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Mentzer Index as a Screening Tool for Detecting Iron Deficiency Anemia Keeping Serum Ferritin as Gold Standard

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ABSTRACT

Background: Iron-deficiency anemia remains a prevalent condition in children, with considerable effect on their development and growth. Early and accurate diagnosis is essential to effective management, particularly in a setting of low resources. The Mentzer index has been proposed to be a good screening tool for IDA based on its low cost and simplicity of performance, although its diagnostic accuracy regarding serum ferritin levels must be established. **Objective:** To determine the diagnostic accuracy of Mentzer index in detecting iron deficiency anemia taking serum ferritin as gold standard in children. **Study Design:** Cross-sectional validation study. **Duration and Place of Study:** The study was conducted from April 2024 to October 2024 at the Department of Pediatrics Medicine, ATH Abbottabad. **Methodology:** A total of 162 children aged 1 to 5 years, presenting with symptoms suggestive of IDA, were enrolled through convenient sampling. The Mentzer index was calculated for each participant, and serum ferritin levels were measured. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were calculated for the Mentzer index using a 2x2 contingency table to compare with the serum ferritin test. **Results:** The study found that the Mentzer index demonstrated high sensitivity of 91.6% and specificity 87%)for diagnosing IDA in children. The diagnostic accuracy was 90%, with a PPV of 91% and an NPV of 88%. Stratified analysis indicated better performance in rural populations (sensitivity 93%, specificity 88%) compared to urban areas (sensitivity 67%, specificity 87%). Gender-based differences were observed, with males showing a higher PPV (97%) compared to females (77%). **Conclusion:** The Mentzer index is a reliable, cost-effective screening tool for iron deficiency anemia in children, particularly in resource-constrained settings.

INTRODUCTION

Iron-deficient anemia (IDA) is one of the most common dietary deficiencies in the world, and it exists predominantly in children.[1] IDA results due to low iron content in the body and, as a consequence, loss of hemoglobin and impaired carrying capacity of oxygen by red blood cells.[2] IDA, in children, will damage cognitive development, impair immune status, and affect physical growth.[3] The syndrome will typically manifest as a result of low dietary intake of iron, malabsorption, or increased iron requirements when there is increased growth.[4] If uncontrolled, iron-deficient anemia will cause permanent damage to child health and development, and hence its detection and treatment at an initial level are crucial.[5]

Diagnosis of childhood iron deficiency anemia is critical to forestall its complications. Traditionally, diagnosis of IDA is done by laboratory assessment of hemoglobin, serum ferritin, and other iron store indices.[6] However, access to these is at places limited, costly, and time-consuming, especially in resource-poor settings. Clinicians hence often rely on a constellation of clinical presentation and limited laboratory measurements, e.g., mean corpuscular volume (MCV) and red cell distribution width (RDW) to inform diagnosis.[7] While useful, these tools aren't always absolute, and there's need to develop and implement an effective and low-cost screen to enable earlier detection.

Mentzer index is an effective screener of iron deficiency anemia in children.[8] The index is an uncomplicated formula that employs MCV and RDW of a patient's blood sample to estimate the chances of IDA.[9] The formula is calculated as a ratio of MCV to RDW, and a reading below a certain threshold suggests iron deficiency anemia, and higher values tend to be attributed to other types of anemia such as thalassemia.[10] The Mentzer index is uncomplicated to perform, cost-effective, and can be easily used in routine clinical practice to quickly screen children at risk of IDA.[11] Its use as a screen can boost accuracy of early diagnosis in areas where access to costlier diagnosis is limited and provide an immediate intervention to treat iron deficiency anemia in children.[12]

A research conducted by Alam S and colleagues demonstrated that the Mentzer index exhibits a sensitivity of 80.7% and specificity of 77.7% when diagnosing iron deficiency anemia in children.[13] Similarly, a study by Din JU and others revealed that the prevalence of iron deficiency anemia among children was 37.1%.[14]

The background behind undertaking this research is because of the growing importance of early and accurate detection of iron deficiency anemia in children, a condition that can have severe long-term health consequences when undetected. The Mentzer index, an uncomplex and low-cost screen, can potentially advance diagnosis by providing an effective tool to detect IDA, especially in low-resource settings. The purpose of this study is to investigate whether or not the Mentzer index can offer enhanced accuracy of IDA detection with the possibility of improved health outcomes and well-targeted intervention in children.

METHODOLOGY

This was a cross-sectional validation study and was carried out in the Department of Pediatrics Medicine, ATH Abbottabad. The study was conducted from April 2024 to October 2024 at the Department of Pediatrics Medicine, ATH Abbottabad. The sample size was determined using the WHO sensitivity and specificity calculator, with an expected sensitivity of 80.7%, specificity of 77.7%, and a prevalence of iron deficiency of 37.1%.[13,14] A 95% confidence interval and 10% precision for both sensitivity and specificity were used, resulting in a sample size of 162.

The participants were recruited through convenient sampling. The inclusion criteria were children between ages 1 and 5 years of either sex presenting with apparent or abnormal pallor of skin, nails, conjunctiva, and/or oral mucosa, as evaluated through visual observation on physical examination. The exclusion criteria were children with a history of blood transfusion in the previous 3 months, chronic diseases with associated anemia (thalassemia), blood diseases, chronic liver or renal diseases, or congenital abnormalities.

Upon obtaining ethical approval and informed consent from the parents, data was collected, which included baseline demographic information such as age, gender, weight, residential status, and family socioeconomic status. All participants underwent blood sampling by trained phlebotomists. A 5 ml blood sample was collected in an EDTA tube for a complete blood count and a 5 ml sample in a yellow-top vacutainer for serum ferritin levels. The Mentzer index was calculated by dividing the mean corpuscular volume (MCV, in femtoliters) by the red blood cell count (RBC, in millions per microliter). A serum ferritin level of less than 30 μg/ml was considered indicative of iron deficiency anemia. Both the Mentzer index and serum ferritin levels were recorded as per the criteria described.

The data was analyzed using SPSS version 23. Descriptive statistics were applied, with continuous variables such as age, weight, Mentzer index, and serum ferritin levels reported as means ± standard deviations. Categorical variables, including gender, residential status, family socioeconomic status, and the presence of iron deficiency anemia, were presented as frequencies and percentages. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were computed using a 2x2 contingency table.

The diagnostic accuracy of the Mentzer index was evaluated by calculating its sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy against the serum ferritin test. These values were derived from the standard formula for each, with results classified into true positive, false positive, true negative, and false negative categories as described earlier.

RESULTS

The patient demographics (as shown in Table-I) reveal that the mean age was 3.07 ± 1.23 years, and the average weight was 13.43 ± 2.48 kg. The Mentzer Index averaged at 13.80 ± 1.61, with serum ferritin levels at 29.95 ± 16.84. In terms of gender, 84 males (51.9%) and 78 females (48.1%) were included. Regarding residential status, 103 participants (63.6%) were from rural areas, while 59 (36.4%) were from urban areas. Socioeconomic status indicated that 84 participants (51.9%) were from poor backgrounds, 56 (34.6%) from middle-class, and 22 (13.6%) from wealthy households.

Table I

Patient Demographics

Demographics		Mean ± SD
Age (years)		3.07±1.23
Weight (Kg)		13.43±2.48
Mentzer Index		13.80±1.61
Serum ferritin		29.95±16.84
Gender	Male n (%)	84 (51.9%)
	Female n (%)	78 (48.1%)
Residential Status	Rural n (%)	103 (63.6%)
	Urban n (%)	59 (36.4%)
Socioeconomic Status	Poor n (%)	84 (51.9%)
	Middle n (%)	56 (34.6%)
	Rich n (%)	22 (13.6%)

The overall results of iron deficiency anemia diagnosis using the Mentzer Index and serum ferritin (Table-II) showed that 96 patients (59.3%) tested positive using the Mentzer Index, and 95 (58.6%) tested positive using serum ferritin. The total number of patients in the study was 162, with 66 (40.7%) testing negative on the Mentzer Index and 67 (41.4%) testing negative on serum ferritin.

Table II

Overall results of Iron Deficiency Anemia diagnosis using Mentzer Index and Serum Ferritin

Iron Deficiency Anemia	Mentzer Index	Serum Ferritin
Positive	96 (59.3%)	95 (58.6%)
Negative	66 (40.7%)	67 (41.4%)
Total	162 (100%)	162 (100%)

A comparison of the Mentzer Index versus serum ferritin in diagnosing iron deficiency anemia (as shown in Table-III) revealed that the Mentzer Index had 87 true positives (TP) and 9 false positives (FP), while serum ferritin had 96 true positives (TP) and 58 true negatives (TN). The Chi-square value for the comparison was 99.38, with a p-value of 0.000, indicating a significant difference between the two diagnostic methods.

Table III

Comparison of Mentzer Index versus Serum Ferritin in diagnosis of iron deficiency anemia

Mentzer Index	Serum Ferritin		Total
	Positive	Negative	
Positive	87 (TP)	9 (FP)	96
Negative	8 (FN)	58 (TN)	66
Total	95	67	162

Chi square = 99.38
P value = 0.000
Key:
TP = True positive
FP = False positive
FN = False negative
TN = True negative

Sensitivity, specificity, diagnostic accuracy, positive predictive value (PPV), and negative predictive value (NPV) for the Mentzer Index in diagnosing iron deficiency anemia (Table-IV) were as follows: sensitivity 91.6%, specificity 87%, diagnostic accuracy 90%, PPV 91%, and NPV 88%.

Table IV

Sensitivity, Specificity, Diagnostic Accuracy, PPV and NPV of Mentzer Index in diagnosis of iron deficiency anemia

Diagnostic Parameter	Result
Sensitivity	91.6%
Specificity	87%
Diagnostic Accuracy	90%
PPV	91%
NPV	88%

The stratified analysis (Table-V) showed variations in diagnostic parameters based on gender and residential status. In males, sensitivity was 91%, specificity 86%, diagnostic accuracy 90%, PPV 97%, and NPV 67%. For females, sensitivity was 92%, specificity 87%, diagnostic accuracy 88%, PPV 77%, and NPV 96%. Among rural residents, sensitivity was 93%, specificity 88%, diagnostic accuracy 92%, PPV 98%, and NPV 67%, whereas, in urban residents, sensitivity was lower at 67%, with specificity 87%, diagnostic accuracy 85%, PPV 36%, and NPV 96%.

Table V

Stratified analysis of Sensitivity, Specificity, Diagnostic Accuracy, PPV and NPV of Mentzer Index in diagnosis of iron deficiency anemia with gender and residential status

Variables	Groups	Diagnostic Parameter	Result
Gender	Male	Sen	91%
		Spec	86%
		DA	90%
		PPV	97%
		NPV	67%
	Female	Sen	92%
		Spec	87%
		DA	88%
		PPV	77%
		NPV	96%
Residential Status	Rural	Sen	93%
		Spec	88%
		DA	92%
		PPV	98%
		NPV	67%
	Urban	Sen	67%
		Spec	87%
		DA	85%
		PPV	36%
		NPV	96%

DISCUSSION

The findings indicate that the Mentzer Index was highly sensitive (91.6%) and specific (87%) in identifying IDA, indicating it is a valid and precise screening test for this condition. The excellent diagnostic accuracy (90%) and positive predictive value (91%) also attest to its usability in clinics.

The strong relationship between the Mentzer Index and serum ferritin (Chi-square = 99.38, p-value = 0.000) supports the argument that the two are strongly correlated since the Mentzer Index is very effective in identifying true positives (87 among a total of 96). This supports why the Mentzer Index can serve to offer a fast, inexpensive, and non-invasive alternative to screening, especially in resource-poor areas.

Gender-based differences were noted in stratified analyses, where males showed a greater PPV (97%) than females (77%). This variation might be due to iron metabolism or body composition differences affecting diagnostic performance of the Mentzer Index. The rural population performed better in all parameters and might be explained by greater exposure to nutritional deficits such that the Mentzer Index was more applicable in identifying IDA in this population. On the other hand, lower performance in urban communities, especially in terms of PPV, might be due to a relatively lower prevalence of IDA in urban communities such that accuracy in the screening tool is compromised.

The study involved 162 participants, with a mean age of 3.07 ± 1.23 years and a mean weight of 13.43 ± 2.48 kg, predominantly consisting of 51.9% males and 48.1% females. The Mentzer Index had an average value of 13.80 ± 1.61, and serum ferritin levels averaged at 29.95 ± 16.84. These demographic findings are consistent with the general characteristics observed in other studies, such as those by Sherali et al. [15] where a similar age group was assessed, and Awais et al. [16] who reported an average age of 7.28 years in their study, and both noted that the majority of their participants were male. However, our study's slightly younger mean age (3.07 years) may be due to the focus on a younger pediatric population compared to studies that have examined a broader age range (1-16 years) like Iqbal et al. [17]

The results of our study indicate that 59.3% of patients tested positive for IDA using the Mentzer Index, while 58.6% tested positive using serum ferritin, showing a high correlation between the two methods. This closely aligns with the findings of Sherali et al. [15] and Awais et al. [16] who also observed that the Mentzer Index demonstrated a comparable level of sensitivity and specificity in diagnosing IDA. Specifically, Sherali et al. [15] reported a sensitivity of 80.7%, specificity of 77.7%, and a diagnostic accuracy of 78.4%, while Awais et al. [16] found a sensitivity of 67.3% and specificity of 93.8%. These findings suggest that the Mentzer Index, while offering good diagnostic accuracy, might vary slightly across different settings, with some studies showing lower sensitivity, such as in our urban residents group (67%).

Our study found the sensitivity of the Mentzer Index to be 91.6%, specificity 87%, diagnostic accuracy 90%, positive predictive value (PPV) 91%, and negative predictive value (NPV) 88%, which are consistent with the results from Iqbal et al. [17] where they reported a sensitivity of 90.1%, specificity of 90.1%, and diagnostic accuracy of 90.8%. The higher specificity and PPV observed in our study, especially in rural areas (PPV 98%) compared to urban areas (PPV 36%), reflect the challenges of diagnosing IDA in different settings. In urban areas, where the prevalence of IDA may be lower, the lower PPV could indicate that the Mentzer Index might not perform as effectively in populations with lower disease prevalence, similar to findings by Alkamali et al. [18] who observed that sensitivity of the Mentzer Index was high (99%) but the specificity was lower (54.5%).

In our stratification, diagnostic accuracy of the Mentzer Index was influenced by gender and place of residence. That is, males exhibited a better PPV (97%) compared to females (77%), while rural residents exhibited better diagnostic accuracy (sensitivity 93%, specificity 88%, PPV 98%) compared to urban residents (sensitivity 67%, specificity 87%, PPV 36%). Variation in performance based on gender and residency concurs with Awais et al. [16]'s results in that they too observed similar tendencies in demographic stratifications, mostly in specificity and PPV. The better performance in rural residents may be due to the fact that in rural areas there is perhaps more exposure to nutritional deprivations such that IDA is more common and is easily identified with the help of the Mentzer Index.

Despite small differences in sensitivity and specificity between sites, the test has good diagnostic performance in low-resource settings. The stratified analysis also shows how factors such as residential status and gender influence its diagnostic performance and warrants future work and development to optimize it in various population groups.

Nevertheless, there are some restrictions to this investigation to be considered. First, it was conducted at a single center, and this will likely limit generalizability to other regions or healthcare institutions. The sample was fairly small and even though results are replete with meaning, larger multi-site studies will be needed to rigorously establish findings and evaluate performance of the Mentzer Index in different demographic groups. Second, only children aged between 1 and 5 years were considered in this investigation so applicability to younger or older patient groups remains uncertain. Finally, while a gold-standard of serum ferritin was used, iron supplementation or inflammatory illnesses may possibly have effect on diagnostic precision of these tests so extra investigations to account for these factors are warranted.

CONCLUSION

Our study has discovered that the Mentzer Index is a viable and cost-saving screening tool for iron deficient anemia in children. It is a good diagnostic tool and is particularly useful in those regions with limited technological capabilities to implement more sophisticated diagnostic methodologies. The findings point to its utility in early detection of IDA but more studies including larger, multi-centered studies are warranted to establish its utility in other patients and healthcare systems.

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