

Original Article

Serum Fatty Acid Binding Protein 4 (FABP4) as a Potential Diagnostic Biomarker in Obesity-Associated Breast Cancer: A Cross-Sectional Study

Zhikal Omar Khudhur^{1*} , Mohammed Fatih Rasul^{2,3} , Yara Omar Khudhir¹, Ahmad Halkawt Jamal⁴, Mardin Frsat Ghazali⁵, Awin Khattab Tahir⁵, Hivi Musadaq Abdulrahman⁵, Raman Azeez Mohammad¹

1 Biology Education Department, Faculty of Education, Tishk International University, Erbil, 44001, Iraq

2 Department of Women's and Children's Health, Karolinska Institutet, Stockholm, 171 77, Sweden

3 Department of Pharmaceutical Basic Science, Faculty of Pharmacy, Tishk International University, Erbil, 44001, Iraq

4 Water Treatment Plants Department, General Directorate of Water and Sewerage of Erbil, Erbil, 44001, Iraq

5 Laboratory Department, Hawler Private Hospital laboratory, Erbil, 44001, Iraq

* Correspondence

Zhikal.omer@tiu.edu.iq

Article Info

Received: May 15, 2026

Revised: Jun 24, 2026

Accepted: Jul 02, 2026

Published: Jul 30, 2026

Abstract

Breast cancer (BCa) remains one of the leading causes of cancer-related death among women worldwide, and obesity has been increasingly implicated in its development through metabolic and inflammatory pathways. Fatty acid binding protein 4 (FABP4) has been proposed as potential mediator linking obesity to cancer, while C- reactive protein (CRP) reflects systemic inflammation. This cross-sectional study included 170 women, comprising 81 healthy controls and 89 breast cancer patients. Participants were classified as obese and non-obese according to their body mass index (BMI). For each group, serum levels of FABP4 and CRP were measured, and their diagnostic performance was evaluated. FABP levels were significantly elevated in obese cancer patients compared to both obese and non-obese controls, demonstrating a progressive increase across study groups. CRP levels were also higher in obese BCa patients. FABP4 showed moderate diagnostic performance (AUC = 0.685), comparable to CRP (AUC = 0.661), while their combination did not improve diagnostic accuracy. Collectively, these findings shows that FABP4 is associated with obesity-related inflammation in BCa and may have potential as a biomarker. However, its strong association with adiposity indicates that it is likely reflects metabolic inflammation rather than tumor specific process. Further large-scale studies are required to validate clinical utility.

Keywords: Breast Cancer, Diagnostic, FABP4, C- reactive protein, Obesity, biomarkers, Inflammation.



© 2026 Zhikal Omar Khudhur, Mohammed Fatih Rasul, Yara Omar Khudhir, Ahmad Halkawt Jamal, Mardin Frsat Ghazali, Awin Khattab Tahir, Hivi Musadaq Abdulrahman, and Raman Azeez Mohammad. This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY 4.0) license.

INTRODUCTION

Breast cancer (BCa) ranks as the most diagnosed cancer among women worldwide, and leading cause of a cancer mortality¹. Despite advances in screening and treatment, accurate risk stratification and early detection remain critical challenges, especially in populations with increasing prevalence of

metabolic disorders. Among these, epidemiological evidence consistently demonstrates that obesity is associated with higher incidence and poorer clinical outcomes, particularly in postmenopausal women, largely through its complex metabolic and inflammatory effect².

Obesity is associated with chronic low-

grade inflammation and altered lipid metabolism, both of which contribute to tumor initiation and progression ³. Adipose tissue, beside energy storage acts as an active endocrine organ that secretes a range of bioactive factors such as adipokines and inflammatory mediators ⁴. These mediators can affect the TME, inducing cellular proliferation, metastasis and angiogenesis ⁵.

Recently, increasing attention has been directed toward lipid-binding proteins, particularly Fatty Acid Binding Protein 4 (FABP4), a lipid chaperone primarily expressed in adipocytes and macrophages involved in intracellular fatty acid transport, mitochondrial-oxidation, inflammatory signaling pathway and metabolic regulation ^{5,6}.

Unlike many intracellular proteins, FABP4 is secreted into circulatory system via a non-classical pathway linked to lipolysis ⁷. Emerging evidence recommends that circulating FABP4 plays an important role in cancer biology by linking lipid metabolism with inflammatory signaling pathways mainly through enhancing lipid accumulation and lipolysis in tumor associated macrophage ⁸. Mechanistically, FABP4 has been revealed to enhance pro-inflammatory signaling through pathways such as NF-Kb and IL-6, hence contributing to a tumor-promoting microenvironment ⁹.

Recent studies have shown that FABP4 expression varies significantly across BCa subtypes, with specifically high association found in Luminal A and estrogen receptor positive tumors ¹⁰. This relationship highlights the potential impact of FABP4 as a moderator of obesity-cancer axis ¹¹. Accordingly, given that FABP4 is strongly influenced by adiposity, distinguishing its role as cancer-specific biomarker versus a marker of metabolic

inflammation remains a key challenge. This is particularly important because circulating FABP4 levels may reflect obesity related inflammatory status rather than tumor specific alteration. However, despite growing evidence, the diagnostic value of serum FABP4 in BCa remains insufficiently characterized, particularly when compared with conventional inflammatory markers or evaluated in combination with them ¹².

Accordingly, the present study sought to investigate the serum levels of FABP4 and CRP in obese and non-obese BCa patients and to evaluate their potential diagnostic performance. By exploring the interplay between metabolic and inflammatory pathways, this study aims to provide further insight into the role of FABP4 as a potential biomarker in obesity-associated BCa.

MATERIALS and METHODS

Study Design and Participants

The present study is a cross-sectional study conducted at Erbil Breast Center of Erbil-Iraq between January 2025 and August 2025. A total of 170 women were included, comprising 81 healthy controls and 89 patients diagnosed with breast cancer.

The minimum sample size was assessed using the method for comparison of two independent means:

$$n = \frac{2(Z_{\frac{\alpha}{2}} + Z_{\beta})^2}{d^2}$$

where at a 95% confidence level and for 80% power. Assuming a moderate effect size ($d = 0.5$), the required sample size was estimated to be approximately 63 participants per group. The final enrolled sample surpassed this requirement. Participants were categorized by BMI as non-obese ($\text{BMI} < 30 \text{ kg/m}^2$) or obese ($\text{BMI} \geq 30 \text{ kg/m}^2$).

Inclusion criteria comprised women with histopathologically confirmed BC and age-matched healthy controls. Exclusion criteria

included individuals with autoimmune disease, chronic inflammatory conditions, liver or renal disease, and those receiving anti-inflammatory or lipid-lowering medications. The study methodology was approved by Research and Ethics Committee of Tishk International University and written informed consent was obtained from all participants before sample collection.

Sample Collection and Preparation

Blood samples from venous were collected into vacuum tubes specific for serum with clot activator. After the sample collection, it has been left to clot for 20-30 minutes at room temperature. Samples were centrifuged at $3,000 \times g$ for 15 minutes at 8°C . Serum was isolated, aliquoted, and stored at -80°C until further analysis. Each sample underwent a single thaw cycle prior to measurement.

Measurement of Serum Biomarkers

Serum level of FABP4 were quantified using an enzyme-linked immunosorbent assay (ELISA) kits (Solarbio, China) according to manufacturer's guidelines. The absorbance was quantified at 450 nm using a microplate reader. Serum C-reactive protein levels were determined by immunoturbidimetry using the

Cobas c311 analyzer (Cobas, Roche Diagnostic, Mannheim, Germany).

Statistical Analysis

Statistical analysis was conducted using SPSS version 27.0 (IBM Corp.) and MedCalc 20, while GraphPad Prism9 was used for graphical presentation of the data. Results were presented as mean $\pm$ standard deviation (SD). The distribution of data was assessed for normality prior to analysis. Differences among each group were assessed using one-way analysis of variance (ANOVA). The receiver operating characteristic (ROC) curve was performed to assess the diagnostic performance of FABP4, CRP, and their combination in BCa patients. $P < 0.05$ was considered statistically significant.

RESULTS

Demographic and Clinical Characteristics

The demographic and clinical characteristics of the study participants are summarized in table 1. The mean age of non-obese control and obese control groups were 41.40 ± 1.869 and 46.15 ± 3.559 , respectively. The mean age of non-obese BCa and obese BCa groups were 51.80 ± 2.377 and 46.94 ± 3.019 years, respectively. There was no statistically significant difference in age among groups ($p=0.056$) (Figure 1a).

Table 1. Demographic characteristics and serum biomarker levels among study groups.

Parameters	(N=81)		(N=89)		p-value
	Non-Obese Control	Obese Control	Non-Obese BCa	Obese BCa	
Age (years)	41.40 ± 1.869	46.15 ± 3.559	51.80 ± 2.377	46.94 ± 3.019	0.056
BMI	23.18 ± 0.458	31.01 ± 0.515	23.32 ± 0.587	36.25 ± 2.228	<0.0001
FABP4 (pg/ml)	190.3 ± 9.565	213.5 ± 10.15	217.5 ± 12.11	280.1 ± 19.46	0.0004
CRP (mg/L)	1.438 ± 0.2974	5.429 ± 1.192	4.936 ± 1.490	13.49 ± 3.935	0.005

In contrast. BMI differed significantly across all groups ($p < 0.0001$), with higher values observed in obese participants compared to non-obese individuals, (mean of BMI= 23.18 ± 0.458 , 31.01 ± 0.515 , $23.32 \pm$

0.587 , and 36.25 ± 2.228 for non-obese control, obese control, non-obese BCa, and obese BCa groups, respectively) (Tables I and figure 1b).

Serum level of CRP showed statistically significant increase in the obese BCa group

compared to non-obese control group ($p = 0.005$) (Tables I and figure 1c). Concerning FABP4, a significant increase was observed in obese BCa group compared to both the non-obese control group (280.1 ± 19.46 pg/ml vs.

190.3 ± 9.565 pg/ml, $P=0.0004$) and the obese control group. Notably, FABP4 level demonstrated a progressive increase across groups, with the highest levels observed in obese BCa patients (Tables 1 and figure 1d).

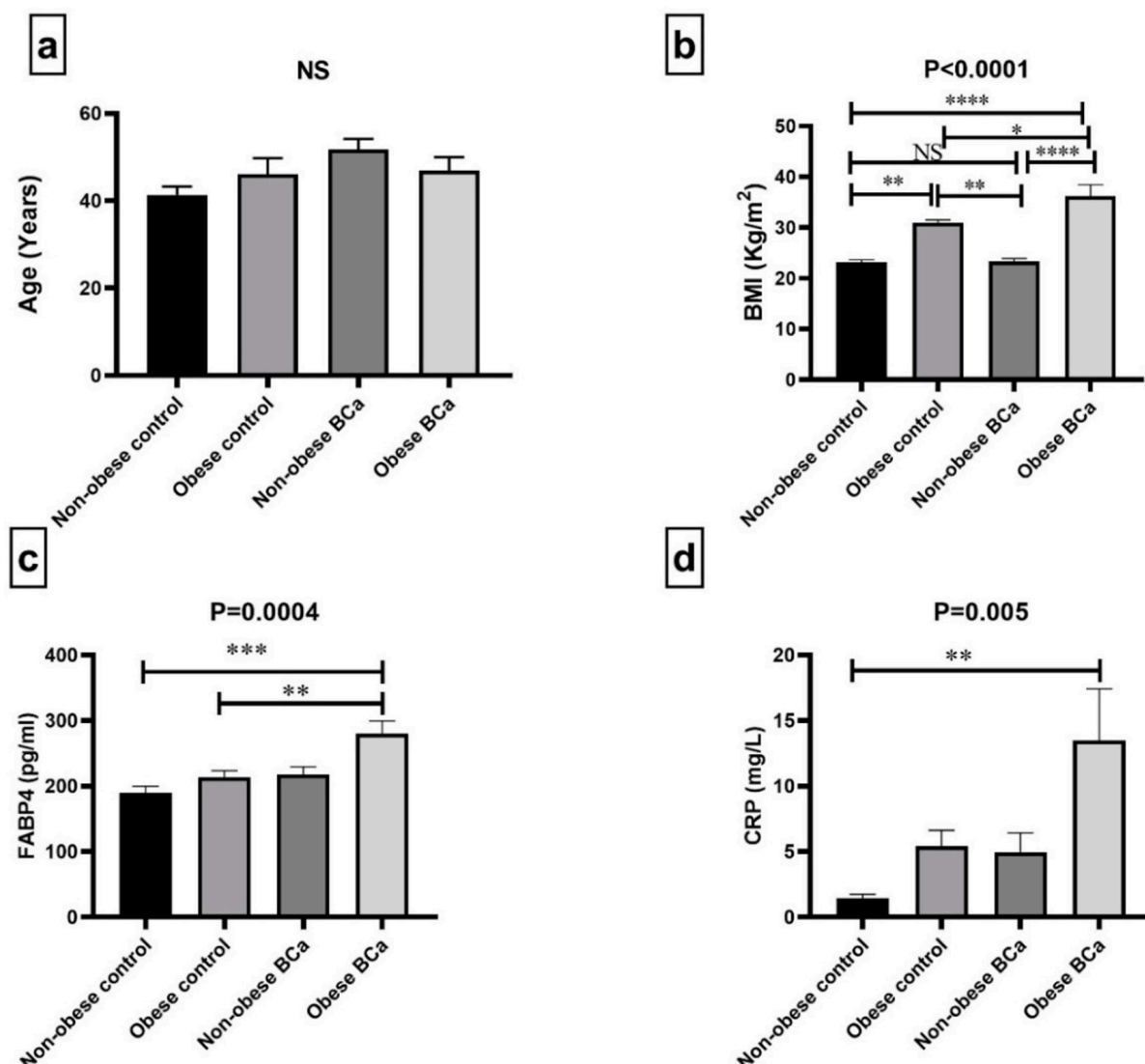


Figure 1. Comparison of age, BMI, and serum markers between groups of BCa patients and healthy controls. One-way ANOVA was used for the comparison of (a) age; (b) BMI; (c) FABP4, and (d) CRP. CRP, C-reactive protein; FABP4, fatty acidbinding protein 4. Probability (P)-value less than 0.05 was considered significant.

Diagnostic Value of Fabp4 and Crp

The ROC curve analysis was conducted to assess the diagnostic potential of FABP4 and CRP in distinguishing BCa patients from control.

For FABP4, the area under the curve (AUC) for participant diagnosed with BCa was 0.685 (95% CI, 0.567–0.787). The optimal cut-off value was 233.5, with a sensitivity of 71.43% and a specificity of 70.00%. On the

other hand, for serum CRP, the AUC was 0.661 (95% CI, 0.553–0.759), with a cut-off value equals to 1.34, with sensitivity of 84.00%, and specificity of 47.37%. Then, the two single factors, CRP and FABP4, were used as combinations in the diagnosis of BCa patients. The AUC of this combination for the diagnosis of BCa patients was 0.634 (95% CI, 0.513–0.744), the cut-off value was 0.46, the sensitivity was 71.43% and the specificity was

57.89% (Tables 2 and figure 2).

Table 2. Diagnostic performance of serum FABP4 and CRP in breast cancer patients based on ROC curve analysis

Variables	AUC	95% CI	P-value	Cut-off	Sensitivity	95% CI	Specificity	95% CI	PPV	95% CI	NPV	95% CI
FABP4	0.685	0.567 to 0.787	0.004	>233.5	71.43	53.7 - 85.4	70.00	53.5 - 83.4	67.6	55.4 - 77.8	73.7	61.5 - 83.1
CRP	0.661	0.553 to 0.759	0.008	>1.34	84.00	70.9 - 92.8	47.37	31.0 - 64.2	67.7	60.3 - 74.4	69.2	52.3 - 82.2
FABP4+CRP	0.634	0.513 to 0.744	0.042	>0.460	71.43	53.7 - 85.4	57.89	40.8 - 73.7	61.0	50.5 - 70.6	68.7	54.9 - 79.9

ROC curve analysis was performed using MedCalc 20. Participants were categorized into two groups which are control and BCa considering as status in the ROC curve analysis. AUC, area under curve; CI, confidence interval; CRP, C-reactive protein; FABP4, fatty acid binding protein; NPV, negative predictive value; PPV, positive predictive value; ROC, receiver operating characteristic curve. Probability (P)-value less than 0.05 was considered as significant.

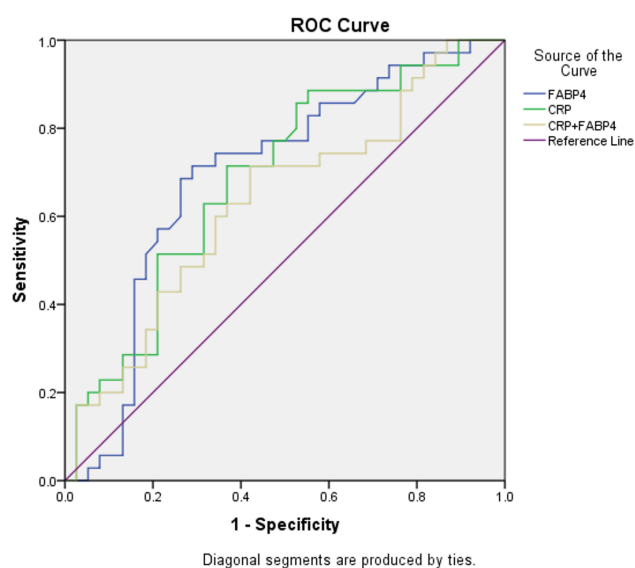


Figure 2. ROC curve analysis of CRP, FABP4, and their combination to the diagnosis of BCa. ROC curve analysis was drawn by SPSS 27. The participants were classified into control and BCa considering as status in the ROC curve analysis. CRP, C-reactive protein; FABP4, fatty acid-binding protein; ROC, receiver operating characteristic curve.

DISCUSSION

Although substantial evidence has linked obesity and inflammation to cancer initiation, the molecular mechanisms driving this relationship remain poorly understood ¹³. The present study investigated the relationship

between obesity, inflammation and BCa by evaluating serum levels of FABP4 and CRP in obese and non-obese BCa patients in comparison to obese and non-obese control. Our findings demonstrated that FABP4 level was significantly elevated (p -value = 0.0004) in obese BCa compared to both control groups which are obese and non-obese controls. Notably, FABP4 levels revealed a progressive increase across study groups, with the highest levels observed in obese BCa patients. This pattern suggests a combined effect of obesity and cancer status rather than an isolated tumor-specific alteration.

These results are consistent with earlier studies demonstrating increased level of FABP4 in breast and other malignancies ^{14,15}, including ovarian, colorectal, lung, cervical, and liver cancer ^{16,17,18,19,20,21}. Mechanistically, FABP4 has been shown to promote tumor progression through enhancement of inflammatory signalling pathways such as NF- κ B and IL-6 ^{22,23}. In addition, FABP4 mediated lipid metabolism and its interaction with tumor-associated macrophages may facilitate tumor growth, angiogenesis, and metastasis ^{6,24} through the IL-6/STAT3/ALDH1 pathway. These mechanisms support the biological plausibility of FABP4 as a mediator linking metabolic dysregulation and cancer progression.

In parallel, CRP levels were also elevated in obese BCa patients in our study, highlighting the contribution of systemic inflammation to tumor development. Chronic

inflammation contribute to cancer progression through activation of cytokines and immune cells, particularly macrophages²⁵. After IL-6 is synthesized in the initial stage of inflammation, it moves to the liver through the bloodstream, followed by the rapid induction of an extensive range of acute phase proteins such as C-reactive protein (CRP)²⁶. Consistent with this mechanism, CRP levels were increased in obese BCa patients in ($p = 0.0004$) the current study. Interestingly, despite its lower specificity, CRP demonstrated higher sensitivity in our study, which is aligned with its role as sensitive but nonspecific inflammatory marker in cancer²⁷. Although CRP is a sensitive indicator of systemic inflammation, it is highly nonspecific and may be influenced by acute transient infections or short-term inflammatory events²⁸. In our study, participants with documented chronic inflammatory and autoimmune diseases were excluded; however, the absence of acute infection at the same time of sample collection was not specifically verified through additional clinical or laboratory assessment. Therefore, transient inflammatory conditions may have contributed to baseline CRP variability and representing a potential source of confounding in the interpretation of the inflammatory profile observed in this study.

However, an important consideration is that FABP4 is strongly influenced by adiposity²⁹. Several studies have suggested that circulating FABP4 levels are closely associated with obesity and metabolic syndrome rather than cancer-specific processes^{5,30}. Therefore, the elevated levels observed in this study may partly reflect obesity-related metabolic inflammation rather than tumor-specific alteration. This further supported by evidence demonstrating that obesity-induced insulin resistance and

macrophage activation contribute to chronic inflammatory states³¹ and altered adipokine secretion^{32,33}. Accordingly, distinguishing whether FABP4 represents a cancer-specific biomarker or a marker of metabolic inflammation remains a key challenge.

In term of diagnostic performance, FABP4 demonstrated a moderate ability to distinguish BCa patients from control. Although its performance was slightly higher than that of CRP, the difference was modest, indicating comparable rather than superior diagnostic value. Furthermore, the combination of FABP4 and CRP did not enhance diagnostic accuracy, suggesting potential overlap in their biological roles and reflecting shared inflammatory pathways. Previous studies have also reported variability in the diagnostic performance of adipokines and metabolic status³⁴.

This study has several limitations. First of all, the cross-sectional design restricts the ability to infer causal relationships. Second, although the sample size was adequate, larger multicenter studies are required to confirm these findings. Additionally, potential confounding factors such as medication use and metabolic comorbidities were not fully controlled. Furthermore, future studies should investigate FABP4 alongside with IL-6, IL-23, IL-1 β , TNF- α , and CD86 to better distinguish tumor-associated inflammation from obesity-related metabolic inflammation.

These findings indicate that while FABP4 may serve as a promising biomarker in obesity-associated BCa, it is unlikely to be sufficient as standalone diagnostic marker. Instead, its clinical utility may be enhanced when integrated with additional markers or clinical parameters. Therefore, FABP4 should be interpreted cautiously in clinical settings, particularly in populations with a high

prevalence of obesity.

CONCLUSION

In conclusion, serum FABP4 and CRP levels significantly elevated in obese BC patients, supporting the relationship between obesity-associated inflammation and BC. FABP4 showed moderate diagnostic performance, comparable to CRP, suggesting its potential role as a biomarker in obesity-associated BCa. However, because FABP4 is strongly influenced by adiposity and metabolic inflammation, its clinical interpretation should be approached cautiously. Further large-scale multicenter studies needed to confirm its clinical utility.

DECLARATIONS

Data Availability Statement

The data analyzed during the current study are available from the corresponding author upon reasonable request.

Funding

The authors declare that no funding was received for this work.

Ethics Approval and Consent to Participate

This study was approved by the

References

- Ouyang X, Liu H, Jin H. Global comparison of breast cancer burden between women aged 20–54 and ≥55 years (1990–2021). *Frontiers in Oncology*. 2026;15:1688642. doi: <https://doi.org/10.3389/fonc.2025.1688642>
- Picon-Ruiz M, Morata-Tarifa C, Valle-Goffin JJ, Friedman ER, Slingerland JM. Obesity and adverse breast cancer risk and outcome: Mechanistic insights and strategies for intervention. *CA: A Cancer Journal for Clinicians*. 2017;67(5):378-397. doi: <https://doi.org/10.3322/caac.21405>
- Mitchelson KAJ, O'Connell F, O'Sullivan J, Roche HM. Obesity, Dietary Fats, and Gastrointestinal Cancer Risk-Potential Mechanisms Relating to Lipid Metabolism and Inflammation. *Metabolites*. 2024;14(1):42. doi: <https://doi.org/10.3390/metabo14010042>
- Brown, Kristy A. Metabolic pathways in obesity-related breast cancer. *Nature Reviews Endocrinology*. 2021;17(6):350-363. doi: <https://doi.org/10.1038/s41574-021-00487-0>
- Pham TT, Nimptsch K, Aleksandrova K, et al. Circulating fatty acid binding protein 4 (FABP-4) concentrations and mortality in individuals with colorectal cancer in the European Prospective Investigation into Cancer and Nutrition study. *International Journal of Cancer*. 2025;158(3):546-559. doi: <https://doi.org/10.1002/ijc.70090>
- Yorek M, Jiang X, Liu S, et al. FABP4-mediated lipid accumulation and lipolysis in tumor-associated macrophages promote breast cancer metastasis. *eLife*. 2024;13:RP101221. doi: <https://doi.org/10.7554/elife.101221>
- Abdalla MA, Abubaker J, Abu-Farha M, et al. Investigating the Role of FABP4 in Diabetes and Obesity and the Influence of Age and Ethnicity: A Comprehensive Analysis of a Cohort from the KEDP-Study. *International Journal of Molecular Sciences*. 2024;25(9):4578. doi: <https://doi.org/10.3390/ijms25094578>
- Yu J, Shilyansky J, Hao J, et al. FABP4 Couples Lipid Metabolism to PD-L1 Stabilization in Immunosuppressive Macrophages. *openRxiv*. 2026. doi: <https://doi.org/10.64898/2026.04.09.717546>

Research and Ethics Committee of Tishk International University. All procedures were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment and sample collection.

Conflict of Interest

The authors declare no conflict of interest.

Use of Generative AI

Generative AI tools were used only for language improvement and proofreading. The authors reviewed and approved the final content and take full responsibility for the manuscript.

Acknowledgments

The authors sincerely thank the staff of the Erbil Breast Center for their valuable assistance with sample collection. The authors also gratefully acknowledge all patients and healthy control participants for their cooperation and contribution to this study.

9. Wang M, Hawanga M, Wan S, et al. FABP4 in lipid metabolism and the tumor microenvironment: mechanisms and therapeutic potential. *Lipids in Health and Disease*. 2025;25(1):29. doi: <https://doi.org/10.1186/s12944-025-02833-x>
10. Jiang X, Xiong Y, Yu J, et al. Expression profiles of FABP4 and FABP5 in breast cancer: clinical implications and perspectives. *Discover Oncology*. 2025;16(1):357. doi: <https://doi.org/10.1007/s12672-025-02117-x>
11. Ali ETO, Min EJ, Cho W, Park YM. Expression analyses of fatty acid binding proteins (FABPs) in breast cancer subtypes: implications for immune modulation and clinical outcomes. *Translational Cancer Research*. 2026;15(2):92-92. doi: <https://doi.org/10.21037/tcr-2025-aw-2483>
12. Tsakogiannis D, Kalogera E, Zagouri F, Zografos E, Balalis D, Bletsas G. Determination of FABP4, RBP4 and the MMP-9/NGAL complex in the serum of women with breast cancer. *Oncology Letters*. 2020;21(2):85. doi: <https://doi.org/10.3892/ol.2020.12346>
13. Sultana A, Rana S. Mechanisms underlying obesity-malignancy connection: a systematic narrative review. *Journal of Physiology and Biochemistry*. 2025;81(2):403-439. doi: <https://doi.org/10.1007/s13105-025-01084-9>
14. Guaita-Esteruelas S, Gumà J, Masana L, Borràs J. The peritumoural adipose tissue microenvironment and cancer. The roles of fatty acid binding protein 4 and fatty acid binding protein 5. *Molecular and Cellular Endocrinology*. 2018;462:107-118. doi: <https://doi.org/10.1016/j.mce.2017.02.002>
15. Tsakogiannis D, Kalogera E, Zagouri F, Zografos E, Balalis D, Bletsas G. Determination of FABP4, RBP4 and the MMP-9/NGAL complex in the serum of women with breast cancer. *Oncology Letters*. 2020;21(2):85-85. doi: <https://doi.org/10.3892/ol.2020.12346>
16. Gharpure KM, Pradeep S, Sans M, et al. FABP4 as a key determinant of metastatic potential of ovarian cancer. *Nature Communications*. 2018;9(1):2923. doi: <https://doi.org/10.1038/s41467-018-04987-y>
17. Zhang Y, Zhao X, Deng L, et al. High expression of FABP4 and FABP6 in patients with colorectal cancer. *World Journal of Surgical Oncology*. 2019;17(1):171. doi: <https://doi.org/10.1186/s12957-019-1714-5>
18. Mukherjee A, Chiang CY, Daifotis HA, et al. Adipocyte-Induced FABP4 Expression in Ovarian Cancer Cells Promotes Metastasis and Mediates Carboplatin Resistance. *Cancer Research*. 2020;80(8):1748-1761. doi: <https://doi.org/10.1158/0008-5472.can-19-1999>
19. Li G, Wu Q, Gong L, et al. FABP4 is an independent risk factor for lymph node metastasis and poor prognosis in patients with cervical cancer. *Cancer Cell International*. 2021;21(1):568. doi: <https://doi.org/10.1186/s12935-021-02273-4>
20. Tang Z, Shen Q, Xie H, et al. Elevated expression of FABP3 and FABP4 cooperatively correlates with poor prognosis in non-small cell lung cancer (NSCLC). *Oncotarget*. 2016;7(29):46253-46262. doi: <https://doi.org/10.18632/oncotarget.10086>
21. Yang H, Deng Q, Ni T, et al. Targeted Inhibition of LPL/FABP4/CPT1 fatty acid metabolic axis can effectively prevent the progression of nonalcoholic steatohepatitis to liver cancer. *International Journal of Biological Sciences*. 2021;17(15):4207-4222. doi: <https://doi.org/10.7150/ijbs.64714>
22. Yan F, Shen N, Pang J, et al. Fatty acid-binding protein FABP4 mechanistically links obesity with aggressive AML by enhancing aberrant DNA methylation in AML cells. *Leukemia*. 2017;31(6):1434-1442. doi: <https://doi.org/10.1038/leu.2016.349>
23. Makowski L, Brittingham KC, Reynolds JM, Suttles J, Hotamisligil GS. The Fatty Acid-binding Protein, aP2, Coordinates Macrophage Cholesterol Trafficking and Inflammatory Activity. *Journal of Biological Chemistry*. 2005;280(13):12888-12895. doi: <https://doi.org/10.1074/jbc.m413788200>
24. Wu L, Ou GL, Zhang W, et al. Fatty acid-binding proteins in cancers. *International Journal of Surgery*. 2025;111(11):8402-8422. doi: <https://doi.org/10.1097/js9.0000000000003049>
25. Nishida A, Andoh A. The Role of Inflammation in Cancer: Mechanisms of Tumor Initiation, Progression, and Metastasis. *Cells*. 2025;14(7):488. doi: <https://doi.org/10.3390/cells14070488>
26. Heinrich PC, Castell JV, Andus T. Interleukin-6 and the acute phase response. *Biochemical Journal*. 1990;265(3):621-636. doi: <https://doi.org/10.1042/bj2650621>
27. Zubair M, Mishra PK, Singhal S. Structured role of C-reactive Protein (CRP) in Clinical diagnostic and Prognostic medicine. *Chemical Biology Letters*. 2025;12(4):1280. doi: <https://doi.org/10.62110/sciencein.cbl.2025.v12.1280>
28. Luan YY, Yao YM. The Clinical Significance and Potential Role of C-Reactive Protein in Chronic Inflammatory and Neurodegenerative Diseases. *Frontiers in Immunology*. 2018;9:1302. doi: <https://doi.org/10.3389/fimmu.2018.01302>
29. Liu S, Wu D, Fan Z, et al. FABP4 in obesity-associated carcinogenesis: Novel insights into mechanisms and therapeutic implications. *Frontiers in Molecular Biosciences*. 2022;9:973955. doi: <https://doi.org/10.3389/fmolb.2022.973955>
30. Hardaway AL, Podgorski I. IL-1 β , Rage and Fabp4: Targeting the Dynamic Trio in Metabolic

- Inflammation and Related Pathologies. *Future Medicinal Chemistry*. 2013;5(10):1089-1108. doi: <https://doi.org/10.4155/fmc.13.90>
31. Shimobayashi M, Albert V, Woelnerhanssen B, et al. Insulin resistance causes inflammation in adipose tissue. *Journal of Clinical Investigation*. 2018;128(4):1538-1550. doi: <https://doi.org/10.1172/jci96139>
32. Moreno-Vedia J, Girona J, Ibarretxe D, Masana L, Rodríguez-Calvo R. Unveiling the Role of the Fatty Acid Binding Protein 4 in the Metabolic-Associated Fatty Liver Disease. *Biomedicines*. 2022;10(1):197. doi: <https://doi.org/10.3390/biomedicines10010197>
33. Uysal KT, Scheja L, Wiesbrock SM, Bonner-Weir S, Hotamisligil GS. Improved Glucose and Lipid Metabolism in Genetically Obese Mice Lacking aP2. *Endocrinology*. 2000;141(9):3388-3396. doi: <https://doi.org/10.1210/endo.141.9.7637>
34. Morawiec ML, Wendlocha D, Kabut J, Mielczarek-Palacz A. Dysregulation of adipokines in the serum of breast cancer patients – role in pathogenesis and potential clinical application (preliminary studies). *Frontiers in Immunology*. 2026;17:1724900. doi: <https://doi.org/10.3389/fimmu.2026.1724900>