses during doing class work. Therefore, efforts have been made to provide a desk, which would be suitable for the students while sitting on the floor. Dimension for designing a writing desk, the required body dimension were selected which are followed:

Desk height (5th percentile of the elbow rest heights from the floor), Desk depth (95th percentile of arm reach), Length of desk (the 95th percentile of elbow-to-elbow length in writing condition).

For the design of writing desk for the primary school children, the wood was preferred as the material for furniture.

For the optimization of desk height three prototypes of desk were prepared viz., Prototype-I (desk height-17.0 cm), Prototype-II (desk height-19.0 cm) and Prototype-III

(desk height-21.0 cm). from the results, it was found that the EMG of shoulder muscle (upper trapezius) and back muscle (latissimus dorsi) of the children were the lowest when they performed their class work by using prototype-II compared to other prototypes. it was found that there was a significant differences ($p<0.01$) of neck flexion angle of the primary school children between the sitting postures without writing desk as well as by using different Prototypes. The deviation of neck joint angle, shoulder angle elbow angle and hip joint angle in both boys and girls was lower in case of using desk Prototype-III than that of the Prototype-I and Prototype-II. From the results, it was revealed that the lumber spinal angle and deviations of spinal angle of the children during using different desk prototypes from that of normal erect posture were found to vary significantly ($p<0.01$). More the angle deviated from the reference position making the sitting posture more slumped. Considering the results of both boys and girls, it may be stated that for adopting a good back posture the prototype -III might be better than other two models. From the result, it was noted that the Prototype-III (PR-III) having a desk height of 21.0 cm showed the best users' response score among three prototypes. The users felt better comfort and easiness during using PR-III in comparison to other prototype models of writing desk.

For the assessment of inclination of writing surface, three prototypes were prepared viz., the work surface with flat tops (Prototype-1), prototypes with 10^0 (Prototype-2) and 15^0 (Prototype-3) slope in the working surface. The deviation of neck joint angle (in both boys and girls was lower in case of using desk Prototype-3 than that of the Prototype-1 and Prototype-2. It was observed that there was no such difference between the shoulder angles when the children sat with different prototypes. No significant difference was also found between the reference sitting posture and sitting with different Prototypes.

The deviation of elbow joint angle in both boys and girls was lesser during sitting with Prototype-2 than that of other Prototypes. The minimum deviation of elbow angle in case of the Prototype-2 indicated that there was lowest degree of abduction of upper arm during working with the said prototype. So, the children would have lesser discomfort during using the Prototype-2. The results indicated that there was lesser deviation of hip angle in both boys and girls during using Prototype-3 than that of other prototypes. Such lower deviation of hip angle meant lower degree of bending during using the prototype desk. A greater deviation of hip angle of the students during performing class activities by

sitting on the floor might be the cause of the back pain because the students had to bend forward due to lack of an appropriate working surface.

From the results, it was revealed that deviation of spinal angle was found lesser when primary school children used to sit with Prototype-3 during their class performances. Considering the results of both boys and girls, it may be stated that for adopting a good back posture the prototype -3 might be better than other two models.

From the above results, it was observed that the spinal was lesser kyphotic during using desk with 15^0 slope (Prototype-3) than other two types, viz., desk with flat surface (Prototype-1) and desk with 10^0 slope (Prototype-2). So, first one gives lesser stress on spine and make the task for the children easier. From the results it was noted that the prototype PR-3 had highest preference scores among three models. Thus it indicated that the desk with 15° slope was better than the other two prototypes according to the preference of the users.

A book case may be provided in the desk. This was an important facility that provides space for keeping books and writing materials etc. For providing book space, the design of desk was modified without altering the proposed dimensions, viz., desk height, desk length, desk width and desktop inclination selected by the students' preference.

The dimensions of the book case were made lower than that of the size of the desk top. The depth of the book case was 15 cm from the lower side of the desk top. Thus there was gap of 6 cm between the lower side of the book case and the ground. The length and width of the book case was lesser than that of the desk top by 6 cm and 3 cm respectively. The book case was mounted under the desktop, as it was convenient to pick books and other writing materials while sitting erect. This provision is presumed to reduce awkward posture that student's normally take when they leave their books on floor.

The result showed that the desk with book case (WBC) had got the higher preference score than that of desk without book case (WOBC). This indicated that the students had preferred the book case for keeping their books and other study materials.

The results showed that the sensation pain in the neck was less prevalent among the children while using desk (boys: 6% and girls: 4.4%) than that of the sitting without the desk (boys: 82% and girls: 86.7%). The percentage of affected students was significantly lower ($p<0.001$) while attending the class with newly designed desk than that of without

using desk. This was because during sitting without desk, the children should bend their body forward to reach their work surface (floor) and thus they were required to flex their neck forward. Forward tilting of neck may be the reason of neck pain. Similar trend of results was also noted in case of pain in shoulder. A large number of subjects (boys: 54% and girls: 73.3%) reported discomfort or pain in their shoulder while they sat without desk; however, the percentage of respondent was also reduced significantly ($p<0.001$) (boys: 14% and girls: 11.1%) in case of using desk. Only 38% boys and 24.4% girls reported discomfort in their elbow during sitting without desk. A significantly higher percentage of children reported pain ($p<0.001$) at the back (boys:78%, girls:82.2%) when the children sat without the desk than that of sitting with desk (boys:34%, girls: 28.9%). This was due to the forward bending pose that the children were compelled to adopt to reach the working surface (floor) when they sat without any desk in front of them. From the subjective assessment it appeared the newly designed desk is more suitable for the rural primary school children for betterment of sitting posture.

From the results of the productivity study it has been revealed that there was a little increase in productivity (12.4% for boys and 13.1% for girls) in case of using the newly designed desk. The children were habituated to perform their writing task on the floor. But they were not so habituated with newly designed desk. This might be the reason for a little increase in productivity with newly designed desk. However, it is expected that after regular use of desk, the productivity would be increased further.

It was found that writing desk was much cheaper than the bench and desk unit. So the school authority can adopt this design protocol without changing the conventional sitting habit on the floor.

Conclusions:

The main goal of the present study was to design a writing desk for the primary school children. Efforts have been made to make the design compatible to the body size and posture adopted by the children. From the present study, it was revealed that the protein and of energy consumption was lower than the recommended values of NNMB (2002). The children belonging to the lower economic class were deprived from sufficient

nutritive foods for their fulfilment of body requirements. The body height and weight of the present children were higher than that of the Indian rural school children of same age groups but BMI and arm circumferences were lower in case of Bengali rural children than Indian rural children. BMI and arm circumference are two very good indicators for evaluating nutritional status of the children. Most of the studies are based on BMI. MUAC also showed similar results compared to BMI in this study. The study revealed a prevalence of malnutrition among the primary school children of studied rural area of West Bengal and nature of malnutrition indicated that the causes of malnutrition were not only poverty but also the lack of proper selection of nutritive food items.

In a large number of primary school children in the rural areas of West Bengal were not provided with bench and desk for their class performances. That was probably due to the economic burden of school authority. But some of the primary schools were able to provide a unit of bench and desk for the primary school children. But those were not sufficient for the children in a classroom. It was found that in most of the schools children could not get sufficient space for seating on the bench provided. The study of match/mismatch between school furniture measures and anthropometric dimension of the children revealed a substantial frequency of mismatch especially for desk height, seat height and seat depth. Deviations from the defined accepted limits, that is, the extent of mismatch varied among the children of different age groups and between the genders signifying their special requirements and their different potential problems. Thus it may be stated that the school authority should be aware about the need of comfortable and optimum accommodation of students in the classroom. Ergonomically designed classroom furniture may solve the problems of seating in the classroom.

The children spend about 4-5 hours in the school and about to 3 hours for class performances. Uncomfortable postures could be painful for the children due to the spending prolonged periods at the school. Most of the cases, it was also observed that the bench height as well as the desk height was not suitable for children considering ergonomic point of views. Therefore very often they complained pain/discomfort at different body parts. Most complained parts were neck, lower arm, lower and upper back, buttock and thigh region. Probably it was an important reason of absence mind and absenteeism of school. The girls were found more susceptible for suffering MSDs than that

of boys. This difference might be related to the difference in body composition and the physiological limitations of the girls.

From the studies of different parameters , viz., centre of gravity and EMG , it was revealed that the stability of the body became greater as well as the effort of back muscle (latissimus dorsi) and shoulder muscle (upper trapezius muscle) became lower during adopting traditional Indian sitting posture than sitting on the bench. Lower value of CG during sitting on the floor denoted downward location of CG indicating the higher equilibrium state of body. Increased body contact area in sitting on the floor produced greater stability and balance of the body in comparison to the sitting on the bench. The results of the study of body contact area supported this view. Greater contact with the support surface plays an important role in maintaining a comfortable stance which may be applicable to sitting. Thus it may be suggested that the sitting on the floor with folded legs may a better sitting posture for the primary school children in comparison to sitting on the bench.

During sitting on the floor, body weight was mostly supported by hips and legs. When children were used to read or write they were compelled to maintain forward bend pose because the books and exercise books were kept on the floor which may be the fundamental cause of backache. The current study showed the higher degree of discomfort that might be associated with awkward sitting posture like bending forward.

Musculoskeletal disorders and postural stress was reduced by providing a writing desk in front of the children. A writing desk was designed by considering the body dimension and posture adopted by the children in the class room. The newly designed desk uplifted the spine and corrected the forward head/neck tilt during sitting in the classroom compared to the traditional sitting posture, i.e., sitting on the floor with folded legs. The newly designed desk increased the angle between trunk and thigh, thus producing a more neutral lumbar position than that of without desk. The results of the student posture analysis revealed that the newly designed desk had better and comfortable poses, which denoted by different body joint angles like, neck, back, and hip, in comparison to the traditional sitting posture on the floor without using desk. The analysis of student's preference score indicated the acceptability of the writing desk in the classroom. They

preferred desk height, desktop inclination and provision for bookcase in the newly designed furniture.

As the cost was lesser than other school sitting furniture, the school authority can adopt this design for the classroom. Even with good seating, some efforts are still required on the part of the child. Poor postural habits, once established, are difficult to remove. So it is essential that the child is frequently reminded by the teacher to adopt a natural and relaxed posture, bending from the hips rather than the waist when writing.

The present study focused on the suitability of school furniture design to the anthropometric characteristics of Bengali rural primary school children of 6 to 9 years. The design of a writing desk was finalized after a lot of trials and consultations with children. One of the drawbacks of the newly designed desk was that it required larger space in the classroom than the earlier condition (no desk) because each child would use one desk and some gap between two desks should be kept as walking for the children. A change in the design may reduce the problem of space occupancy. An alternative design of desk with larger length may be developed where two children can be accommodated. Thus number of aisle in the class room can be reduced which may be a measure for reducing the requirement of space.

There is another scope of further study for arranging proper layout of the desk in the classroom. This should be designed considering the anthropometric dimension and user's operational behavior. The layout can be designed considering the desk size, space required between two rows of desk (aisle) as well as total area of classroom etc.

Further investigation may be made to change in the design so that the children may get more freedom of movement while using the desk. It may be achieved by removing the bookcase from its place and shifting it elsewhere. Thus the students can stretch their legs beneath the desk top occasionally. It may help the students to get rid of continuous folding of legs at knee joints. The suitability of placing the bookcase in the side of the desk may be investigated.

Another investigation may be undertaken for designing the adjustable desk because there were variations of different body dimensions of children of different grades as well as gender. It may be pointed out that there is enough scope for redesigning the desk.