

Original Article

Relationship Between Plantar Pressure, Body Mass Index and Balance in Children: A Cross-Sectional Study

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Abstract

Objective: The aim of this study was to investigate the relationship between foot pressure, body mass index and balance in children aged 8-12 years. **Methods:** Ninety normal children aged from 8 to 12 years old participated in this study. Foot pressure was recorded by a pedograph, BMI was calculated by weight/height² (CDC chart), and balance was assessed by Bidex balance system. **Results:** Subjects who were overweight or obese had significantly higher peak plantar pressure on both their right and left sides when compared to those who were normal weight ($p < 0.05$) and underweight ($p < 0.001$), and those who were normal weight had significantly higher peak plantar pressure on both sides when compared to those who were underweight ($p < 0.05$). Subjects who were overweight or obese had significantly higher anterior-posterior stability index, medial-lateral stability index, and overall stability index than those who were underweight or normal weight ($p < 0.001$). **Conclusion:** According to the results of our research, it includes positive association between plantar pressure, body mass index and balance in normal children with different weight characteristics. Our findings indicate that while obese and overweight children exhibit significantly higher peak plantar pressure, their higher stability indices suggest reduced postural stability compared to normal and underweight children with different weight characteristics. This implies that increased body mass in these children poses challenges to their balance control. **Clinical Trial.gov ID:** NCT06478836.

Keywords: Balance, Body Mass Index, Children, Normal, Plantar Pressure

Introduction

Foot plantar pressure, the force exerted between the foot and a supporting surface during ambulation, provides crucial biomechanical insights. This knowledge is indispensable across various fields, including sports biomechanics, injury prevention, shoe design, diagnosis of lower limb issues in gait and posture studies, balance control assessment, and the development of rehabilitation support systems¹. The distribution and magnitude of plantar pressure are

fundamental biomechanical indicators of an individual's standing balance and can reveal various foot pathologies².

Individuals with higher body mass index (BMI) and waist circumference often experience challenges with balance, gait, and maintaining strength and mobility in daily activities³. Obesity is associated with improperly distributed joint stresses and increased musculoskeletal loading, particularly during weight-bearing activities like walking and stair climbing. Furthermore, obese individuals often exhibit structural changes in their musculoskeletal system, decreased range of motion, and altered gait patterns, including modifications to knee flexion, single and double support phases, and stance and swing phases⁴.

Balance is the body's ability to maintain its center of gravity within its base of support, requiring constant adjustments from muscles and joints. This complex process relies on a healthy interplay between the neurological and musculoskeletal systems. Maintaining postural balance involves an adequate motor response, the central nervous system's integration of sensory-motor information, and

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the body's ability to sense its own movements through visual, vestibular, and somatosensory inputs. Effective muscle control and dynamic balance depend on coordinated muscular activity. Increased body fat and higher body mass can negatively impact balance, significantly increasing the risk of falls, especially when combined with insufficient muscle mass, which compromises the body's stabilizing mechanisms⁵.

Previous research indicates that overweight and obese individuals demonstrate larger foot contact areas, reduced longitudinal foot arches, elevated peak pressures, and higher force-time integrals compared to normal-weight individuals⁶. These differences, particularly the persistent malformation of the foot arch in overweight children, suggest that excess weight is not compensated for by active gait processes or passive foot structure and may worsen with age^{6,7}.

Barbosa et al.'s study on the ability to maintain balance in low and high BMI groups found that the high BMI group was less able to do so throughout daily activities⁸. The rise in midfoot pressure is expected to counteract the degeneration of A/P⁹.

Reduced height of the medial longitudinal arch may have an impact on anteroposterior balance. Moreover, the changed anteroposterior balance results in issues with the foot's mechanoreceptors in addition to a decrease in the height of the medial longitudinal arch⁹. By pushing the weight over the foot's mechanoreceptors that detect it, Handrigan et al. found that carrying extra weight can degrade the quality of proprioceptive information needed for balance¹⁰⁻¹².

Overweight individuals often experience higher midfoot pressures due to increased midfoot contact area and a decrease in the medial longitudinal arch height, directly resulting from weight gain^{9,13}. Excessively high lordotic curvature of lumbar spine, issues with shifting one's weight, and poor biomechanics are all consequences of obesity¹⁴. Consequently, obesity is linked to an increased risk of falls, as well as related injuries and impairments¹⁵.

We need postural balance to go about our everyday lives in a normal manner. Equilibrium is defined as the ability to regulate the center of mass within the base of support that maintains the body's balance¹⁶. This requires continuous adjustments in joint alignment and muscle activity¹⁷. Obesity-related balance instability, a concern across all age groups globally, arises when forces disrupt the body's equilibrium, causing postural sway. Precise coordination of visual, auditory, and somatosensory inputs to the central nervous system is vital for achieving both static and dynamic balance¹⁸.

Furthermore, obesity's impact on body proportions and increased mass hinders daily activities, leading to postural instability even during quiet standing¹⁹. These physical changes make fundamental movements like lifting, carrying, stooping, kneeling, and bending challenging for individuals with higher waist circumference and body mass, ultimately impeding their strength, mobility, and ability to

perform everyday tasks^{19,20}.

Despite extensive research on plantar pressure, obesity, and balance in isolation, there remains a critical research gap in understanding the specific interrelationships between foot pressure distribution, body mass index, and balance performance in children. Previous studies have often focused on adult populations or examined these factors separately, overlooking the comprehensive interplay in a pediatric context where growth and development can profoundly influence these relationships. This gap is significant because early identification of altered foot pressure patterns and balance deficits in overweight and obese children could inform targeted interventions to prevent long-term musculoskeletal complications and improve overall functional mobility.

Therefore, the current study sought to address earlier shortcomings by examining the connection between children's foot pressure, body mass index, and balance.

Methods

Study design

This was a cross-sectional study.

Participants

The study was carried out in 2023 from April to September at Giza primary and elementary schools. Ninety typically developing children between the ages of eight and twelve were recruited to participate in the study (according to sample size power calculation). Children of both sexes were selected randomized informed that participation in the study was voluntary and confidential, as well as the study technique. The sample was chosen using inclusion and exclusion criteria. Recent fractures or surgeries, open wounds on the lower limbs, and any fixed abnormalities of the lower limbs were the exclusion criteria.

Sample size

Sample size calculation has been done through using G*POWER software, version 3.1.9.2; Franz Faul, Universitat Kiel, Germany. It has been found that the needed sample size for this investigation was $N=90$, $\alpha=0.05$, $\beta=0.2$, effect size = 0.33. The previously mentioned measures were used in the calculations.

Procedures

1. Pedograph

The usage of a pedograph is one of the processes used to determine plantar pressure. The apparatus consists of a program that is synchronized with a flat mat that is set on the ground and measures one meter in length and fifty centimeters in width²¹.

The method of obtaining the plantar footprint was through a pressure platform (Sensor Medica SRL, Rome, Italy; controller S/N: 130-220000132). The child was placed on

the pressure platform, and after assessing the appropriate position, the plantar footprint was recorded in static.

Each child stepped barefoot on a pressure plate equipped with sensors that converted the mechanical pressure of the foot into electrical signals that were sent to the computer system to begin the process of assessing plantar pressure and getting participants ready. Additionally, the "eclipse software" application has been used in the current study to calculate pressure values depending on the pressure applied to the plate. Additionally, it employs a range of pre-programmed colors to show the pressures on the foot's plantar surface. The colors red and yellow visually indicated the highest pressure, while the colors green and blue indicated the lowest degrees of assurance. For both the left and right feet of each child, each scan includes Thrust, Maximum Plantar Pressure, Average Plantar Pressure, and Foot Surface Area¹.

The child is instructed not to move for a minute while standing calmly with their arms by the sides. Three attempts were required to ensure the measurement's reproducibility. The calculated area is related to the degree of contact between the sensors and the foot plantar surface⁹.

The pedobarographic device's pressure platform contains a sensor layer that is used to monitor the foot's regional weight transfer during walking phases. Based on the results, objective data on the Antero/Posterior (A/P) and Medio/Lateral (M/L) plantar load and percentage, as well as static total balance factors, are acquired⁹.

The individuals were instructed to place their feet on the pedobarographic equipment while standing for the static analysis. Participants in the dynamic analysis were instructed to walk across the length of the platform for pedobarography⁹.

2. Body Mass Index (CDC chart in pediatrics)

The following formula is used to compute the BMI: Anthropometric data were utilized to measure body weight, height, and BMI. A body mass index with a measure below the fifth percentile is considered underweight. The healthy weight spans from the 5th to the 85th percentile. The 85th to 95th percentiles are considered overweight. Moreover, Obese: 95th percentile or higher²² based on kilograms divided by meters squared (kg/m^2). The BMI was then plotted on the Centers for Disease Control and Prevention (CDC) gender-specific BMI graphs and growth charts for girls and boys with ages ranging from 2 to 20 years. The Center for Disease Control and Prevention (CDC) has a body mass index for age chart which is beneficial in the various studies²³.

3. Bidex Balance System

The Bidex Balance System (BBS) (BSS; Bidex, Inc, Shirley, NY) was used to assess the dynamic balance of all children and is a multiaxial device that measures and records an individual's ability to sustain joint stability under dynamic stress. In contrast to force plate technologies,

the BBS employs a circular platform that may move simultaneously in the anterior-posterior and medial-lateral axes. In order to maximize the stimulation of the ankle joint mechanoreceptors, the BBS allows for a foot platform tilt of up to 20°. The BBS measures the tilt about each axis under dynamic circumstances in degrees to provide the medial-lateral stability index (MLSI), anterior-posterior stability index (APSI), and overall stability index (OSI). These indices display fluctuations close to a zero point that was selected prior to testing to verify platform stability²⁴.

The BBS has an intertester intraclass correlation coefficients (ICCs) equals 0.70 and an intratester ICCs equals 0.82. The BBS was introduced into clinical and research settings in the late 1990s. The BBS is a multi-axial tool used to assess and document an individual's posture maintenance skills in both static and dynamic scenarios. The BBS configuration includes a circular platform with the ability to move anteriorly, posteriorly, medially, and laterally. A range of demographic groups can benefit from the clinical data measures it can produce. Previous studies have shown its accuracy as a technique for objectively assessing postural stability²⁵⁻²⁸.

This dynamic platform offers eight different levels (1-8) of stability, with level 8, which is considered the most stable, and level 1, which is the least stable. In our research, we use the most stable level on dual leg stance for all children. In addition, BSS has a screen displaying the child position on it and a support handle that can be adjusted according to each child's height. The screen gives visual feedback about the degree of tilting that helps the child to maintain the cursor in the center of the screen to obtain a good score of balance.

Statistical Analysis

The Shapiro-Wilk test was used to verify that the data had a normal distribution. To check for group homogeneity, Levene's test for homogeneity of variances was used. Static Arch Index (SAI), peak and average plantar pressure, and stability index were compared amongst patients who were underweight, overweight, and obese in addition to measure effect size (η^2) using MANOVA. For the next multiple comparison, post-hoc analyses were conducted using Tukey's test. For every statistical test, the significance threshold was set at $p < 0.05$. IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA) was used for all statistical analyses.

Results

Subject characteristics

Ninety children participated in this study. Their mean age, weight, height and BMI were 9.32 ± 2.18 years, 33.00 ± 11.06 kg, 134.58 ± 12.58 cm and 17.68 ± 3.47 kg/m^2 . There were 47 (52.2%) girls and 43 (47.8%) boys respectively.

Regarding weight status, 40% were of normal weight,

Table 1. Participant characteristics.

	Normal vs Underweight	Minimum	Maximum
Age (years)	9.32 ± 2.18	6	12
Weight (kg)	33.00 ± 11.06	15	56
Height (cm)	134.58 ± 12.58	108	158
BMI (kg/m²)	17.68 ± 3.47	11.52	27.30
SAI	0.78 ± 0.25	0.40	1.30
Sex, N (%)			
Girls	47 (52.2%)		
Boys	43 (47.8%)		
Weight status, N (%)			
Normal	36 (40%)		
Overweight & Obese	22 (24.4%)		
Underweight	32 (35.6%)		
Foot posture, N (%)			
Normal	42 (46.7%)		
Flatfoot	42 (46.7%)		
High arch	6 (6.7%)		

SD, Standard Deviation; BMI, Body Mass Index; SAI, Static Arch Index.

Table 2. Men Static Arch Index., peak and average plantar pressure and stability index of subjects with normal, overweight & obesity and underweight.

	Normal	Overweight & Obese	Underweight	F-value	p-value	η^2
	mean \pm SD	mean \pm SD	mean \pm SD			
SAI	0.73 ± 0.26	0.92 ± 0.18	0.76 ± 0.25	4.46	0.01	0.09
Peak plantar pressure (g/cm²)						
Right side	887.42 ± 216.62	1058.36 ± 282.04	717.50 ± 205.89	14.44	0.001	0.25
Left side	1069.22 ± 279.93	1261.09 ± 296.68	898.63 ± 283.30	10.59	0.001	0.20
Average plantar pressure (g/cm²)						
Right side	303.86 ± 74.32	370.55 ± 80.91	256.63 ± 54.03	17.47	0.001	0.29
Left side	339.22 ± 83.57	397.27 ± 69.07	284.91 ± 59.37	15.93	0.001	0.27
Stability index						
APSI	2.19 ± 0.09	2.75 ± 0.15	1.92 ± 0.09	391.52	0.001	0.90
MLSI	1.80 ± 0.38	3.27 ± 0.43	2.16 ± 0.45	87.77	0.001	0.67
OSI	1.56 ± 0.29	2.99 ± 0.46	1.82 ± 0.28	130.34	0.001	0.75

SD, Standard Deviation; p Value, Probability Value; η^2 , Partial Eta Squared, SAI, Static Arch Index; APSI, Anterior-Posterior Stability Index; MLSI, Medio-Lateral Stability Index; OSI, Overall Stability Index.

24.4% were overweight & obese, and 35.6% were underweight. For foot posture, 46.7% had a normal foot posture, 46.7% had flatfoot, and 6.7% had a high arch. Table 1 shows the subject's characteristics.

Effect of weight status on Static Arch Index, peak and average plantar pressure and stability index

When people with normal weight were compared to those who were overweight or obese, their SAI significantly

decreased ($p < 0.01$). The SAI did not, however, differ significantly between patients who were underweight and those who were normal weight ($p > 0.05$) or between subjects who were overweight and obese and those who were underweight ($p > 0.05$).

Subjects who were overweight or obese had significantly higher peak plantar pressure on both their right and left sides when compared to those who were normal weight ($p < 0.05$) and underweight ($p < 0.001$), and those who

Table 3. Comparison of SAI, peak and average plantar pressure and stability index between subjects with normal, overweight, obesity and underweight.

Outcome	Normal vs Overweight & Obese		Normal vs Underweight		Overweight & Obese vs Underweight	
	MD (95% CI)	p value	MD (95% CI)	p value	MD (95% CI)	p value
SAI	-0.19 (-0.34: -0.03)	0.01	-0.03 (-0.17: 0.11)	0.85	0.16 (-0.002: 0.31)	0.06
Peak plantar pressure (g/cm²)						
Right side	-170.94 (-319.76: -22.14)	0.02	169.92 (36.32: 303.52)	0.009	340.86 (188.57: 493.16)	0.001
Left side	-191.87 (-375.93: -7.80)	0.03	170.59 (5.34: 335.85)	0.04	362.46 (174.09: 550.84)	0.001
Average plantar pressure (g/cm²)						
Right side	-66.69 (-111.59: -21.78)	0.002	47.23 (6.92: 87.55)	0.01	113.92 (67.96: 159.88)	0.001
Left side	-58.05 (-104.66: -11.44)	0.01	54.31 (12.47: 96.16)	0.007	112.36 (64.67: 160.07)	0.001
Stability index						
APSI	-0.56 (-0.63: -0.49)	0.001	0.27 (0.21: 0.34)	0.001	0.83 (0.76: 0.90)	0.001
MLSI	-1.47 (-1.74: -1.20)	0.001	-0.36 (-0.60: -0.12)	0.002	1.11 (0.83: 1.38)	0.001
OSI	-1.43 (-1.65: -1.22)	0.001	-0.26 (-0.46: -0.07)	0.005	1.17 (0.95: 1.39)	0.001

MD, Mean Difference; CI, Confidence Interval; p Value, Probability Value, SAI, Static Arch Index.;APSI, Anterior-Posterior Stability Index; MLSI, Medio-Lateral Stability Index; OSI, Overall Stability Index.

were normal weight had significantly higher peak plantar pressure on both sides when compared to those who were underweight ($p < 0.05$).

There was a significant increase in average plantar pressure on both the right and left sides of subjects with overweight & obesity compared with subjects with normal ($p < 0.01$) and underweight ($p < 0.001$), and a significant increase in average plantar pressure on both sides of subjects with normal weight compared with subjects with underweight ($p < 0.01$).

There was a significant increase in APSI, MLSI and OSI of subjects with overweight & obesity compared with subjects with normal and underweight ($p < 0.001$).

There was a significant increase APSI of subjects with normal weight compared with subjects with underweight ($p < 0.001$), while There was a significant increase MLSI and OSI of subjects with underweight compared with subjects with normal weight ($p < 0.01$). (Tables 2-3).

Discussion

This study investigated how normal children's foot pressure, body mass index, and balance relate to one another. According to our findings, subjects who were overweight or obese had significantly higher peak plantar pressure on both their right and left sides when compared to those who were normal weight ($p < 0.05$) and underweight ($p < 0.001$), and subjects who were normal weight had significantly higher peak plantar pressure on both sides when compared to those who were underweight ($p < 0.05$). Subjects who were overweight or obese had significantly higher APSI, MLSI,

and OSI than those who were underweight or normal weight ($p < 0.001$). This finding suggests that overweight and obese children exhibited poorer balance control compared to their normal-weight and underweight counterparts, as higher values in these indices indicate increased postural sway and reduced stability. This aligns with previous research highlighting the challenges obese individuals face in maintaining equilibrium due to altered body proportions and increased mass.

Our findings show significantly higher peak and average plantar pressure in overweight and obese children compared to normal weight and underweight groups, aligning with a substantial body of literature. Numerous studies have consistently reported that increased body mass, as indicated by higher BMI, leads to elevated plantar pressures in children and adolescents, particularly in weight-bearing areas like the forefoot. These studies suggest that the greater body weight directly contributes to increased mechanical load on the feet during both static standing and dynamic movement. However, it is also important to note that some research indicates that the relationship between BMI and plantar pressure may not be uniform across all weight categories, or that other factors like muscular strength and walking habits can also play a significant role. This suggests a more nuanced interaction than a simple linear relationship, emphasizing the complexity of how weight impacts foot biomechanics^{3,29,30,31,32,33}.

Plantar pressure and balance are interconnected. Balance is crucial for postural control in children, and plantar pressure distribution provides insights into how effectively the body can maintain stability. A study by AÇIKGÖZ et al.

(2023) found a significant relationship between plantar pressure distribution and balance performance in children, showing that more balanced plantar pressure patterns were associated with improved postural control during static standing. There is a strong correlation between plantar force and balancing reach distance during dynamic exercise in the dominant leg (anterior and posteromedial direction) and nondominant leg (posteromedial and posterolateral direction). In individuals with a high static balance error score for the nondominant leg, the forefoot plantar pressure distribution in both feet were lower than the rearfoot plantar pressure distribution²⁰. Similar findings were reported by Cerezci-Duygu et al. (2024), who observed that children with more even plantar pressure distribution during dynamic tasks, such as walking, exhibited better overall balance, suggesting that plantar pressure patterns could predict balance stability³⁴. In contrast, a study by Youssef et al. (2025) found no significant association between plantar pressure and balance in normal children, arguing that balance is influenced by a combination of neuromuscular control and sensory input rather than plantar pressure alone³⁵. Similarly, research by Kumar et al. (2018) found that while plantar pressure can vary in children, it does not necessarily correlate with balance performance, suggesting that factors like coordination and motor control play a more pivotal role in determining balance ability³⁶.

BMI can influence balance in children. Balance is essential for maintaining postural control during various activities, and body composition, as indicated by BMI, might affect a child's ability to maintain stability. A study by Rusek et al. (2021) found that children with higher BMI exhibited poorer balance performance, particularly during dynamic tasks, suggesting that excess body weight may impair a child's ability to maintain stability during movement³⁷. Similarly, Kolic et al. (2020) observed that children with higher BMI had reduced postural control, especially during single-leg stance tasks, which are sensitive to shifts in body mass and alignment³⁸. Also, a study by Prasetyowati et al. (2017) concluded that compared to overweight and normal children, obese children have considerably higher absolute knee extensor muscle strength and worse postural balance. Muscle strength and postural balance do not significantly correlate³⁹. In contrast, a study by Alhusaini et al. (2020) found no significant correlation between BMI and balance in normal-weight children, suggesting that factors such as neuromuscular control and physical activity level may be more important in determining balance performance⁴⁰. Another study by Ludwig (2017) reported that although obesity negatively impacts balance, BMI within the normal range had little to no effect on balance performance in children, indicating that BMI alone may not be a reliable predictor of balance in normal-weight children⁴¹.

While our study highlights a direct relationship between increased BMI and altered plantar pressure distribution, as well as reduced postural stability, it is important to consider the potential role of biomechanical compensation and muscular adaptations in these observed differences. Excess

body weight necessitates the musculoskeletal system to adapt to increased loads. For instance, changes in gait patterns, joint kinematics, and muscle activation strategies may occur as the body attempts to maintain equilibrium and distribute forces more broadly across the plantar surface. These adaptations, such as increased co-contraction of ankle muscles or altered alignment of lower limb joints, might initially serve to stabilize the body, but could also contribute to the observed higher plantar pressures and, paradoxically, less efficient postural control over time. Future research could explore these adaptive mechanisms through kinetic and kinematic analyses to provide a more comprehensive understanding of how overweight and obesity influence balance beyond the direct effect of increased mass.

Furthermore, a notable finding from our participant characteristics was the high prevalence of flatfoot (46.7%) within the study cohort. This observation is particularly relevant given the established connections between foot posture, plantar pressure distribution, and balance. Flatfoot, characterized by a reduced or collapsed medial longitudinal arch, can significantly alter foot biomechanics, leading to increased pressure in the midfoot region and potentially affecting overall postural stability. While our study primarily focused on the influence of BMI, the high incidence of flatfoot in our sample may represent a confounding factor or an additional contributor to the observed plantar pressure patterns and balance outcomes. Future research should consider a more detailed analysis of foot posture variations and their interaction with body mass index influencing biomechanical parameters in children. This could involve sub-group analyses based on foot posture or the use of more detailed foot posture assessment tools to disentangle the independent and combined effects of weight status and foot structure.

Regarding the relationship between elevated plantar pressures and structural changes that may impact balance, it is crucial to differentiate between cause and consequence. Our findings, consistent with existing literature, indicate that higher body weight directly leads to increased plantar pressures. This elevated mechanical load is a direct consequence of excess weight. Over time, however, persistent high plantar pressures, particularly in the presence of altered foot posture like flatfoot (as observed in our cohort), can contribute to structural adaptations and deformities in the foot, such as the progressive reduction of the medial longitudinal arch. While our cross-sectional design does not allow for the establishment of causality, it is plausible that these weight-induced structural changes, in turn, further compromise the foot's ability to act as a stable base of support, thereby negatively impacting balance mechanisms. This suggests a complex, bidirectional relationship where excess weight drives initial plantar pressure changes, which can then contribute to structural modifications that exacerbate balance impairments. Longitudinal studies are warranted to fully elucidate this progressive relationship and the long-term implications of

these changes on musculoskeletal health and balance in children.

Study limitations are the impact of psychological variables that may affect the study was not assessed and the results' applicability to pediatric populations will be impacted by their restriction on children ages 8 to 12. Furthermore, the cross-sectional nature precludes causality and lack of longitudinal data or assessment of physical activity level is a notable limitation.

Recommendations for future research include assessing joint proprioception and gait kinetic characteristics as well as researching various approaches in various children age groups to gauge the relationship between BMI and balance.

Conclusion

According to the results of our research, it includes positive association between plantar pressure, body mass index and balance in normal children with different weight characteristics. Our findings indicate that while obese and overweight children exhibit significantly higher peak plantar pressure, their higher stability indices suggest reduced postural stability compared to normal and underweight children with different weight characteristics. This implies that increased body mass in these children poses challenges to their balance control.

Ethics approval

This study was approved by the Ethical Committee of the faculty of Physical Therapy, Cairo University (NO: P.T.REC/012/004586) on June 11th, 2023.

Consent to participate

Written informed consent was obtained from each child's parents or legal guardian before enrolment and assessment in the study.

Authors' contributions

SMS was responsible for the study's conceptualization and design, implementation, supply of research materials, and gathering and organizing of data. MU, MSM, and SA wrote the initial and final drafts of the article, analyzed and interpreted the data, and helped with the logistics. All authors, who are also responsible for the content and similarity index of the work, have carefully reviewed and approved the final text.

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