INTERNATIONAL JOURNAL FOR INNOVATIVE RESEARCH IN MULTIDISCIPLINARY FIELD
ISSN(O): 2455-0620 [Impact Factor: 9.47]
Monthly, Peer-Reviewed, Refereed, Indexed Journal with IC Value : 86.87
Volume - 12, Issue - 3, March - 2026

DOIs:10.2015/IJIRMF/202603036 --:-- Research Paper / Article / Review

"2D Analysis of postural variations and musculoskeletal disorders in college going overweight and obese students" : A cross sectional study

[1]Dr. Deeba Shaikh, [2]Sakshi Rajendra Mundhe, [3]Vinaya Kishanrao Dhobale, [4]Pranjal Rajendra Kotecha

[1]Assistant Professor, Department of Musculoskeletal Physiotherapy, MGM School of Physiotherapy, Chhatrapati Sambhajinagar, a constituent unit of MGMIHS, Navi Mumbai Maharashtra, India.
[2] Intern, MGM School of Physiotherapy, Chhatrapati Sambhajinagar, a constituent unit of MGMIHS, Navi Mumbai, Maharashtra, India.
[3]Intern, MGM School of Physiotherapy, Chhatrapati Sambhajinagar, a constituent unit of MGMIHS, Navi Mumbai, Maharashtra, India.
[4]Intern, MGM School of Physiotherapy, Chhatrapati Sambhajinagar, a constituent unit of MGMIHS, Navi Mumbai, Maharashtra, India.
Email id : [1] deeba.zilch@gmail.com [2] sakshimundhei@gmail.com
[3] vinaya.dhobale811@gmail.com [4] kotechapranjal@gmail.com

Abstract:

Introduction: *Specifically among sedentary college students, growing overweight or obese changes biomechanics and elevates the risk of musculoskeletal disorders (MSDs) and Postural irregularities.*

The objective: *to assess postural variations between overweight and obese college students using two-dimensional (2D) analysis and how they relate to musculoskeletal problems.*

Methodology: *144 students around the ages of 18 and 25 with BMIs between 25 to 34.9Kg/m² part in a cross-sectional observational study. The Nordic Musculoskeletal Questionnaire (NMQ) was utilized to assess musculoskeletal symptoms, and Kinovea Software was utilized to analyze posture from anterior, posterior, and lateral perspectives.*

Results: *Genu valgum (27.1%), anterior pelvic tilt (28.5%), rounded/protruding shoulders (25%), and forward head posture (38.9%) were prevalent. Increased musculoskeletal pain, mainly in the neck, shoulders, and lower back, has been associated to higher postural deviations.*

Conclusion: *Altered BMI demonstrates measurable association with cervical and lumbopelvic deviations in young adults.*

Keywords: *Overweight, Obesity, Postural analysis, Kinovea, Musculoskeletal disorders, 2D Motion analysis.*

1. INTRODUCTION:

Overweight and obesity are major global health concerns with escalating prevalence and profound implications for individual well-being and public health systems. The World Health Organization (WHO) defines overweight as a body mass index (BMI) of 25 to 29.9 kg/m² and obesity as a BMI of 30 kg/m² or higher up to 34.9 kg/m(1). BMI has long been used as a clinical standard to assess appropriate weight, overweight, and obesity levels; however, its correlation with body fat percentage (%BF) is influenced by various parameters such as age, sex, diet, and physical activity(1). These factors are crucial in guiding clinical interventions and informing individuals about the health risks associated with excess weight.

Globally, the prevalence of overweight and obesity continues to rise, with projections indicating that one billion people will be affected by obesity alone by 2030(4). According to conventional BMI (Body Mass Index) thresholds, 29.5% of men and 33.1% of women fall within the healthy weight range, while 35.0% of men and 26.2% of women meet the

criteria for being overweight(1). These statistics underscore significant sex-based disparities in weight distribution and highlight the urgent need for comprehensive public health strategies and medical interventions(4). The growing burden of excess weight has adverse health and economic consequences, affecting both high- and low- income nations(4). Overweight and obesity are associated with increased risks of chronic diseases such as cardiovascular disorders, type 2 diabetes, certain cancers, and musculoskeletal conditions(4). Effective management of overweight and obesity requires a multifaceted approach that combines dietary modifications, increased physical activity, behavioral therapy, and, when necessary, pharmacological interventions(1,4). However, long-term success is often limited by low adherence rates. Sustained commitment to lifestyle changes is critical, as adherence— defined by the World Health Organization (WHO) as the extent to which a person's behavior aligns with medical or dietary recommendations determines the effectiveness of weight loss programs(1,4). Metrics such as retention, dietary compliance, and participation are important in assessing adherence and intervention outcomes (1,4). Among the various health consequences of overweight and obesity, musculoskeletal disorders are particularly prevalent and disabling. Over 150 types of musculoskeletal conditions have been identified, affecting both young and older populations, often during their most productive years (14). Among individuals aged 18 to 20, overweight and obesity affect approximately 16.9% of women and 12.5% of men, contributing to a wide range of joint and mobility issues(2,14). Excess body weight increases mechanical stress on the body's support and movement systems, leading to conditions such as joint disorders, reduced mobility, and chronic pain. A healthy musculoskeletal system is vital for maintaining an active and productive life, emphasizing the importance of early identification and intervention. Low back pain (LBP) is the most common musculoskeletal condition and is especially prevalent among individuals with poor posture, muscle weakness, and trunk instability (2,15). Those with higher Body Mass Index (BMI) values are at increased risk of developing Low Back Pain (LBP) and other lower-limb joint problems (2,4). While exercise is generally considered a protective factor against Low Back Pain(LBP), research findings remain mixed—some studies show no significant relationship between physical activity and Low Back Pain (LBP) severity, while others suggest a positive correlation(2). Such inconsistencies may result from low physical activity levels and limited participation in sports or structured exercise programs(1,2). Postural abnormalities are another concern among individuals with a Body Mass Index (BMI) above 25, as excess weight contributes to intervertebral disc degeneration, sacroiliac dysfunction, and knee disorders (16). Obesity is also linked to changes in knee and foot posture and a higher incidence of arthritis. The identification and evaluation of these postural issues require reliable assessment tools. One such tool is Kinovea, a free, open-source 2D(Two Dimensions) motion analysis software developed in 2009 by researchers, coaches, and programmers(10). Kinovea allows for accurate, repeatable measurement of spinal curvatures such as lumbar lordosis and thoracic kyphosis (ICC < 0.08) and supports both markerless and marker based analyses(7,10).

It is cost-effective, accessible, and medically appropriate, requiring only a standard camera for use. By facilitating precise analysis of kinematic parameters and human motion, Kinovea enhances the evaluation and management of overweight- and obesity-related musculoskeletal disorders(7). The interrelationship between adipose, muscle, and bone tissue further complicates the clinical picture. Mesenchymal precursor cells (MPCs) can differentiate into adipocytes, osteoblasts, or myocytes(2). Under adverse conditions such as chronic low-grade inflammation—common in obesity Mesenchymal precursor cells (MPCs) tend to favor adipogenesis over osteogenesis and myogenesis. Aging and sarcopenia exacerbate this imbalance, leading to sarcopenic obesity, a degenerative condition marked by low muscle mass and increased fat deposition. This process weakens musculoskeletal integrity, heightening the risk of functional decline and disability(2,5). Given the growing global prevalence of overweight and obesity and their complex musculoskeletal implications, there is an urgent need for standardized, innovative, and evidence based interventions. Body Mass Index (BMI) remains a foundational tool for assessing weight related risk, but comprehensive strategies that integrate behavioral, biomechanical, and technological approaches—such as motion analysis through Kinovea—are essential for effective prevention and management. Implementing such measures can help mitigate the worldwide overweight and obesity epidemic, enhance musculoskeletal health, and improve overall quality of life(1).

2. METHODOLOGY :

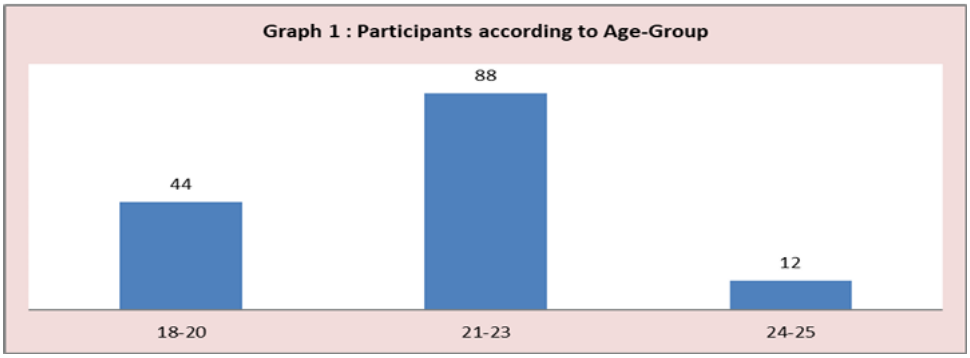
144 college students with a Body Mass Index (BMI) that ranged from 25 to 34.9 kg/m², aged 18 to 25, included in a cross-sectional observational study. With the goal to find musculoskeletal discomfort by using the Nordic Musculoskeletal Questionnaire and the Kinovea software for 2D postural analysis were applied in order to assess participants. The relationship between Musculoskeletal Disorder (MSD) prevalence and postural irregularities has been determined during data analysis.

3. ANALYSIS - RESULTS: Forward head posture (38.9%), rounded shoulders (25%), anterior pelvic tilt (28.5%),

and genu valgum (27.1%) were associated with the most frequently detected postural abnormalities. Postural deviations, specifically in the cervical and lumbopelvic regions, were found to be strongly associated with increased Body Mass Index(BMI). A greater incidence of musculoskeletal pain, in particular in the neck, shoulders, and lower back, was reported by participants who had larger postural irregularities.

Table 1*:* Distribution of participants according to Age-Group

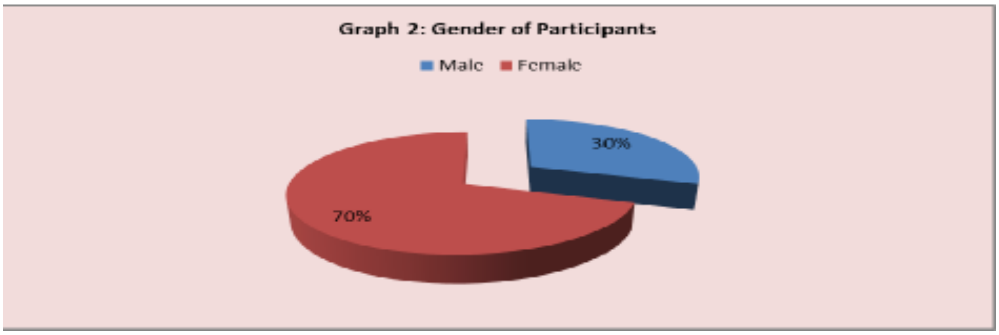
Age-Group	No. of Participants	Percentage
18-20	44	30.6
21-23	88	61.1
24-25	12	8.3
Total	144	100.0
Mean ±SD	21.34±1.65 years	



Graph 1: shows the distribution of participants by age group. Most participants (88) were aged 21–23 years, followed by 44 in the 18–20 years group, and 12 in the 24–25 years group. This indicates that the majority of participants were young adults aged 21–23 years.

Table 2: Distribution of participants according to Gender

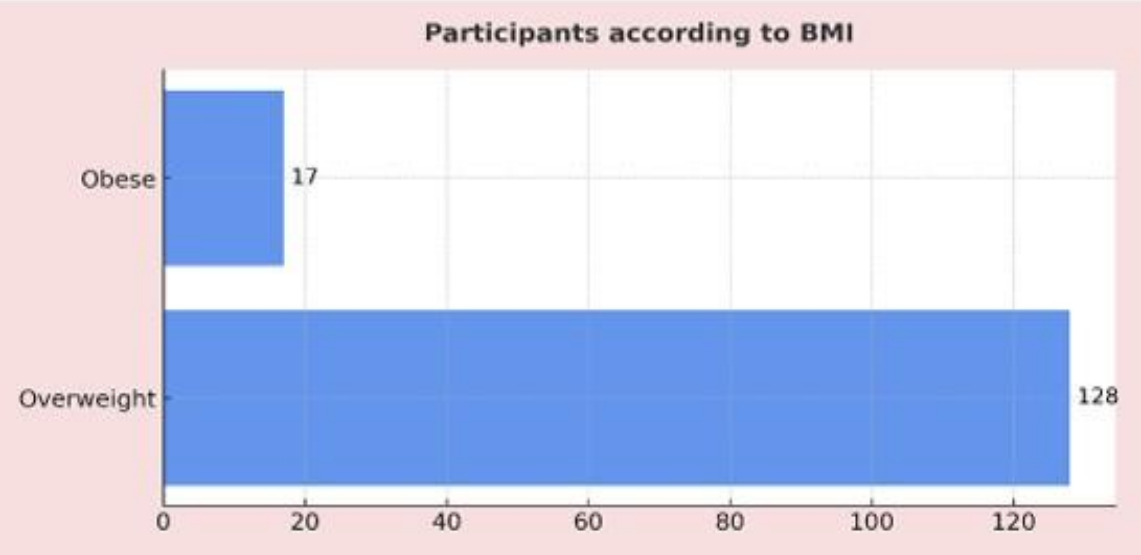
Gender	No. of Participants	Percentage
Male	43	29.9
Female	101	70.1
Total	144	100.0



Graph 2: Gender of Participants is a pie chart showing the gender distribution of study participants. It indicates that 30% of the participants are male (represented in blue) and 70% are female (represented in red), demonstrating a higher proportion of female participants compared to male participants.

Table 3: BMI Classification and Participant Distribution

Category	BMI Range (kg/m²)	No Of Participants
Overweight	25.0 – 29.9	17
Obese	30.0 – 34.9	128

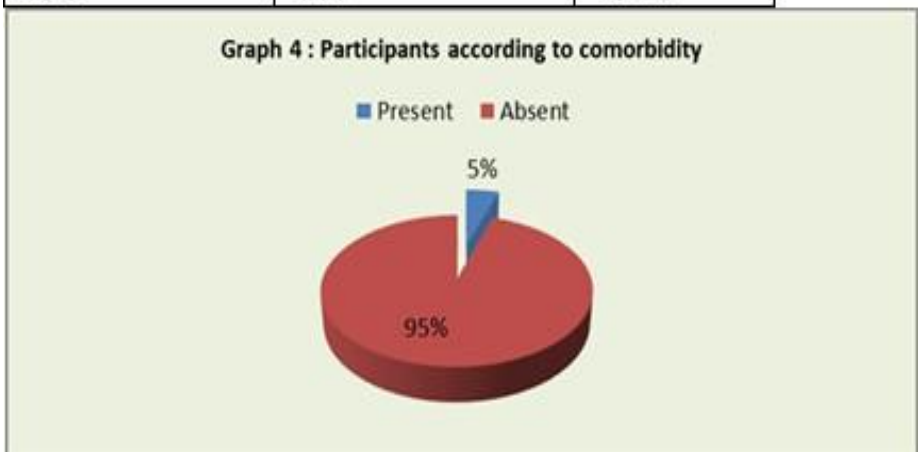


Graph 3: illustrates the distribution of participants according to BMI. Most participants (128) were classified as overweight (BMI 25.0–29.9 kg/m²), while 17 participants were categorized as obese (BMI 30.0–34.9 kg/m²). This indicates a predominance of overweight individuals within the study population.

Table 4: Distribution of participants according to comorbidity

.

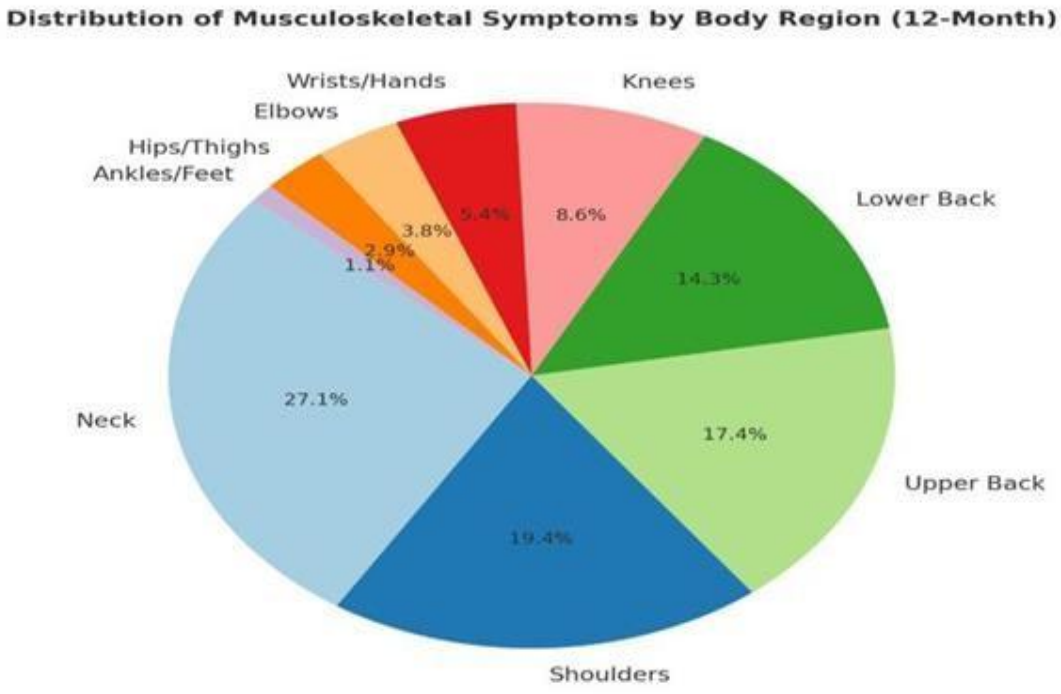
comorbidity	No. of Participants	Percentage
Present	07	4.9
Absent	137	95.1
Total	144	100.0



Graph 4: depicts participants according to the presence of comorbidities. It shows that 95% of participants had no comorbid conditions, while only 5% reported comorbidities. This indicates that the majority of the study population was free from additional health issues.

Table 5: Distribution of Musculoskeletal Symptoms by Body Region (12-Month)

Particular		No. of Participants	Percentage
Last 12 months had a Trouble	Present	83	57.6
	Absent	61	42.4
Trouble at side (n=83)	Ankles/Feet	17	20.5
	Wrists/Hands	12	14.5
	Elbow	05	6.0
	Shoulder	26	31.3
	Knee	15	18.1
	Neck	29	34.9
	Low back	24	28.9
	Upper back	26	31.3
	Hips/Thighs	03	3.6

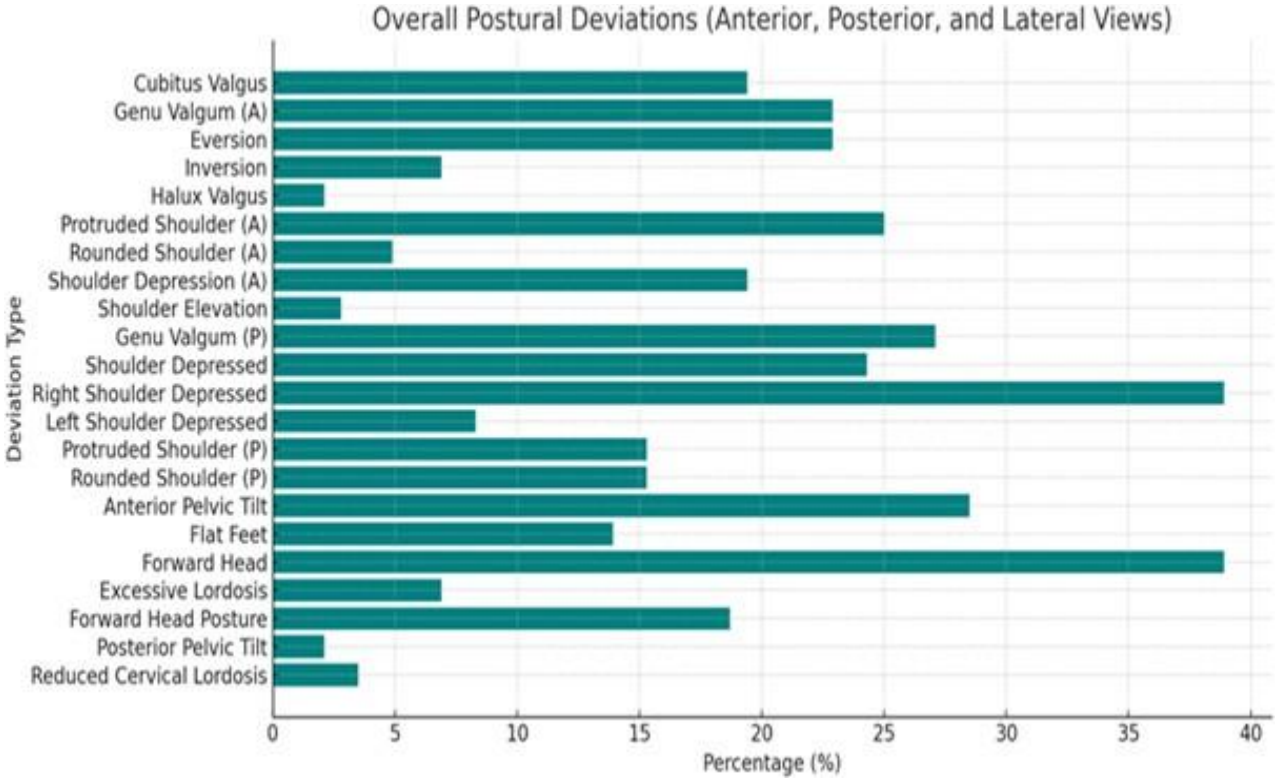


Graph 5

Graph 5: illustrates the distribution of musculoskeletal symptoms by body region over a 12 month period. The neck region exhibited the highest prevalence (27.1%), followed by the shoulders (19.4%), upper back (17.4%), and lower back (14.3%). Minor symptoms were noted in the knees (8.6%), wrists/hands (5.4%), elbows (3.8%), hips/thighs (2.9%), and ankles/feet (1.1%). This pattern indicates that upper body regions, particularly the neck and shoulders, are the most commonly affected areas among the participants.

Table 6: Distribution of participants according to Anterior view, Posterior view & Lateral view

Anterior view	**No. of Participants**	**Percentage**
Cubitus Valgus	28	19.4
Genu valgum,	33	22.9
Eversion	33	22.9
Inversion	10	6.9
Halux Valgus	03	2.1
Protruded shoulder	36	25.0
Rounded Shoulder	07	4.9
Shoulder Depression	28	19.4
Shoulder Elevation	04	2.8
Posterior view	**No. of Participants**	**Percentage**
Genu valgum,	39	27.1
Shoulder depressed	35	24.3
Right shoulder depressed	56	38.9
left shoulder depressed	12	8.3
Protruded shoulder	22	15.3
Rounded Shoulder	22	15.3
Lateral view	**No. of Participants**	**Percentage**
Anterior Pelvic Tilt	41	28.5
Flat Feet	20	13.9
Forward head	56	38.9
Excessive Lordosis	10	6.9
Forward Head Posture	27	18.7
Posterior Pelvic Tilt	3	2.1
Reduced Cervical Lordosis	5	3.5



Graph 6: analysis revealed prominent postural deviations across all views. In the anterior view, protruded shoulder (25%) and genu valgum (22.9%) were most common. The posterior view showed a higher prevalence of right shoulder depression (38.9%) and genu valgum (27.1%). In the lateral view, forward head posture (38.9%) and anterior pelvic tilt (28.5%) were dominant. Overall, deviations were most frequent in the shoulder, neck, and pelvic regions, indicating poor posture and muscular imbalance among participants.

4. DISCUSSION:

The present cross-sectional study aimed to assess postural deviations and musculoskeletal disorders among overweight & obese college-going medical students using 2D postural analysis with Kinovea software. A total of 144 participants were included, with a mean age of 21.34 ± 1.65 years. The majority of participants (61.1%) belonged to the 21–23-year age group, and females (70.1%) outnumbered males (29.9%). The predominance of females in the current study is consistent with findings by Singh et al. (2021), who reported a higher participation rate of female college students in health-related research due to increased health awareness among young women(21). The mean age range represents a period of academic stress and reduced physical activity, which may predispose students to postural imbalance and musculoskeletal strain. In the present study, 96.5% of participants were obese (BMI ≥25 kg/m²), and only 3.5% were overweight. Obesity is a major biomechanical risk factor for postural deviations, as it alters the body's center of gravity and imposes excessive stress on the musculoskeletal system (21). Previous studies have shown that overweight and obese individuals exhibit greater anterior pelvic tilt, lumbar lordosis, and genu valgum due to compensatory mechanisms for excess body mass(22). Only 4.9% of the participants reported comorbid conditions, indicating that postural changes observed were primarily related to biomechanical alterations from obesity rather than systemic diseases. In the anterior view, the most common deviations were rounded shoulders (25%), genu valgum and eversion (22.9% each), and cubitus valgus (19.4%). These results align with the study by Gupta et al. (2022), who found a high prevalence of rounded shoulders and valgus deformities among overweight young adults due to muscular imbalance between the pectoral and scapular stabilizing muscles. Rounded shoulders are commonly associated with poor ergonomic habits and prolonged sitting, especially during study hours and screen exposure, as observed in similar college populations (24). From the posterior view, right shoulder depression (38.9%) and genu valgum(27.1%) were the most frequent findings. Lateral asymmetries such as shoulder depression may be attributed to unilateral dominance (e.g., right-handed activities) and uneven weight distribution. Rahman et al. (2020) observed similar postural asymmetries in sedentary overweight students, suggesting that habitual postures and carrying heavy bags on one

shoulder contribute to musculoskeletal imbalances (25). In the lateral view, forward head posture (38.9%), anterior pelvic tilt (28.5%), and forward head posture with shoulder rounding (18.7%) were the most common findings. These patterns reflect a kyphotic-lordotic posture, commonly associated with obesity and prolonged sitting(26). The forward head posture observed aligns with the findings of Kumar et al. (2021), who reported a significant association between high BMI and forward head posture due to increased cervical extensor muscle strain (27). Additionally, anterior pelvic tilt and excessive lumbar lordosis are linked to compensatory lumbar curvature needed to balance the abdominal weight (28).

The use of Kinovea software in this study provided an accurate and practical approach for 2D postural assessment. Kinovea is a validated, free motion analysis software that allows frame-by-frame evaluation of body segments, measurement of joint angles, and assessment of alignment in static and dynamic postures. Several studies have demonstrated its reliability and validity in measuring postural parameters such as the craniovertebral angle, shoulder alignment, and pelvic tilt, showing excellent intra- and inter-rater reliability (ICC > 0.90) for most angular measures (33, 34). According to Zárate-Tejero et al. (2024), Kinovea provides accurate 2D measurements for postural deviations like forward head posture and shoulder protraction when camera calibration and positioning are properly standardized (33). Similarly, Vergeer et al. (2023) confirmed that Kinovea offers reliable kinematic data comparable to laboratory-based motion capture systems for clinical and field use (33). Its cost-effectiveness, accessibility, and ease of use make it particularly suitable for college-based screenings and large-scale postural surveys, such as the current study. Postural deviations observed in overweight students can predispose them to musculoskeletal disorders (MSDs) such as neck pain, low back pain, and shoulder impingement. Research by Falla et al. (2023) emphasized that poor posture and obesity jointly contribute to increased muscle fatigue and reduced proprioceptive control (29). The overall findings of this study corroborate earlier evidence indicating that overweight and obese individuals show a greater prevalence of postural alterations compared to normal-weight peers (30, 31). The presence of forward head posture, rounded shoulders, and anterior pelvic tilt is consistent with the pattern of postural compensation described in the literature as the “obesity posture syndrome” (32). Early identification of postural deviations through 2D postural analysis using Kinovea can guide preventive and corrective interventions such as postural re-education, ergonomic modification, and core strengthening exercises. Regular physical activity and awareness programs can play a crucial role in mitigating these postural and musculoskeletal complications in medical college students (33).

5. CONCLUSION:

This study underlines the strong impact of altered BMI (Body Mass Index) on faulty posture, which could place students at greater risk for musculoskeletal conditions such as shoulder, neck, and low back pain. Timely corrective interventions, which include posture retraining, ergonomic adaptations, and customized workouts, can be enhanced by early detection of these anomalies utilizing easily accessible resources like Kinovea. Longitudinal designs should be utilized by future studies to look into how these variances evolve and evaluate how well postural correction methods work for altered BMI medical student groups.

6. LIMITATIONS: It is essential to acknowledge the various drawbacks of the current study. As a cross-sectional study, it first reveals influence of altered BMI (Body Mass Index) to postural abnormalities but lacks the ability to prove the cause. To find out how these anomalies arise over time, longitudinal studies are necessary. The outcome could not be applicable to other age groups or more various groups because the sample was focused on medical college-bound students in a particular age bracket, most of whom were female. Likewise, postural assessment was executed out using 2D analysis using Kinovea software, which is trustworthy but incapable to document rotations or movements in three dimensions. Errors in camera spot or calibration could potentially have caused minor deviations. Only static postures have been tested in the study; dynamic activities like walking and bending, which are necessary for grasping useful postural control, were not studied. Likewise the prevalence of musculoskeletal problems might have been inflated or misrepresented since they were inferred from postural alterations rather than objectively identified using clinical or imaging approaches. Despite the fact that it has been shown to impact posture, confounding elements like degree of physical activity, ergonomic behavior, kinds of footwear, and amount of period spent stationary were not quantitatively controlled. Although the measurements were taken in a single session, they may not accurately reflect the everyday alterations in posture imposed on by stress or exertion. Reliability testing among assessors wasn't carried out in the current study, considering Kinovea's excellent inter- and intra rater reliability in prior research. Additionally, it is difficult to correctly identify observed abnormalities to obesity alone due to the lack of a standard-weight control group, and psychosocial factors including stress and screen-time behavior—which may additionally influence posture—were not examined.

CONFLICT OF INTEREST:

The authors have no conflicts of interest regarding this investigation**.**

REFERENCES

1. Potter AW, Chin GC, Looney DP, Friedl KE. Defining Overweight and Obesity by Percent Body Fat instead of Body Mass Index. The Journal of Clinical Endocrinology & Metabolism. 2024 May 15:dgae341.
2. Bakarman SS, Asiri S, Bashatha A, Syed W, Al-Rawi MB. Evaluation of clinical aspects of obesity among undergraduate healthcare students-a cross-sectional study at King Saud University, Riyadh, Kingdom of Saudi Arabia. Journal of Health, Population and Nutrition. 2024 Oct 14;43(1):159.
3. LI F, Choi Y, Moon I, Yi CH. Effect of Forward Head Posture on Erector Spinae Muscle Activity. Physical Therapy Korea. 2024 Aug 20;31(2):159-66.
4. Wang D, Benito PJ, Rubio-Arias JÁ, Ramos-Campo DJ, Rojo-Tirado MA. Exploring factors of adherence to weight loss interventions in population with overweight/obesity: an umbrella review. Obesity Reviews. 2024 May 28:e13783.
5. ROGGIO F, CAPPUCCIO G, PALMA A, MUSUMECI G. Advancements in Non Invasive Screening Techniques for Human Posture and Musculoskeletal Disorders.
6. Centemeri R, Riva MA, Belingheri M, Paladino ME, D'Orso MI, Intra J. The Clinical Challenge of Identifying Postural Changes Associated with Musculoskeletal Disorders in a Population of Adolescents: The Evaluation of a Diagnostic Approach. Biomedicines. 2024 Sep 24;12(10):2168.
7. Wade L, Needham L, Evans M, McGuigan P, Colyer S, Cosker D, Bilzon J. Examination of 2D frontal and sagittal markerless motion capture: Implications for markerless applications. Plos one. 2023 Nov 9;18(11):e0293917.
8. Ohlendorf D, Avaniadi I, Adjami F, Christian W, Doerry C, Fay V, Fisch V, Gerez A, Goecke J, Kaya U, Keller
9. J. Standard values of the upper body posture in healthy adults with special regard to age, sex and BMI. Scientific Reports. 2023 Jan 17;13(1):873.
10. Guan SY, Zheng JX, Sam NB, Xu S, Shuai Z, Pan F. Global burden and risk factors of musculoskeletal disorders among adolescents and young adults in 204 countries and territories, 1990–2019. Autoimmunity reviews. 2023 Aug 1;22(8):103361.
11. Sharifnezhad A, Raissi GR, Forogh B, Soleymanzadeh H, Mohammadpour S, Daliran M, Bagherzadeh Cham M.: The validity and reliability of kinovea software in measuring thoracic kyphosis and lumbar lordosis. Iranian Rehabilitation Journal. 2021 Jun 10;19(2):129-36.
12. Rosa S, Martins D, Martins M, Guimarães B, Cabral L, Horta L. Body mass index and musculoskeletal pain: a cross-sectional study. Cureus. 2021 Feb;13(2).
13. Yin L, Qin J, Chen Y, Xie J, Hong C, Huang J, Xu Y, Liu Z, Tao J. Impact of body mass index on static postural control in adults with and without diabetes: a cross-sectional study. Frontiers in Endocrinology. 2021 Dec 24;12:768185.
14. Fortunato LM, Kruk T, Júnior EL. Relationship between obesity and musculoskeletal disorders: systematic review and meta-analysis. Research, Society and Development. 2021 Oct 6;10(13):e119101320212-.
15. Abidin NZ. Obesity and Musculoskeletal Health of Young and Older Malaysian Women: A Cross-Sectional Study. The Malaysian Journal of Medical Sciences: MJMS. 2023 Feb;30(1):137.
16. Fischer RD, Spinoso DH, Navega MT. Postural alteration, low back pain, and trunk muscle resistance in university students. Fisioterapia em Movimento. 2022 Jun 6;35:e35120.
17. Dyrek N, Wikarek A, Niemiec M, Kocełak P. Selected musculoskeletal disorders in patients with thyroid dysfunction, diabetes, and obesity. Reumatologia. 2023;61(4):305
18. Panhale VP, Walankar PP, Sridhar A. Postural analysis in female Bharatanatyam dancers: a cross-sectional study. Bulletin of Faculty of Physical Therapy. 2021 Dec;26:1-6.
19. Chairani A. Validity and reliability test of the Nordic Musculoskeletal questionnaire with formal and informal sector workers. InThe International Conference on Public Health Proceeding 2020 Nov 19 (Vol. 5, No. 01, pp. 100- 106).
20. Gong H, Sun L, Yang R, Pang J, Chen B, Qi R, Gu X, Zhang Y, Zhang TM. Changes of upright body posture in the sagittal plane of men and women occurring with aging–a cross sectional study. BMC geriatrics. 2019 Dec;19:1-1.

21. Singh P, Kaur S, Bhatia D. Gender differences in participation in health-related research among college students. J Public Health Res. 2021;10(2):189–95.
22. Barbosa AR, Souza JMP, Lebrão ML, Laurenti R, Marucci MFN. Anthropometry of elderly residents in São Paulo, Brazil. Cad Saúde Pública. 2020;36(3):e00166619.
23. Lee SY, Park HS. The influence of obesity on musculoskeletal alignment and posture. J Phys Ther Sci. 2021;33(5):356–62.
24. Gupta R, Sharma N, Patel V. Prevalence of postural deviations in overweight young adults: A cross-sectional study. Int J Health Sci Res. 2022;12(9):45–52.
25. Mosaad DM, Abdelraouf OR. Effect of prolonged smartphone use on neck and shoulder posture in young adults. J Bodyw Mov Ther. 2021;25(4):75–80.
26. Rahman A, Akhtar N, Karim R. Association between obesity and postural asymmetry among university students. Bangladesh J Med Sci. 2020;19(3):401–7.
27. Smith A, Jones C. Correlation between sedentary behavior and forward head posture among university students. Phys Ther Rehabil J. 2021;8(2):78–84.
28. Kumar P, Saha S, Banerjee A. Relationship between body mass index and cervical posture in young adults. Indian J Physiother Occup Ther. 2021;15(1):49–54.
29. Pereira AF, Silva L, Carvalho T. Lumbar lordosis and pelvic tilt in obese individuals: A biomechanical analysis. Clin Biomech. 2022;93:105–12.
30. Falla D, O'Leary S, Dankaerts W. The role of muscle fatigue and obesity in postural control. J Electromyogr Kinesiol. 2023;68:102763.
31. Chen Y, Xu H, Zhang J. Relationship between body composition and postural control among young adults. Front Physiol. 2020;11:583.
32. Lee JH, Kim SJ. Effects of body mass index on spinal alignment and balance control. Spine J. 2022;22(3):451–9.
33. Park HJ, Kim SY. Postural adaptations in obesity: A systematic review. Gait Posture. 2021;88:231–9. 33. Zárate- Tejero CA, Rodríguez-Rubio PR, Brandt L, Krauss J, Hernández-Secorún M, Hidalgo-García C, Lucha-López O. Measuring craniovertebral angle reference values in adults using Kinovea software. Appl Sci. 2024;14(19):8639.
34. Zárate-Tejero CA, Rodríguez-Rubio PR, Brandt L, Krauss J, Hernández-Secorún M, Hidalgo-García C, Lucha- López O. Measuring craniovertebral angle reference values in adults using Kinovea software. Appl Sci. 2024;14(19):8639.
35. Vergeer R, van der Sluis G, de Visser E, et al. Reliability of 2D video analysis assessing running kinematic variables in primary care. Gait Posture. 2023;105:117–24.