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Biomechanical Approach for evaluating Musculoskeletal Problems in Girl's Students of General Schools and Madrasah in West Bengal, India

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Abstract

Introduction: Musculoskeletal disorders (MSDs) are becoming increasingly common among school-aged children, particularly adolescent girls, due to prolonged exposure to ergonomically unsuitable classroom environments. This study examines the prevalence and patterns of MSDs among 603 female students aged 10–15 years, drawn from two High Madrasahs and two General Schools in West Bengal, India. **Methods:** Data were collected through the Standardized Nordic Questionnaire and a Visual Analogue Scale (VAS), enabling students to self-report discomfort across ten body regions. Additionally, postural assessments were conducted using goniometric analysis of joint angles and photographic evaluation of the centre of gravity (CG). **Results:** Findings revealed a notably high incidence of discomfort in the neck (84.21%), lower arms (80.00%), and trunk (72.00%) among 15-year-old Madrasah students. In contrast, students from General Schools demonstrated greater deviations in shoulder and elbow joint angles, primarily due to mismatched desk heights. The knee joint exhibited the highest angular deviation, indicating significant stress from prolonged sitting. Center of gravity assessments indicated a forward shift in both vertical and horizontal axes during working postures—particularly among General School students—suggesting a tendency toward forward-leaning and poor spinal alignment. **Conclusion:** These results highlight the critical need for ergonomic intervention in classroom furniture design to better match students' anthropometric dimensions. Prolonged use of inappropriate seating significantly contributes to MSDs, with the impact intensifying with age and extended exposure. Effective mitigation strategies, such as posture education, ergonomic furniture redesign, and structured posture breaks, are essential to reduce biomechanical stress. This study underscores that ergonomic improvements are not merely a matter of comfort but are fundamental to safeguarding the health and enhancing the academic performance of adolescent girls.

Keywords: Adolescents, Musculoskeletal Disorders (MSDs), Prevalence, Posture, Awareness

Resumen

Introducción: Los trastornos musculoesqueléticos (TME) son cada vez más comunes entre los niños edad escolar, en particular las adolescentes, debido a la exposición prolongada a entornos de aula ergonómicamente adecuados. Este estudio examina la prevalencia y los patrones de los TME entre 603 estudiantes mujeres de 10 a 15 años, extraídas de dos madrasas superiores y dos escuelas generales en Bengala Occidental, India. Métodos: Los datos se recopilaron a través del CuestionarioNórdicoEstandarizado y una Escala Visual Analógica (EVA), lo que permitió a las estudiantes de informar el malestar diez regiones corporales. Además, se realizaron evaluaciones posturales mediante análisis goniométrico de los ángulos articulares y evaluación fotográfica del centro de gravedad (CG). Resultados: Los hallazgos revelaron una incidencia notablemente alta de malestar en el cuello (84,21%), antebrazos (80,00%) y tronco (72,00%) entre las estudiantes de madrasas de 15 años. Por el contrario, las estudiantes de escuelasgeneralesdemostraronmayoresdesviacionesenlosángulosarticulares de loshombros y loscodos, principalmentedebido a la falta de coincidenciaen las alturas de lospupitres. La articulación de la rodilla presentó la mayor desviación angular, lo que indica un estrés significativo por estar sentado durante períodos prolongados. Las evaluaciones del centro de gravedad indicaron un desplazamiento hacia adelante, tanto vertical como horizontal, durante las posturas de trabajo, especialmente entre estudiantes de la escuela general, lo que sugiere tendencia a la inclinación hacia adelante y una mala alineación de la columna. Conclusión:

Estos Resultados Resaltan la necesidad crucial de una intervención ergonómica en el diseño del mobiliario del aula para que se ajuste mejor a las dimensiones antropométricas del alumnado. El uso prolongado de asientos inadecuados contribuye significativamente a los TME, y su impacto se intensifica con la edad y la exposición prolongada. Estrategias de mitigación eficaces, como la educación postural, el rediseño del mobiliario ergonómico y los descansos posturales estructurados, son esenciales para reducir el estrés biomecánico. Este estudio subraya que las mejoras ergonómicas no se limitan a la comodidad, sino que son fundamentales para proteger la salud y mejorar el rendimiento académico de las adolescentes.

Palabras Clave: Adolescentes, Trastornosmusculoesqueléticos (TME), Prevalencia, Postura, Concienciación

Introduction

Musculoskeletal disorders (MSDs) are a significant health concern among students of various ages and academic levels. MSDs are defined as injuries or dysfunctions of the musculoskeletal system, including nerves, tendons, muscles, joints, ligaments, bones, and supporting structures such as intervertebral discs (Jemeela et al., 2018).These conditions can result from acute or cumulative trauma causing pain or sensory disturbances in areas such as the back, neck or shoulders.

Numerous studies (Shehab et al., 2004; Bejia et al., 2005; Mohammad and El-Sais., 2013) have highlighted the high prevalence of MSDs among school- aged children, particularly due to the prolonged use of ill-fitted classroom furniture. Students often spend 6-7 hours daily seated at desk and chairs of arbitrary sizes, fostering poor postural habits such as the persistent “head down” posture. Overtime, these prolonged exposures to improper sitting positions lead to fatigue and eventually, chronic MSDs. These disorders often have long-term consequences persisting into adulthood (Science Direct).

Indian Schools, particularly in rural areas, are no exception. Limited resources and funding make it challenging to address basic needs, let alone prioritize ergonomic furniture design. Madrasah schools, which primarily cater to muslim students, face additional funding challenges. These systematic limitations likely increase the prevalence of MSDs among students.

Despite the numerous studies examining the causes of MSDs, limited research has focused on girls students in high schools and madrasahs in West Bengal. A previous study by the authors assessed the mismatch between classroom furniture and anthropometric measurements in madrasah girl students, revealing a high degree of mismatch (Parvin and Dhara, 2018). This mismatch indicate significant risk of MSDs in this demographic.

Objectives

To evaluate the health hazards experienced by girl students while attending classes in Select High Madrasah and general School in the State of West Bengal.

Materials and Methods

Selection of Site and Subjects

Four Schools in West Bengal region were selected for the study: two High Madrasahs and two General Schools. A total of 603 students aged 10 to 15 years, from classes V to X, participated in the study**.**

Evaluation of the Musculoskeletal Disorder

The Nordic questionnaire (Kuorinka et.al, 1987) was employed to determine the prevalence of MSDs. Students were provided with a visual Analogue scale (VAS) to score their pain levels while sitting on the bench during attending the class when working on the desk, on a scale of 0-10.

Body Part Discomfort (BPD) Rating

In present study, human body was divided into 10 segments (Fig: 1) for subjective assessment of discomfort. A modified pain mapping scale (Corlette and Bishop, 1985) rated discomfort on a 10-point scale, categorized as mild (1-4), severe (5-7) or very severe (>7).

Joint Angle Measurement

Joint angles were measured using a goniometer (Lafette, USA, Model APM-I) in both erect and working postures.

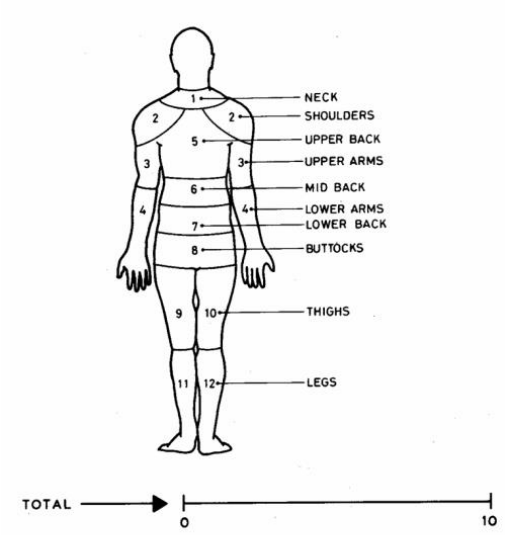

Figure 1. Different segments of the body

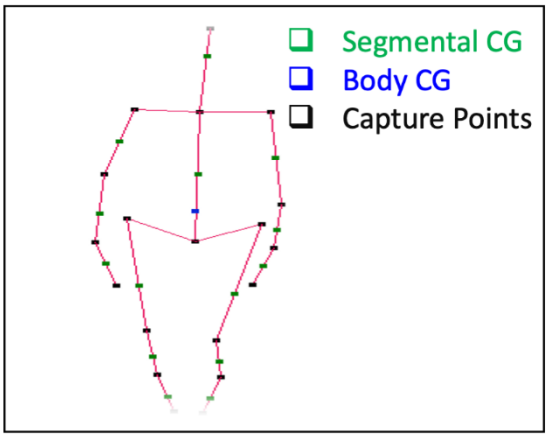

Figure 2. Static Posture

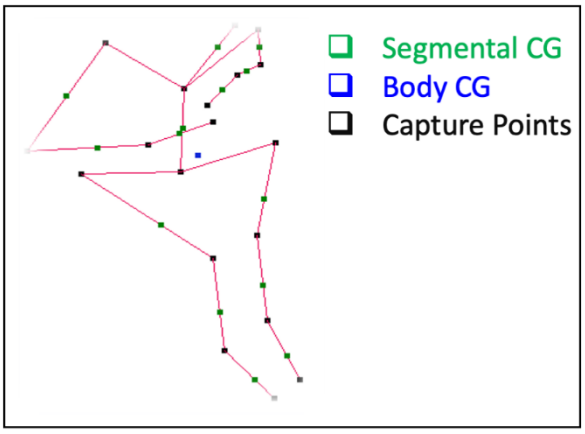

Figure 3. Sitting posture while attending Class

Joint Angle Measurement

Joint angles were measured using a goniometer (Lafette, USA, ModelAPM-1) in both erect and working postures.

The following joint angles were evaluated:

- **Neck flexion angle:** Measured between the trunk and neck/head segment.
- **Shoulder joint angle:** Assessed between the trunk and upper arm.
- **Elbow joint angle:** Angle between upper arm and lower arm.
- **Wrist joint angle:** Measured theangle between the lower arm and hand.
- **Hip joint angle:** The hip joint angle is the angle between trunk and thigh.
- **Knee joint angle:** Evaluated between the thigh and lower leg**.**
- **Ankle joint angle:** Measured between the lower leg and foot.

Center of Gravity Measurement

The center of Gravity (CoG) was determined using the segmental method (Page, 1978) in normal and working postures. Photographs of students were analyzed using adobe Photoshop and Wise Analyst Software to locate the Horizontal CoG and vertical CoG. In terms of percentage of total length of the subject in the photograph, by using the formula:

Vertical CoG (%) = (Height of whole body CoG/ Full length of subject)*100

Horizontal CoG (%) = (Distance of CoG from the left border of the baseline/distance of the baseline from left and right border)*100

Statistical analysis

Data were summarized as mean and standard deviation values using Microsoft Excel. Statistical analyses, including ANOVA, t-test and Chi-square tests were conducted using Origin 6.1 software.

Results and Discussions

Prevalence of MSDs

Table 1 highlights the prevalence of MSDs in various body segments while students worked at their desk. Neck pain was the most prevalent (84.21%) among 15-year old madrasah students, followed by lower arm discomfort (80.00%) and trunk pain (72%.00). Desk heights were too high contributed to these conditions. Lower back pain was more frequent among students aged 12-15 years, likely due to prolonged fixed postures. Compression of thigh muscles and knee joints also lead to significant discomfort in these areas. These issues could be mitigated by encouraging regular posture changes and designing ergonomic furniture.

Perceived rate of Discomfort (PRD)

Table 2 summarizes the PRD across different body segments using a 10-point scale. Neck and lower arm segments exhibited higher discomfort levels across age groups. High neck flexion and static, awkward postures were key contributors (Murphy et al., 2007; Grimmer et al., 1999). Additionally, carrying heavy schoolbags exacerbated forward leaning of the head and trunk (Pascoe et al., 1997).

Gender and age influenced

The prevalence of neck and shoulder pain was significantly influenced by poor desk height and inadequate backrest design. Prolonged sitting and postural habits in the classroom were primary factors contributing to MSDs in students.

Analysis of body joint angles

Table 3, represents mean joint angles (±SD) in standing and witting on the bench postures, along with deviations for 12 and 13 years old girls in madrasah and general schools.

Shoulder Joint (Left and Right)

- Both left and right shoulder angles exhibit significant deviations from standing to sitting posture, indicating forward arm elevation when writing.

12 years: Madrash students show deviations of -40.30º (L) and -37.81º (R), while general school students show larger deviations of -41.62º (L) and -39.82º (R).

13 years: Deviations are smaller compared to 12-years-old: Madrasah -24.00º (L) and -38.59º (R); general school -22.50º (L) and -34.60º (R).

Interpretation

General school students tend to elevate their arms more than madrasah students when writing, which might be due to different desk heights.

Table 1. Frequency and Percentage (%) of musculoskeletal disorders (MSD) reported while working on the desk (N=603) in class.

Body Segment	Classes											
	10 years (n=103)		11 years (n=123)		12 years (n=129)		13 years (n=106)		14 years (n=77)		15 years (n=63)	
	Madrasah (n=37)	**General School (n=66)**	**Madrasah (n=53)**	**General School (n=70)**	**Madrasah (n=44)**	**General School (n=85)**	**Madrasah (n=41)**	**General School (n=65)**	**Madrasah (n=34)**	**General School (n=43)**	**Madrasah (n=38)**	**General School (n=25)**
Neck	17 (45.95)	34(51.52)	25 (47.17)	33**(47.14)	11(25.00)	28(32.94)	21(50.00)	20*(30.77)	22 (62.86)	27*(62.79)	**32 (84.21)**	19(76.00)
Shoulder	20 (54.05)	22*(33.33)	27 (50.94)	32 (45.71)	19 (43.18)	28(32.94)	21 (50.00)	31 (47.69)	14 (40.00)	19 (44.19)	23 (60.53)	16(64.00)
Upper Arm	17**(45.95)**	12**(18.1)	14(26.42)	19 (27.14)	11 (25.00)	23(27.06)	13 (30.95)	21 (32.31)	6 (17.14)	11 (25.58)	9 (23.68)	6 (24.00)
Elbow	15 (40.54)	25 (37.88)	33 (62.26)	29*(41.43)	13 (29.55)	21(24.71)	27 (64.29)	36 (55.38)	15 (42.86)	19 (44.19)	16 (42.11)	14(56.00)
Lower Arm	22 (59.46)	33 (50.00)	17 (32.08)	32 (45.71)	33 (75.00)	59(69.41)	28 (66.67)	44 (67.69)	17 (48.57)	22 (51.16)	30 (78.95)	20(80.00)
Wrist	12 (32.43)	25 (37.88)	14 (26.42)	23 (32.86)	12 (27.27)	23(27.06)	19 (45.24)	24 (36.92)	16 (45.71)	22 (51.16)	12 (31.58)	8 (32.00)
Trunk	4 (10.81)	20*(30.03)	15 (28.30)	33* (47.14)	20 (45.45)	39(45.88)	27 (64.29)	42 (64.62)	17 (48.57)	21 (48.84)	26(68.42)	18(72.00)
Hip	1 (2.07)	3 (4.55)	4 (7.55)	3 (4.29)	1 (2.27)	3 (3.53)	11 (26.19)	15 (23.08)	3 (8.57)	5 (11.63)	2 (5.26)	2 (8.00)
Thigh	8 (21.62)	17 (25.37)	12 (22.64)	17 (24.29)	10 (22.73)	30(35.29)	11 (26.19)	15 (23.08)	6 (17.14)	9 (20.93)	8 (21.05)	7 (28.00)
Knee	7 (18.92)	12 (18.18)	25 (47.17)	19* (27.14)	20 (45.45)	41(48.25)	17 (40.48)	28 (43.08)	16 (45.71)	21 (48.84)	17 (44.74)	12 (48)
Calf	15 (40.54)	25 (37.88)	22 (41.51)	25 (35.71)	4 (9.09)	12(14.12)	6 (14.29)	13 (20)	4 (11.43)	7 (16.28)	7 (18.42)	5 (20.00)
Ankle	7 (18.92)	20 (30.03)	21 (39.62)	25 (35.71)	12 (27.27)	23(27.06)	13 (30.95)	26 (40.00)	6 (17.14)	8 (18.06)	14 (36.84)	10(40.00)
Feet	7 **(18.92)**	7 (10.61)	9 (16.98)	8 (11.43)	0(0.00)	0(0.00)	4 (9.52)	8 (12.31)	4 (11.43)	6 (13.95)	0 (0.00)	0 (0.00)

W.r.t. Madrasah*p<0.05, **p<0.01

Table 2. The perceived rate of discomfort (PRD) Mean ± SD in different segments of the body (in a 10 point scale).

Body Segment		Age (Years)											
		10 years (n=103)		11 years (n=123)		12 years (n=129)		13 years (n=106)		14 years (n=77)		15 years (n=63)	
		Madrasah (n=37)	General School (n=66)	Madrasah (n=53)	General School (n=70)	Madrasah (n=44)	General School (n=85)	Madrasah (n=41)	General School (n=65)	Madrasah (n=34)	General School (n=43)	Madrasah (n=38)	General School (n=25)
Neck		0.78±0.95	1.06±1.08	0.81±1.02	1.03±1.19	1.63±1.02	0.73±1.10	1.00±1.05	0.71±1.06	1.12±0.91	1.30±1.17	1.03±1.20	1.44±1.04
Shoulder	Right	0.76±1.12	0.56±0.99	1.02±1.12	1.01±1.26	0.68±0.91	0.74±1.22	0.80±0.93	0.75±0.95	1.03±1.11	1.21±1.21	1.11±1.45	1.08±1.26
	Left	0.49±0.99	0.30±0.70	0.32±0.75	0.67±1.46	1.05±1.58	0.74±1.21	0.29±0.81	0.23±0.61	1.00±1.18	0.98±1.16	1.05±1.49	0.88±1.30
Upper Arm	Right	1.14±1.80	1.18±2.01	1.11±1.91	0.43±1.25*	0.77±1.52	0.28±0.77*	0.68±1.80	0.69±1.14	0.76±1.23	0.33±0.84	0.34±0.75	0.56±1.19
	Left	1.00±1.68	1.02±1.88	1.04±1.89	0.16±0.71***	0.23±0.89	0.42±1.23	0.41±1.16	0.34±1.00	0.47±0.96	0.47±1.01	0.26±0.79	0.40±0.87
Lower Arm	Right	2.14±1.58	2.11±1.84	2.23±1.71	2.20±1.89	2.50±1.11	1.75±1.45**	2.44±1.05	2.17±1.34	1.41±1.33	1.65±1.36	2.03±1.35	1.68±1.22
	Left	0.95±1.35	0.98±1.72	1.15±1.13	0.94±1.40	1.16±1.20	0.85±1.06	0.73±1.07	0.62±1.10	0.88±1.30	0.53±1.12	0.79±1.28	0.72±1.10
Upper Back		0.05±0.33	0.14±0.52	0.23±0.93	0.10±0.59	0.48±1.17	0.29±0.95	0.20±0.60	0.18±0.58	0.12±0.69	0.26±0.82	0.34±1.10	0.44±0.92
Middle Back		0.19±0.62	0.14±0.78	0.70±1.44	1.01±1.64	0.84±1.52	1.06±1.78	1.63±1.95	1.60±2.00	1.71±1.93	2.05±1.68	2.03±1.82	2.16±1.84
Lower Back		0.00±0.00	0.55±1.00**	0.28±1.04	0.87±1.38**	0.91±1.49	1.64±1.73*	1.59±1.58	2.02±1.62	1.59±1.64	1.86±1.71	2.18±1.81	1.96±1.72
Buttock		0.00±0.00	0.06±0.49	0.30±0.97	0.17±0.72	0.07±0.47	0.00±0.00	0.02±0.16	0.00±0.00	0.24±0.96	0.37±1.09	0.11±0.45	0.00±0.00
Thigh	Right	0.35±0.75	0.39±0.78	0.53±1.25	0.63±1.38	0.39±0.99	0.28±0.85	1.00±1.66	1.25±1.76	1.03±1.49	1.02±1.42	1.55±1.78	1.56±1.78
	Left	0.46±0.84	0.30±0.72	0.43±1.03	0.64±1.53	0.52±1.19	0.56±1.26	1.05±1.72	0.86±1.51	1.06±1.59	1.07±1.49	1.47±1.84	1.36±1.44
Leg	Right	1.84±1.21	1.14±1.23**	2.75±1.60	2.16±1.78	1.61±1.75	1.15±1.65	1.34±1.39	1.26±1.46	1.03±1.40	1.12±1.43	1.63±1.75	1.56±1.73
	Left	1.41±1.36	1.27±1.40	1.79±1.81	1.46±1.71	1.25±1.50	1.01±1.45	1.20±1.38	1.11±1.38	1.03±1.45	1.09±1.39	1.37±1.72	1.40±1.61
Over all discomfort rating on the body		0.89±1.32	0.75±1.35	0.98±1.53	0.90±1.50	0.86±1.37	0.82±1.37	0.96±1.39	0.98±1.43	0.96±1.37	1.02±1.38	1.19±1.56	1.23±1.47

W.r.t. Madrasah*p<0.05, **p<0.01,***p<0.001

Table 3. Mean ±SD of joint angles (In degrees) of the secondary girl's students of different age groups in normal erect posture and during writing on the existing school furniture.

Body joint angles		10 years (N=91)						11 Years (N=126)					
		Madrasah (N=27)			General School (N=64)			Madrasah (N=56)			General School (N=70)		
		Standing	writing on the Bench		Standing	Writing on the Bench		Standing	Writing on the Bench		Standing	Writing on the Bench	
		Angle (°)	Angle (°)	Deviation (°)	Angle (°)	Angle (°)	Deviation(°)	Angle (°)	Angle (°)	Deviation(°)	Angle (°)	Angle (°)	Deviation (°)
Shoulder	L	34.11±6.05	67.22±22.76	-33.11	27.91±5.29	49.17±19.97	-21.27*	28.18±5.10	67.71±25.33	-39.54	24.29±9.07	71.26±23.63	-46.97
	R	32.96±5.37	62.33±23.70	-29.37	27.94±5.31	69.61±23.45	-41.67*	28.43±5.04	60.21±22.82	-31.79	24.23±8.34	59.39±19.78	-35.16
Elbow	L	167.9±6.67	91.63±16.17	76.30	166.27±7.34	84.81±31.51	81.45	162.23±19.09	85.50±19.81	76.33	166.27±5.04	90.00±16.57	76.27
	R	166.1±4.50	91.30±13.75	74.81	167.13± 6.31	90.33±23.86	76.80	164.91±5.77	85.57±22.18	79.34	166.06±5.61	102.71±29.92	63.34**

Wrist	L	176.8±4.07	167.5±12.66	9.33	177.22±2.21	169.28±12.25	7.94	174.46±3.82	170.57±10.20	3.89	176.67±2.92	173.76±6.36	2.91
	R	178.5±2.29	164.7±12.53	13.85	177.16±2.63	171.3±13.09	5.83*	175.18±3.33	167.0±14.19	8.14	176.13±12.23	157.47±29.05	18.66*
Hip	L	166.2±3.99	118.4±38.42	47.78	171.95±4.74	113.8±34.08	58.09	164.50±6.57	101.18±10.71	63.32	163.85±5.07	103.43±13.42	60.43
	R	164.6±5.68	121.5±42.12	43.15	171.31±5.13	105.03±16.39	66.28***	165.73±5.24	114.5±33.75	51.21	162.91±3.63	120.06±32.83	42.86
Knee	L	175.4±3.09	108.3±42.60	67.11	173±3.82	112.05±33.51	60.95	171.52±4.88	88.80±20.55	82.71	170.76±5.39	84.37±16.15	86.39
	R	177.1±1.82	112.9±43.05	64.22	173.25±4.39	89.44±20.63	83.81**	172.82±5.02	115.23±39.04	57.59	173.76±5.20	118.44±36.89	55.31
Ankle	L	99.44±6.46	94.04±12.00	5.41	102.53±7.86	99.89±15.32	2.64	101.32±11.84	95.98±10.64	5.34	100.76±6.81	93.30±11.46	7.46
	R	98.48±5.95	96.81±11.53	1.67	102.72±7.26	93.63±14.24	9.09*	101.96±8.40	95.56±15.05	6.39	99.99±8.38	92.81±11.84	7.17

Table 3 continuation. Mean ±SD of joint angles (In degrees) of the secondary girl's students of different age groups in normal erect posture and during writing on the existing school furniture

Body joint angles	**12 years (N=87)**							**13 Years (N=76)**					
	Madrasah (N=37)				**General School (N=50)**			**Madrasah (N=41)**			**General School (N=35)**		
	Standing		**Writing on the Bench**		**Standing**	**Writing on the Bench**		**Standing**	**Writing on the Bench**		**Standing**	**Writing on the Bench**	
	Angle (°)		**Angle (°)**	**Deviation (°)**	**Angle (°)**	**Angle (°)**	**Deviation(°)**	**Angle (°)**	**Angle (°)**	**Deviation(°)**	**Angle (°)**	**Angle (°)**	**Deviation (°)**
Shoulder	L	27.62± 3.86	67.92±18.08	-40.30	27.96± 3.90	69.58±17.63	-41.62	28.73± 4.17	52.73±10.43	-24.00	28.2± 3.99	50.7±7.86	-22.5
	R	27.54± 3.19	65.35±15.95	-37.81	27.84± 3.05	67.66±16.33	-39.82	29.22± 4.37	67.80± 15.87	-38.59	28.07±4.18	63.3± 8.75	-34.6
Elbow	L	165.1± 5.87	92.65±20.50	72.46	165.84±6.30	92.22±20.96	73.42	165.73±6.22	64.29± 12.78	101.44	165.09±5.79	61.4± 8.51	104.5
	R	166.9± 5.08	79.38±12.51	87.57	167.3± 5.37	79.68±12.36	87.62	166.02± 6.16	82.93± 11.58	83.10	166.02±5.57	81.9±11.91	84.03
Wrist	L	177.7± 1.87	171.4±18.36	9.00	177.56±2.12	168.2±26.17	9.32	178.02± 1.62	161.5± 10.16	16.44	177.05±1.82	162.6±9.85	14.09
	R	177.5± 1.82	176.4± 7.67	1.08	177.54±1.90	175.8± 7.92	1.66	177.63± 2.33	165.3± 16.48	12.27	177.02±2.22	168.3±10.91	8.9
Hip	L	165.1± 4.94	101.4±10.07	63.62	165.2± 5.03	101.3±10.96	63.09	164.85± 1.88	95.41± 13.20	69.44	164.09±1.97	95.02±12.63	69.07
	R	164.0± 5.83	102.5± 8.64	61.49	163.94±6.01	102.5± 8.75	61.04	165.34± 1.46	106.78±15.68	58.56	165.04±1.63	105.03±9.21	60.1
Knee	L	174.2± 5.24	101.2±11.83	72.95	174.28±5.17	101.0±12.94	73.02	175.22± 2.39	79.32± 14.75	95.90	175.05±2.11	78.04±14.72	97.01
	R	174.7± 5.49	102.7±13.13	72.03	174.86±5.25	101.3±13.61	73.48	173.41±15.75	82.73± 8.46	90.68	175.09±2.47	83.6± 7.59	92.40
Ankle	L	110.1± 17.20	95.84±17.54	14.27	105.96±5.20	95.78±18.18	10.18	106.98± 4.77	92.07± 5.72	14.90	106.05±4.51	90.03± 5.14	16.10
	R	112.0± 17.06	101.9±13.65	10.11	107.8± 5.37	101.8±14.08	5.94	108.27± 4.14	87.76±6.68	20.51	108± 4.27	87.0± 4.13	21.00

Table 3 continuation. Mean ±SD of joint angles (In degrees) of the secondary girl's students of different age groups in normal erect posture and during writing on the existing school furniture

Body joint angles		14 years (N=76)						15 Years (N=63)					
		Madrasah (N=34)			General School (N=42)			Madrasah (N=38)			General School (N=25)		
		Standing	Writing on the Bench		Standing	Writing on the Bench		Standing	Writing on the Bench		Standing	Writing on the Bench	
		Angle (°)	Angle (°)	Deviation (°)	Angle (°)	Angle (°)	Deviation(°)	Angle (°)	Angle (°)	Deviation(°)	Angle (°)	Angle (°)	Deviation (°)
Shoulder	L	32.41±5.16	70.15±17.13	-37.74	29.38±3.18	79.74±12.73	-50.36**	33.08±4.83	74.95±13.97	-41.87	30.02±3.08	78.48±15.6	-48.28
	R	31.76±04.16	68.59±14.98	-36.82	29.36±3.38	74.98±11.52	-45.62	32.97±4.76	73.97±12.29	-41.00	30.24±3.21	74.36±12.8	-44.12
Elbow	L	164.3±05.74	91.97±27.35	72.35	164.98±4.54	100.45±22.89	64.52	164.71±4.36	99.42±24.79	65.29	164.88±4.46	102.08±27	62.8
	R	166.5±05.72	91.09±20.12	75.50	166.52±4.12	96.64±18.82	69.88	165.84±4.49	95.79±22.06	70.05	166.92±4.10	101.24±14	65.68
Wrist	L	178.3±02.61	172.8±8.42	5.44	177.29±1.93	174.62±5.82	2.67	177.05±2.00	174.68±5.87	2.37	176.56±2.00	175.4±5.17	1.16
	R	177.6±2.22	172.5±9.76	5.06	177.40±1.61	171.81±9.11	5.60	177.34±1.62	171.50±9.83	5.84	177.04±1.54	172.72±8.3	4.32
Hip	L	163.3±06.31	94.00 ±13.20	69.38	165.40±4.64	93.93±10.15	71.48	165.95±3.84	95.97±10.20	69.97	166.02±3.43	97.48±10.6	68.72
	R	163.6±05.65	102.6±13.04	61.00	165.36±3.65	100.19±14.19	65.17	165.37±3.67	101.76±13.08	63.61	166.08±3.30	101.68±16	64.4
Knee	L	175. 47±03.78	91.59±12.27	83.88	174.14±3.43	92.71±13.61	81.43	173.82±3.42	90.29±13.77	83.53	173.88±3.27	91.44±13.2	82.44
	R	175.5±02.86	90.91±13.23	84.62	174.45±2.84	92.52±11.22	81.93	174.11±2.64	89.45±13.69	84.66	174.28±2.48	90.84±12.4	83.44
Ankle	L	103.1±06.43	92.32±11.35	10.85	100.31±4.12	88.33±18.59	11.98	102.55±4.71	91.08±13.46	11.47	99.12±3.49	89±13.67	10.12
	R	103.0±07.18	90.56±13.00	12.44	100.83±3.60	91.55±15.27	9.29	103.08±4.74	91.47±15.03	11.61	99.36±2.81	92.44±10	6.92

Elbow Joint (Left and Right)

- Left Elbow
  - Deviation increases with age in both groups. For-13 year-olds, madrasah student's show a deviation of 101.44º, while general school student show 104.5º.
- Right Elbow
  - Deviation is also significant, with a slight decrease in older students.
  - General school students display slightly higher deviations then madrasah students.

Interpretation

A larger deviation suggests a more acute angle at the elbow, potentially indicative of higher strain due to the forward-leaning posture.

Wrist Joint (Left and Right)

- Deviations are smaller compared to other joints.
- Left Wrist: Deviation ranges from 9.00º to 16.44º with older students showing slightly greater variation.
- Minimal deviation (1.08º to 21.00º), through the right wrist of general school students in both age groups shows a higher deviation than madrasah students.

Interpretation

The smaller wrist deviations reflect less wrist movement, as the writing posture primarily involves shoulder and elbow adjustments.

Hip Joint (Left Right)

- Both left and right hips show substantial deviations (~60º-70º) across all groups, indicating a significant reduction in hip angles due to sitting posture.
- Deviation slightly increases with age, more prominently in general school students.

Interpretation

This indicates that both groups experience substantial hip flexion when writing, which could lead to postural fatigue if sustained for long durations.

Knee Joint (Left and Right)

- Knee joints exhibit the largest deviations among all joints, particularly in 13-years olds:
    - Madrasah: 95.90º (L) and 90.68º (R)
    - General School: 97.01º (L) and 92.40º (R)

Interpretation

Large deviations suggest that sitting posture forces students into significant knee flexion, which could increase strain overtime.

Ankle Joint (Left and Right)

- Deviations are relatively small (~10º-21º) compared to other Joints.
- General school students generally exhibit slightly larger deviations than madrasah students.

Interpretation

Ankle deviations are less concerning compared to hip and knee joints but still indicate postural adjustments to accommodate sitting posture.

Shoulder Joint (Left and Right)

- Deviations: Both left and right shoulder angles show significant deviations from standing to writing posture, with general school students experiencing larger deviations compared to madrasah students.
    - 14-year-olds
        - Madrasah: -37.74º (L), -36.82º (R)
        - General School: -50.36º (L), -45.62º (R)
    - 15-year-olds
        - Madrasah: -41.87 º (L), -41.00º (R)
        - General school: -48.28 º (L), -44.12 º (R)

Interpretation

General school students exhibit a greater forward arm elevation (higher deviation), likely due to differences in desk height. The smaller deviations in madrasah students might reflect more neutral or relaxed shoulder positions.

Elbow Joint (Left and Right)

- Deviation: Both left and right elbows exhibit significant flexion in writing posture, but deviations are slightly lower for 15-year-olds compared to 14-year-olds.
    - 14-year-old
        - Madrasah:72.35º (L), 75.50º (R)
        - General School: 64.52º (L), 69.88º (R)
    - 15-year-olds
        - Madrasah: 65.29º (L), 70.05º (R)
        - General school: 62.80º (L), 65.68º (R)

Interpretation

The significant flexion in the elbow suggests strain in forearm movement during writing. Slightly reduced deviations in older students could indicate greater adaptation or postural maturity.

Wrist Joint (Left and Right)

- Deviations: Deviations in the wrist joint are much smaller compared to other joints, reflecting limited wrist movement while writing.
    - 14-year-olds
        - Madrasah: 5.44º (L), 5.05º (R)
        - General School: 2.67º (L), 5.60º (R)
    - 15-year-olds
        - Madrasah: 2.37º (L), 5.84º (R)
        - General school: 1.16º (L), 4.32 º (R)

Interpretation

Minimal wrist deviation suggests that writing involves primarily shoulder and elbow adjustments, while the wrist remains relatively stable.

Hip Joint (Left and Right)

- Deviations: Both hips show significant flexion during writing, with deviation ranging from 60º-70º, slightly higher in general school students.
    - 14-year-olds
        - Madrasah: 69.38º (L), 61.00º (R)
        - General School: 71.48º (L), 65.17º (R)
    - 15-year-olds
        - Madrasah: 69.97º (L), 63.61º (R)
        - General school: 68.72º (L), 64.40º (R)

Interpretation

The higher deviations reflect significant hip flexion in the seated posture, suggesting strain on the lower body, particularly in general school students.

Knee Joint (Left and Right)

- Deviations: Knee flexion is the most pronounced across joints, with deviations averaging 81º-85º, indicating a high degree of strain during writing.
    - 14-year-olds
        - Madrasah:83.88º (L), 84.62º (R)
        - General School: 81.43º (L), 81.93º (R)
    - 15-year-olds
        - Madrasah: 83.53º (L), 84.66º (R)
        - General school: 82.44º (L), 83.44º (R)

Interpretation

The significant knee flexion reflects typical sitting posture, which can lead to discomfort and if maintained for long durations without breaks.

Ankle Joint (Left and Right)

- Deviations: Ankle deviations are relatively small (~10º-12º), indicating limited adjustments in this joints.
    - 14-year-olds
        - Madrasah: 10.85º (L), 12.44º (R)
        - General School: 11.98º (L), 9.29º (R)
    - 15-year-olds
        - Madrasah: 11.47º (L), 11.61º (R)
        - General school: 10.12º (L), 6.92º (R)

Interpretation

Smaller ankle deviations suggest that the feet remain relatively stationary, with little strain or adjustment required in this area.

Analysis of Center of Gravity (CoG)

Table 4. Mean ±SD of center of gravity in the secondary girl students of different age groups.

Age Groups	Madrasah (N=60)				School (N=63)			
	Standing CG		Working CG (sitting on the bench during attending the class when working on the desk)		Standing CG		Working CG (sitting on the bench during attending the class when working on the desk)	
	Vertical CG (%)	Horizontal CG (%)	Vertical CG (%)	Horizontal CG (%)	Vertical CG (%)	Horizontal CG (%)	Vertical CG (%)	Horizontal CG (%)
10 year	54.39 ±2.30	41.01 ±13.03	52.24 ±3.37	58.89## ±3.96	53.05 ±3.29	41.63 ±10.38	50.85 ±3.25	52.48 ±13.94
11 year	54.29 ±1.97	50.86 ±6.95	58.18** ±3.38	69.18## ±14.03	53.23 ±1.48	51.80 ±3.78	57.87** ±4.28	69.49### ±12.48
12 year	54.31 ±2.01	58.88 ±10.42	56.48 ±4.58	58.05 ±22.45	54.37 ±2.43	55.14 ±9.81	56.31 ±4.74	60.00 ±7.87
13 year	54.52 ±1.66	48.05 ±13.13	59.31*** ±3.17	43.09 ±19.46	52.65 ±1.82	45.72 ±14.57	57.23** ±4.74	56.01 ±21.45
14 year	55.33 ±3.96	47.53 ±13.37	57.79 ±6.97	76.74### ±8.81	53.59 ±1.97	53.56 ±12.21	59.50* ±7.07	75.78### ±11.61
15 year	54.09 ±1.56	48.93 ±10.67	56.47 ±5.26	77.13### ±10.43	52.63 ±2.05	50.09 ±11.18	55.67* ±3.16	72.35# ±7.90

With respect to (w.r.t) standing vertical CG*P<0.05, **P<0.01, ***P<0.001, w.r.t. Standing Horizontal CG#P<0.05, ##P<0.01, ###P<0.001

Vertical CG

- Standing vertical CG
    - Values remain relatively consistent across age groups, with a slightly increase in older students (14-15 years).
- Working vertical CG
    - Both madrasah and school students show higher vertical CG during sitting postures compared to standing, indicating changes in posture during desk work.
    - Madrasah students generally show slightly higher working vertical CG than general school students in most age groups.

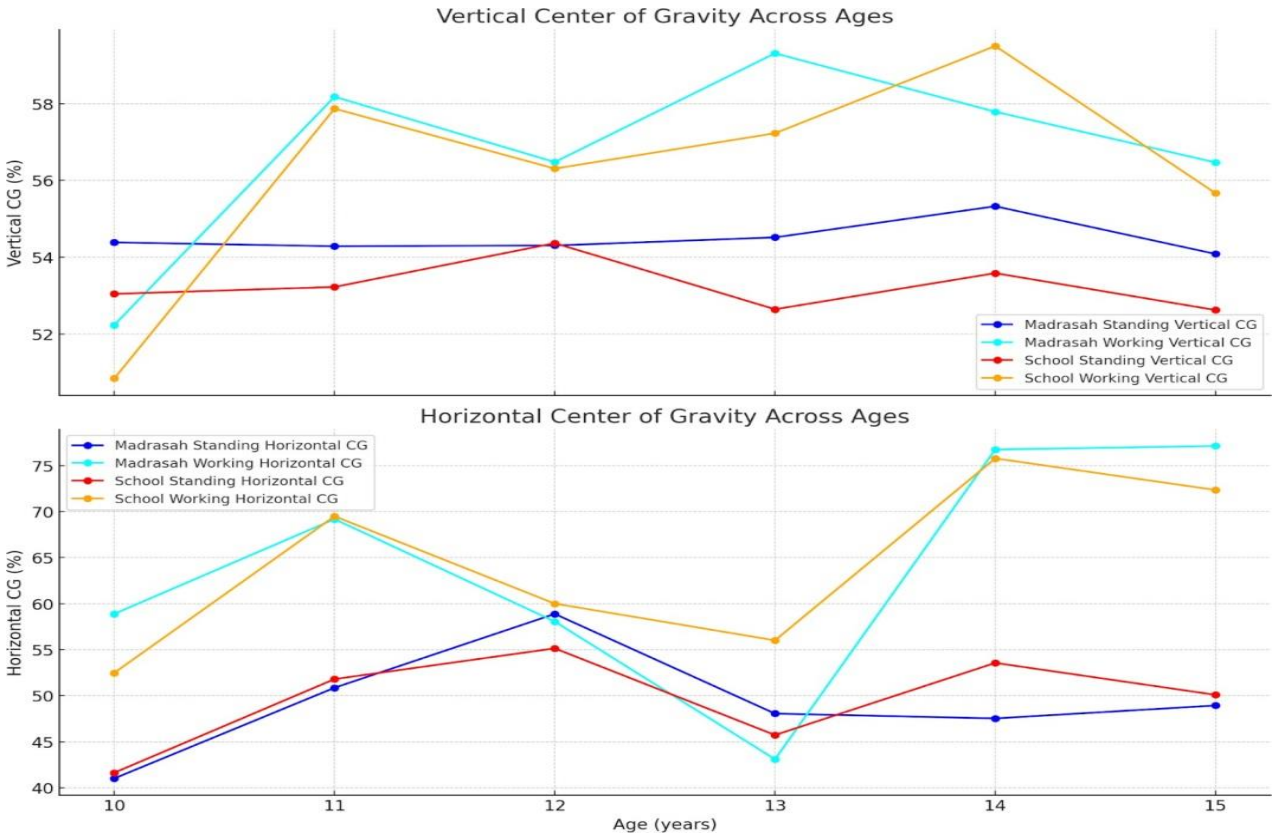

Figure 4. Vertical and horizontal center of Gravity (CoG) across the ages in between standing and working posture

Horizontal CG

- Standing Horizontal CG
  - Horizontal CG percentages remain lower compared to working postures, with little variation across ages.
- Working horizontal CG
  - Significant increases in horizontal CG are observed during sitting postures, particularly in older age groups (14-15 years).
  - Madrasah students show slightly higher horizontal CG percentages compared to general school students, reflecting potentially greater forward lean in their sitting posture.

Conclusion

This study underscores a significant postural imbalance among girl students in both Madrasah and General Schools in West Bengal, especially during seated classroom activities. The shifting of both vertical and horizontal center of gravity (CG) from standing to working posture indicates a forward-leaning sitting position that becomes more pronounced with age. This posture is strongly associated with increased musculoskeletal discomfort, particularly in the neck, trunk, and lower limbs.

The findings reveal that while standing posture remains relatively stable across age groups and school types, working posture—especially in seated conditions—causes a noticeable anterior displacement of the horizontal CG. This shift is significantly higher among General School girls, suggesting inadequate furniture ergonomics that force students to lean forward excessively while working. In contrast, Madrasah students also exhibit a substantial CG shift, though the intensity and pattern vary by age.

The postural stress identified through CG analysis aligns closely with discomfort reports from students, particularly in the lower arms and back. Notably, discomfort increases with age, suggesting that prolonged exposure to poor ergonomics and academic pressure cumulatively impact physical health over time. Feet and hip

discomfort were the least reported, supporting the interpretation that upper body and spinal regions bear the brunt of ergonomic stress.

These outcomes emphasize an urgent need for targeted ergonomic interventions in schools. The implementation of furniture designed to match student anthropometry, posture education, and regular classroom movement breaks can mitigate the biomechanical strain contributing to MSDs. Additionally, school authorities and policymakers must prioritize ergonomic infrastructure, especially in under-resourced Madrasah settings, to prevent long-term health consequences for adolescent girls.

In conclusion, addressing postural imbalance and ergonomic inadequacies is not merely a comfort issue—it is a critical health priority that can profoundly influence the academic performance and well-being of school-aged girls. Proactive ergonomic reforms can foster a healthier, more productive educational environment and reduce the burden of musculoskeletal disorders among future generations.

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Data availability

Full access to data on request.

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Conflicts of Interest

The authors declare that he has no competing interests.

Informed Consent

Statement all the athletes and their parents included in the study provided written informed consent.