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Assessment of Sacral Ratio in Patients with Fecal Incontinence and Its Correlation with Treatment Response among Iranian Pediatric Patients

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Abstract

Background and Objective: Fecal incontinence (FI) is a multifactorial condition characterized by involuntary fecal excretion, impacting quality of life. Approximately 1 in 12 adults worldwide suffer from FI, with a higher prevalence among women and the elderly. FI patients often experience physical and psychological problems, including infections, skin issues, and social anxiety. Sacral anomalies may contribute to FI, and the sacral ratio (SR) is a reliable metric for evaluating sacral development in anorectal malformations. This study aims to investigate changes in SR among children with FI to assess its role in FI diagnosis and prediction.

Methods: This case-control study was conducted on 288 children aged 4-18 years referred to Mofid Children's Hospital in Tehran, Iran. The data were analyzed using SPSS software to control for confounders. Demographic data, FI condition, and radiological findings were evaluated, and SR values were compared between the case and control groups.

Results: The study involved 288 children (158 females, 130 males). The average age for the FI group was 7.12 ± 2.57 years, and for the control group, it was 8.56 ± 2.89 years. The overall SR was 0.6760 ± 0.12369 with a confidence interval of 0.6616 to 0.6904. The control group had a higher SR (0.6968 ± 0.10) compared to the FI group (0.65 ± 0.13), with a significant difference between groups (effect size: Cohen's d = 0.34, p-value = 0.005). Nine subjects in the case group did not respond to treatment. SR (P=0.993) and sex (P=0.237) were not significantly associated with response to treatment

Conclusion: This study highlights the complex role of SR in the field of pediatric FI, emphasizing the need for a nuanced, multidisciplinary approach to address this challenging clinical condition. Continued research in this area will undoubtedly advance our understanding and lead to more targeted and effective interventions for affected children.

Key Words: Chronic constipation, Fecal incontinence, Sacral ratio.

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1- INTRODUCTION

Fecal incontinence (FI) is a multifactorial condition characterized by the involuntary excretion of fecal matter, unrelated to any underlying medical condition, occurring after the individual has achieved bowel control. This diagnosis is typically made after the age of 4, which is the developmental milestone when children are expected to have attained bowel continence (1). FI affects individuals across all age groups, but it is particularly prevalent among women and the elderly. According to a systematic review and meta-analysis study conducted in 2024, approximately 1 in 12 adults worldwide suffer from fecal incontinence. The prevalence of this condition is greater among women and older individuals (2). The condition significantly impacts the quality of life, not only due to the physical symptoms but also because of the associated psychological and social challenges. Patients with fecal incontinence often face a cluster of physical and psychological problems, including repeated infections, skin ulcers, scars, social anxiety disorder, behavioral issues, self-abasement or isolation, and other challenges. These problems can lead to feelings of guilt and embarrassment for the affected individual (3).

Diagnosing and effectively treating FI remains a significant challenge due to its multifactorial nature and complex underlying causes. The potential presence of developmental abnormalities, such as anorectal malformations (ARM) and sacral anomalies, should be considered as causes of FI. Sacral bone disorders, including partial or complete sacral agenesis, can contribute to the development of fecal and urinary dysfunctions, such as urinary reflux, recurrent urinary infections, incontinence, and constipation (4). One of the diagnostic approaches to understanding these anatomical abnormalities is the sacral ratio (SR), a reliable metric introduced by Alberto Pena in 1995 for evaluating sacral development, particularly in individuals with anorectal malformations (5).

The SR measures changes in bone structure, emphasizing the importance of skeletal features in maintaining functional bowel control. (6, 7). This metric compares the size of the sacrum to fixed pelvic bony parameters and is measured on both anteroposterior (AP) and lateral radiographic views. This value is typically calculated based on radiographic studies, including sacral radiograms and distal colostograms. Alternatively, magnetic resonance imaging (MRI) scans can be utilized for these measurements, with demonstrated good inter-rater reliability. This parameter is relevant to this study as it provides a quantifiable measure of sacral development, which is critical for understanding its role in bowel function and fecal continence. The SR is calculated using three horizontal lines: (1) at the top of the iliac crests; (2) at the inferior point of the sacroiliac joints; and (3) at the tip of the coccyx. The lateral view is considered more reliable than the AP view, as the sacrum can appear shorter on the latter due to pelvic tilt. Based on the sacral ratio, patients can be divided into three groups: (1) SR less than 0.4, which indicates poor potential for bowel control; (2) SR between 0.4 and 0.69; and (3) SR 0.7 or higher, which is associated with a higher likelihood of fecal continence (8). In general, it can be said that the SR tends to be higher in healthy individuals compared to those with urinary or intestinal problems. Additionally, the value of the SR index in healthy patients remains relatively constant and does not fluctuate significantly over time. The SR can also be utilized as a predictive tool for evaluating an individual's digestive functional status (9, 10).

To the best of our knowledge, this study is the first to evaluate the role of the sacral

ratio in pediatric fecal incontinence within the Middle Eastern population, an area that has not yet been extensively researched. The purpose of this study was to investigate the changes in the SR among children with FI to assess the role of this metric in the diagnosis and prediction of FI in children.

2- MATERIALS AND METHODS

2-1. Inclusion and Exclusion Criteria

This case-control study was conducted on 288 children aged 4-18 years who wear referred to Mofid Children's Hospital in Tehran, Iran between 2021-2023. The case group consisted of 144 children diagnosed with FI. Additionally, the control group included 144 children without FI who had visited the hospital for other reasons, such as trauma, and were also examined. Subsequently, the SR was compared between these two groups. Children with trauma, anatomical problems of the pelvis and spine, arthritis, any known neurogenic disease, myelodysplasia, cloacal anomaly, Hirschsprung's disease, or vascular disorders were excluded from the study.

2-2. Clinical Assessment

A researcher-developed checklist was used as the data collection tool in this study. The checklist included demographic information, details about the patients' FI condition, and their corresponding radiological findings. The necessary patient information was obtained by reviewing medical records and radiology reports. In cases where the files were incomplete, the research team contacted the patients' families by telephone to gather the missing data.

To calculate the SR from lumbosacral anterior-posterior radiographs, three parallel horizontal reference lines were drawn using precise anatomical landmarks: Line 1 was drawn at the highest point of the iliac crests bilaterally. Line 2 was drawn connecting the inferior points of the sacroiliac joints. Line 3 was drawn connecting the lowest identifiable point of the sacrum or the tip of the coccyx. The SR was then calculated as a ratio of the distances between these lines:

$$SR = \frac{\text{Vertical distance between Line 2 and Line 3}}{\text{Vertical distance between Line 1 and Line 2}}$$

2-3. Ethical Consideration

The ethics committee of Shahid Beheshti University of Medical Sciences approved the study. Written informed consent was obtained from the parents of the children.

2-4. Statistical Analysis

After collecting the data, it was entered into the Statistical Package for the Social Sciences (SPSS) software, version 26, for analysis. Quantitative variables were described using the mean and standard deviation, while qualitative variables were presented using frequency and percentage. The normality of quantitative variables was first assessed using the Kolmogorov-Smirnov test. To compare the groups, t-tests, ANOVA, and chi-square tests were used. Finally, potential confounding effects on the expected effect size were assessed, considering variables such as age, gender, and comorbidities that may influence the relationship between FI and SR. Logistic and linear regression models were used to control for these confounders. Specifically, linear regression was employed to model SR as the dependent variable, with FI status (case or control) as the primary independent variable, and age and gender included as covariates. This allowed us to isolate the effect of FI on SR while accounting for other influencing factors.

3- RESULTS

The study involved 288 children, 158 females and 130 males. The average age for those with fecal incontinence was

7.12 ± 2.57 years, while for the healthy group, it was 8.56 ± 2.89 years (Table 1).

The overall average SR was 0.6760±0.12369, with a 95% confidence interval ranging from 0.6616 to 0.6904 (Table 1). In the control group, the average SR was 0.6968±0.10522, with a 95% confidence interval estimated to be between 0.6793 and 0.7142 (Table 1). Conversely, the case group showed a lower average SR of 0.6556±0.13676, with a 95% confidence interval from 0.6332 to 0.6781 (effect size: Cohen's d=0.34) (Table 1). The Control Group demonstrated a slightly higher SR compared to the other groups, with minor differences observed between genders (Figure 1).

Table-1. Baseline characteristics.

Characteristic			**Value**	
Total Participants, n			288	
Gender, n	Male		130	
	Female		158	
Age, mean ± SD	FI group		7.12 ± 2.57	
	Healthy group		8.56 ± 2.89	
Sacral Ratio (SR)	Overall, mean ± SD (95% CI)		0.6760 ± 0.12369 (0.6616 - 0.6904)	
	Control group, mean ± SD (95% CI)		0.6968 ± 0.10522 (0.6793 - 0.7142)	
	Case group, mean ± SD (95% CI)		0.6556 ± 0.13676 (0.6332 - 0.6781)	
	Ethnicity, mean±SD	Persian	0.69 ± 0.12	
		Lur	0.75 ± 0.12	
		Turk	0.7 ± 0.11	
		Kurd	0.72 ± 0.07	
		Other	0.66 ± 0.11	
	Gender Subgroups	Female (n = 158)	mean ± SD	0.6749 ± 0.12461
			Standard Error of Mean	0.00995
			Adjusted Mean SR	0.6768
			Median SR	0.67
		Male (n = 130)	mean ± SD	0.6773 ± 0.12304
			Standard Error of Mean	0.01079
			Adjusted Mean SR	0.6781
			Median SR	0.6750

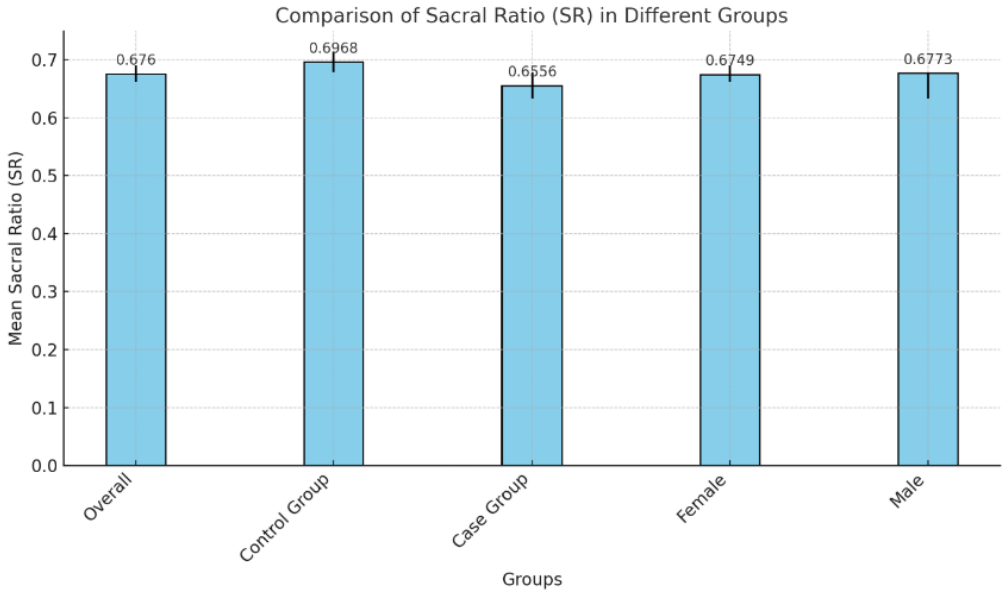

Figure-1: Comparison of Sacral Ratio (SR) in Different Groups.

A statistically significant difference was found between the case and control groups (t = 2.851, df = 285, p = 0.005). The mean SR difference was 0.04112 (95% CI: 0.01273 to 0.06951) (Table 2). The control group had a statistically higher SR than the case group.

In terms of gender, the average SR for females (n=158) was 0.6749±0.12461, and for males (n=130), it was 0.6773±0.12304. There was no statistically significant difference in SR between males and females (t=−0.164, df=285, p=0.870). The average SR difference between the sexes was −0.00242 (95% CI:−0.03134 to 0.02650) (Table 2).

Table-2. Comparison of SR between case and control groups, and gender differences.

Comparison		Value
Comparison between case and control groups	p-value	0.005*
	Mean Difference in SR	0.04112
	95% CI for Mean Difference	0.01273 to 0.06951
Comparison between male and female	p-value	0.875
	Mean Difference in SR	-0.00242
	95% CI for Mean Difference	-0.03134 to 0.02650

*Statistically significant

4- DISCUSSION

The present study examines the complex relationship between SR values and FI in pediatric patients, aiming to elucidate the relationships and potential changes in this important anatomical parameter in this disease. Conducted on a group of 144 children, this study showed how SR differed between those presenting with FI and a control group without this complaint. The key findings of the study, implications for clinical practice, the impact of gender differences, and the need for further investigation in understanding the dynamics of SR in pediatric populations have been discussed.

The mean SR for the entire data set, including both case and control groups, was 0.6760 ± 0.12369, which provides a baseline understanding of SR values in the study population of children. These descriptive statistics provide the basis for subsequent comparisons between distinct subgroups. The normal range of SR in pediatric populations is a critical criterion for clinicians evaluating spinal and pelvic growth in children (11). This range provides a measure that helps clinicians identify deviations from expected values. While the specific normal range may vary slightly among different age groups (7, 12), baseline comprehension is typically in the range of 0.66 to 0.70, although much larger intervals have been considered for it (13). Values in this range represent normal development of the spine and pelvis, helping clinicians distinguish between normal anatomical changes and potential abnormalities. The fact that the value found in our study falls within this reference range validates the methodology used in this study.

The comparison between the control group and the case group showed interesting differences. The control group had a higher mean SR of 0.6968, with a relatively narrow 95% confidence interval (0.6793 to 0.7142). In contrast, the case group showed a lower mean SR of 0.6556, with a wider 95% confidence interval (0.6332 to 0.6781). The significant difference in the mean values of SR between the two groups indicated a potential relationship between low SR and the presence of FI in pediatric patients. The independent t-test confirmed this divergence, showing a statistically significant difference in mean SR (p = 0.005) and further highlighting the lower

SR in the FI group. These statistical findings confirm the distinctness of SR values in the population of children with fecal incontinence compared to the control group.

The present study aligns with previous research indicating significant differences in SR values between subjects with FI and those without. For instance, Ahmadi et al. (5) found that anatomical features of the sacrum and SR seem to directly affect the final functional outcome in ARMs, with abnormal SR associated with poor bowel function. In their study, the mean SR in normal children was ≥0.74, with 17.7% having a value higher than 0.70 and 82.3% having a value lower than 0.69. Among children with ARMs and abnormal SR, 68% had an SR between 0.50-0.69, 21.5% had an SR between 0.40-0.49, and 10.5% had an SR between 0-0.39 (5). Additionally, Kajbafzadeh et al. (6) reported a normal value for anteroposterior SR (APSR) ranging from 0.36-1.33 with an average of 0.71. They also found that the average APSR in patients with urinary and/or fecal symptoms and signs was 0.554, and the difference in SR values between the two groups was statistically significant ($P<0.05$). These previous studies, along with the findings from the present investigation, suggest a potential relationship between lower SR values and the presence of fecal incontinence in pediatric populations.

However, some studies showed this relationship to be non-significant. Specifically, Afzali et al. (14) found that SR showed a wide range of values in both the control and FI groups, and the average SR in the control group was higher than the study group, but this difference was not statistically significant. The mean SR in the case group was 0.8 ± 0.12 and the control group was 0.826 ± 0.15, but this difference was not statistically significant ($P> 0.05$) (14). Additionally, in the study by Caicedo et al. (15), There was no significant difference in SR between patients with FI and the control group. In their study, the mean SR in the normal population was 0.7022 and 0.7087 in the AP view, and 0.7257 and 0.7370 in the lateral (LAT) view. For patients with FI, the average SR value was 0.714 in the AP view and 0.7239 and 0.757 and 0.796 in the lateral view, which did not differ significantly from the control group (15). These contrasting findings suggest that the relationship between SR and fecal incontinence in pediatric populations may be more complex than previously thought and warrants further investigation to elucidate the nuances of this association.

Low SR values in this population suggest potential biomechanical or anatomical factors contributing to this condition. While these findings provide valuable insights, the exact mechanisms underlying this relationship remain an area of ongoing research. Further exploration of the longitudinal dynamics of SR and its association with clinical outcomes is likely to deepen our understanding of its role in FI and potentially pave the way for more targeted diagnostic and therapeutic interventions in pediatric and adult populations.

SR has been recognized as a valuable indicator of pelvic and spine morphology, but its validity as a clinical measure the subject of considerable research and has been seen to depend on various factors including differences in measurement techniques, radiologist expertise, potential confounding factors (12, 16), and its ability to accurately reflect the anatomical and biomechanical aspects of FI. Warne et al (17) found that SR had good inter- and intraobserver reproducibility, but the variability of values among similar patients was high, suggesting that this single value has limited value in distinguishing normal from abnormal sacrum. Metzger et al (18) also showed that among radiologists, the reliability of

SR calculations was excellent for the AP view but poor for the LAT view. Ahmad et al. (19), in a cohort of 646 observations of patients with ARMs who were radiographed in both the AP and LAT planes, found that although the AP view and LAT view of SR had a moderate positive correlation, the mean SR determined by images in the LAT view was 0.07 units larger than the AP view.

Continued research efforts, incorporating larger and more diverse samples, standardized measurement protocols, and longitudinal assessments, are necessary to strengthen the validity of SR as a clinically meaningful parameter.

The examination of potential gender influences on SR reveals nuanced findings. Descriptive statistics for the SR variable in the male and female groups show minor differences, with the female group having an average SR of 0.6749 and the male group having an average SR of 0.6773. However, statistical analysis did not demonstrate any significant variance in SR between the two gender groups. These results indicate that gender does not have a significant effect on SR in the context of children's FI. The mean SR remained consistently stable in both male and female groups, suggesting that changes in SR are more prominently associated with the presence or absence of FI, rather than being driven by gender-specific differences. These findings align with the observations reported by Afzali et al. (4), who also found no significant difference in SR values among gender groups. Collectively, these data suggest that the relationship between SR and FI in pediatric populations may be more strongly influenced by anatomical and biomechanical factors, rather than being significantly moderated by gender.

These findings have important implications for clinical decision-making. The lower mean SR observed in children with FI indicates the potential role of SR assessment in identifying anatomical or biomechanical factors affecting anorectal defects, especially incontinence secondary to chronic constipation (10, 20). Clinicians should consider integrating SR assessments into their evaluations of pediatric FI and recognize its potential utility as an adjunctive diagnostic tool. However, acknowledging the complexity of the causes of FI requires a cautious interpretation.

While this study contributes valuable insights, it is not without limitations. As a case-control design, this study is unable to establish causal relationships between SR and FI. Future longitudinal research will be necessary to further elucidate the dynamics of this association over time. Additionally, the limitation of this study to a single center may limit the generalizability of the findings. Multicenter collaborations in the future would help to expand the sample size and diversity, enhancing the representativeness of the study population. Furthermore, future research efforts should examine age-related changes in SR and explore potential confounding factors that may affect its variability in pediatric populations.

5- CONCLUSION

This study reveals the complex role of SR in the field of pediatric FI research. The observed differences in mean SR values between the case and control groups, along with the absence of significant gender effects, emphasize the potential importance of SR assessments in clinical evaluations of this condition. However, it is crucial to recognize the multifactorial nature of FI in order to achieve an accurate interpretation of the findings. While lower SR values may be associated with FI, the etiology of this condition is complex. As research continues to advance in this area, a more comprehensive understanding of SR and its clinical implications will emerge,

providing opportunities for improved diagnostic and therapeutic approaches for pediatric patients with fecal incontinence. Further large-scale observational studies in Middle Eastern populations, are still required to enhance our understanding of the complexities surrounding SR in pediatric FI and to guide future clinical practice and research efforts.

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