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Advisory Board

Advisory Board

Advisory Board

Advisory Board

Contents

Letter to the Editor

Review

Researches

Contents

Medical Journal of Bakırköy

Med J Bakirkoy 2026;22(3):202-203
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Letter to the Editor

Additional Observations and Contributions to the Study: "Determinants of Conversion from Laparoscopic to Open Cholecystectomy: Türkiye Case"

Ek Gözlemler ve Çalışmaya Katkılar: "Laparoskopik Kolesistektomiden Açık Kolesistektomiye Geçişin Belirleyicileri: Türkiye Örneği"

Alp Ömer Cantürk

Sakarya University Faculty of Medicine, Department of General Surgery, Sakarya, Türkiye

Dear Editor,

I carefully reviewed the study entitled "Determinants of Conversion from Laparoscopic to Open Cholecystectomy: Türkiye Case" (1). Given that it encompasses a broad national patient population (within hospitals of the Turkish Ministry of Health), I believe it provides valuable data on the rates and risk factors for conversion from laparoscopic cholecystectomy (LC) to open cholecystectomy (OC). In reading this manuscript, I identified several points that merit further discussion.

Analyzing national data from the Ministry of Health to design a nationwide study undoubtedly yields significant results. However, one aspect I found lacking in this study is a clear grouping of surgeries by the type of healthcare institution (private hospitals, public hospitals, training and research hospitals, or university hospitals). These factors could also influence the likelihood of conversion from LC to OC. The low conversion rate of 1.1% reported here suggests that LC may have been performed by highly experienced surgeons or in high-volume centers and/or that patient selection was meticulous. This observation is noteworthy given that previous studies commonly report higher conversion rates (2-5). Furthermore, variables such as surgeon experience, annual hospital volume, and whether the procedure was an emergency or elective were not included in the analysis. The literature indicates that these factors can influence LC outcomes (6).

Evidence suggests that ethnic and regional differences can affect surgical outcomes (7). Given that this is a nationwide database study, conducting a regional analysis of cases could further strengthen the study. Additionally, when examining reasons for conversion, an important question is whether the patient presented with acute cholecystitis, underwent percutaneous cholecystostomy, or had prior surgery, as these factors have been shown to be relevant to the risk of conversion (8).

It also appears that no multivariable analyses were conducted. Implementing logistic regression or similar multivariable models would have been beneficial to control for potential interactions among age, sex, and comorbidities, thereby clarifying the independent risk factors (9). Moreover, the nature of the complications (e.g., bile duct injury, hemorrhage, infection) was not described in detail, leaving "complication" as a rather broad term. At a minimum, mentioning these points as limitations in the discussion section could help enhance the overall quality of the study.

This large-scale, nationwide retrospective investigation presents intriguing findings regarding the rate of conversion from laparoscopic to OC and addresses a critical issue. I congratulate the research team on their efforts and hope that these comments provide useful feedback to further enrich the article.

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Review

Future Challenges in Prostate Magnetic Resonance Imaging

Prostat Manyetik Rezonans Görüntülemede Gelecekteki Beklentiler

Hakan Ayyıldız[1], Berke Ersoy[2], Atadan Tunacı[3], Şükrü Mehmet Ertürk[3]

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ABSTRACT

Prostate cancer poses a significant healthcare challenge. Multiparametric prostate magnetic resonance imaging (mpMRI) has emerged as a valuable diagnostic tool, combining anatomical and functional sequences for enhanced accuracy. Advances in mpMRI techniques, including bi-parametric MRI and radiomics, offer promising improvements for prostate cancer detection and management. Prostate cancer is a major cause of morbidity and mortality. Despite the widespread use of the prostate-specific antigen test for screening, its limitations include overdiagnosis. mpMRI, which integrates anatomical and functional sequences, has demonstrated improved diagnostic accuracy, particularly after updates to prostate imaging reporting and data system (PI-RADS). New techniques such as bi-parametric MRI and computed diffusion weighted imaging are increasingly important, spurring research into MRI-based prostate cancer screening. Efforts to shorten MRI acquisition time have led to the development of short-MRI protocols and quality scores, such as PI-quality. Radiomics has also gained importance in prostate imaging. This article explores these advancements and future prospects in prostate MRI. MpMRI's role in prostate cancer diagnosis is expanding. This article discusses the future potential of spectroscopy, innovations in PI-RADS, new MRI protocols and MRI's role in screening and the challenges and solutions for widespread MRI use.

Keywords: Prostate cancer, multiparametric MRI, MR spectroscopy, PI-RADS, bi-parametric MRI, computed DWI, radiomics

ÖZ

Prostat kanseri önemli bir sağlık sorunudur. Multiparametrik prostat manyetik rezonans görüntüleme (mpMRG), gelişmiş doğruluk için anatomik ve fonksiyonel sekansları birleştiren değerli bir tanı aracıdır. Bi-parametrik MRG ve radyomiks dahil olmak üzere mpMRG tekniklerindeki ilerlemeler, prostat kanseri tespiti ve yönetimi için umut verici gelişmeler sunmaktadır. Prostat kanseri önemli bir morbidite ve mortalite nedenidir. Tarama için prostat spesifik antijen testinin yaygın kullanımına rağmen, sınırlamaları arasında aşırı teşhis de bulunmaktadır. Anatomik ve fonksiyonel sekansları entegre eden mpMRG, özellikle prostat görüntüleme raporlama ve veri sistemi (PI-RADS) versiyonlarındaki güncellemelerle artan doğruluk göstermiştir. Bi-parametrik MRG ve bilgisayarlı difüzyon ağırlıklı görüntüleme gibi yeni teknikler daha önemli hale gelmekte ve MRG tabanlı prostat kanseri taramasına yönelik araştırmaları teşvik etmektedir. MRG çekim süresini kısaltma çabaları, kısa MRG protokollerinin ve PI-kalitesi gibi kalite skorlarının geliştirilmesine yol açmıştır. Radyomiks de prostat görüntülemede önem kazanmıştır. Bu makale, prostat MRG'deki bu gelişmeleri ve gelecekteki beklentileri araştırmaktadır. MpMRG'nin prostat kanseri teşhisinde oynadığı rol giderek genişliyor. Bu makalede spektroskopinin gelecekteki potansiyeli, PI-RADS'deki yenilikler, yeni MRG protokolleri ve MRG'nin taramadaki rolünün yanı sıra MRG'nin yaygın kullanımı için zorluklar ve çözümler tartışılmaktadır.

Anahtar Kelimeler: Prostat kanseri, multiparametrik MRG, MR spektroskopi, PI-RADS, bi-parametrik MRG, bilgisayarlı DWI, radyomiks

INTRODUCTION

Prostate cancer is one of the significant causes of morbidity and mortality (1). Although it has been shown that the prostate-specific antigen (PSA) test can lead to overdiagnosis and consequent overtreatment, it is still used for screening purposes (2). A suspicious digital rectal examination, together with PSA values, may indicate a biopsy; however, the sensitivity and specificity of this

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approach are low. Transrectal ultrasound (TRUS), on the other hand, does not have high sensitivity and specificity for diagnosing clinically significant prostate cancer, but is currently used with magnetic resonance imaging (MRI) to guide biopsy and focal treatments, such as high-intensity focused ultrasound (3). Because prostate cancer can be multifocal, and distinguishing clinically significant disease is important, multiparametric prostate MRI (mpMRI) is currently used in the diagnosis of prostate cancer (4).

Multiparametric Prostate Magnetic Resonance Imaging and the Role of Spectroscopy

The history of mpMRI dates to the late 20th century, when conventional MRI techniques were first applied to prostate imaging. However, in the early 21st century, researchers began exploring the potential of imaging that integrates anatomical and functional sequences to enhance the accuracy of prostate cancer detection. MpMRI includes T2-weighted (T2W) and T1-weighted sequences, and functional sequences such as diffusion-weighted imaging (DWI) and dynamic contrast enhancement (DCE).

Although not routinely used at present, *in vivo* MR spectroscopy (also known as 1H-MR spectroscopy) was used previously. Healthy prostate tissue contains high levels of citrate (5). In cancerous prostate tissue, citrate production and secretion decrease as a result of downregulation of zinc transporters (6). In addition, the levels of spermine (a polyamine) and myo-inositol are decreased in cancerous tissue due to defects in myo-inositol metabolism (7). However, choline levels increase due to elevated phosphocholine and glycerophosphocholine content, and lactate levels increase due to enhanced glycolysis in cancerous tissue (Figure 1) (8). MR spectroscopy can be difficult to evaluate due to the low signal-to-noise ratio (SNR) and strong J-coupling in citrate. In addition, the requirement for an endorectal coil in 1.5-Tesla MR systems and the potential need for the operator to be present during acquisition decrease patient comfort and increase acquisition time. In the new 3.0-T MR technologies, similar SNRs can be achieved without an endorectal coil. Thus, limitations such as prolonged duration and patient discomfort are prevented (9). Another limitation with MR spectroscopy is its high sensitivity to magnetic field inhomogeneities. In prostate MR, the air-tissue interface adjacent to the rectum is generally responsible for this problem. Today, some artificial intelligence algorithms can solve this problem, but further studies are needed in this field (10). MR spectroscopy, in fact, shows promise as a potentially useful tool in prostate MRI, as it allows a more functional assessment by detecting metabolites formed as a result of specific mutations; however, there is still no metabolite detectable by spectroscopy in prostate cancer (11). Currently, gallium-68 (^{68}Ga) prostate-specific membrane antigen positron emission tomography (PET) using ^{68}Ga membrane antigen, a cell-surface antigen is increasingly used for functional imaging (Figure 2).

Bi-Parametric Magnetic Resonance Imaging versus Multi-Parametric Magnetic Resonance Imaging

As discussions about the survival benefit of PSA screening increase, mpMRI has become increasingly important as the first-line imaging modality (12). There are some limitations in mpMRI, which is currently used as the first diagnostic tool after the PSA test and is even considered to be used in screening programs (13).

Among the versions of the prostate imaging reporting and data system (PI-RADS), the term "bi-parametric MRI" was

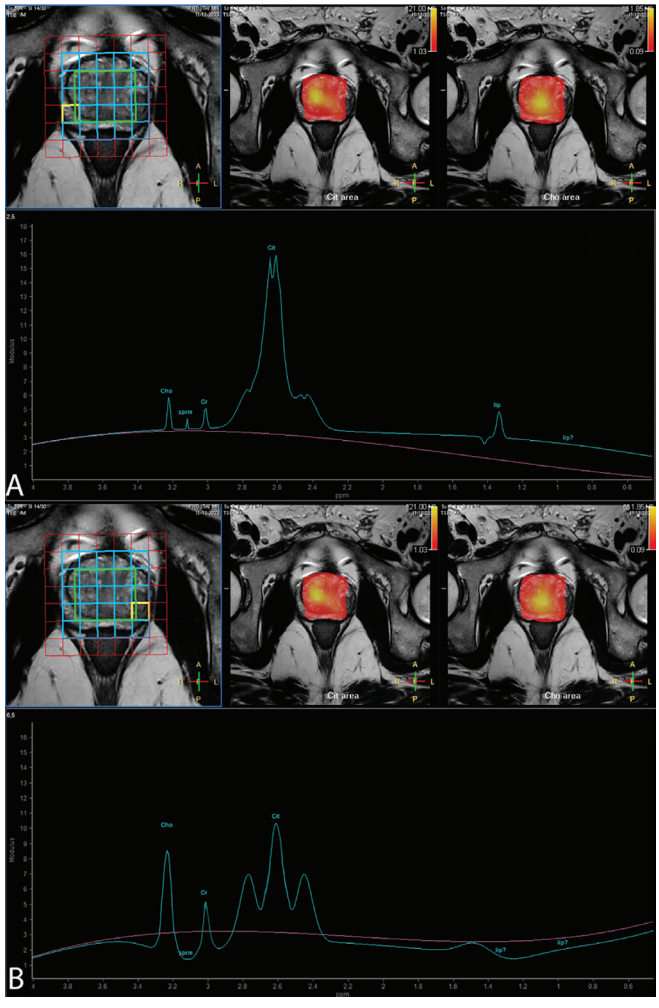

Figure 1. Prostate MRI multivoxel spectroscopy A shows the spectroscopy image of the normal peripheral zone. Note the splitting at the apex at the citrate level. In B, in the spectroscopy image from the suspected cancer area, citrate level is relatively decreased, and choline level is increased

MRI: Magnetic resonance imaging

introduced in PI-RADS v2.1 (14). Studies have shown that the inclusion of DCE images in mpMRI does not result in a statistically significant difference in diagnostic performance between bi-parametric MRI (bpMRI) and mpMRI in the diagnosis of prostate carcinoma (PCa) (15-17). Bosaily et al. (18), who also took transperineal mapping biopsy as the gold standard in the PROMISE trial, reported similar sensitivity and specificity values for bpMRI and mpMRI in their study on 497 patients. However, many of these studies were conducted in academic centers with highly experienced radiologists and standardized protocols, which may not reflect real-world variability. Furthermore, heterogeneity in MRI acquisition parameters, lesion size thresholds, and biopsy techniques complicates direct comparisons. The lack of uniform external validation and limited data from general practice settings call for cautious interpretation. Similarly, Alabousi et al. (19) presented congruent findings in a meta-analysis comprising 31 studies. The area under the receiver operating characteristic curve reached 0.90 for bpMRI and 0.87 for mpMRI. In addition, Christophe et al. (20) showed in a study using radical prostatectomy as the gold standard that mpMRI is not superior to bpMRI for assessing extraprostatic extension. However, readers of the meta-analyses and other studies, who have substantial experience in this field, find these results controversial.

DCE images are sometimes even referred to as "safety-zone" images. Some criteria for biparametric MRI are specified in PI-RADS v2.1 (14). One of the main concerns at this point is that MRI examinations are performed in centers that do not have sufficient technology to obtain adequate DWI. Another reason is that the number of readers with insufficient experience in PI-RADS 3 diagnoses will increase further if DCE series are not available. Hietikko et al. (21) reported that PI-RADS 3 lesions had lower interobserver agreement than PI-RADS 4 and 5 lesions among radiologists with varying levels of experience. Messina et al. (22) showed that lesions with a DWI score of 3 that were DCE-positive and upgraded to PI-RADS 4 did not contribute to the overall diagnosis of clinically significant cancer. However, this study, like other studies, was conducted at an experienced center, and the rate of unnecessary PI-RADS 3 diagnoses may be low.

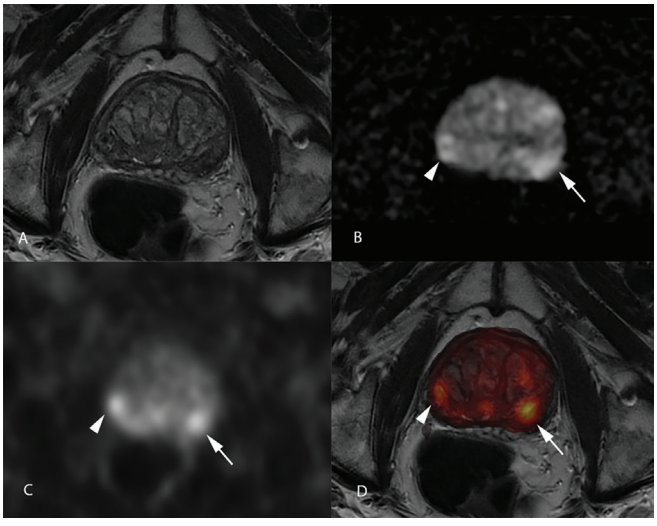

Figure 2. A 76-year-old male patient underwent PET-MR, although the cancer in the left peripheral zone is prominent on DWI (B) (arrow), the lesion in the right peripheral zone is more obscure on DWI (arrowhead). PET (C) and PET-MRI fusion images (D) shows both lesions more clearly. A shows T2W images. The biopsy result of the patient was gleason 4+3 in the left peripheral zone lesion and 3+4 in the right peripheral zone lesion
PET: Positron emission tomography, MRI: Magnetic resonance imaging, DWI: Diffusion-weighted imaging, T2W: T2-weighted

Ideally today, the decision to perform bpMRI should be made by the radiologist at the bedside during the MRI scan. However, this is often not possible under current conditions. Hötker et al. (23) trained and applied an artificial intelligence algorithm to this subject and reported that re-examination was required in only 2% of cases. In addition, a standardized reporting template is required for the development of bi-parametric MRI to eliminate heterogeneity across studies (24). Thus, bi-parametric MRI may become a screening test if adopted at more centers and performed with substantially faster imaging, since DCE is not acquired. Moreover, the implementation of bpMRI may streamline diagnostic workflows by eliminating contrast administration, reducing acquisition time and costs, and improving patient comfort. This may translate into broader accessibility in community settings and reduce patient anxiety. Additionally, streamlined imaging protocols may lower biopsy rates and associated morbidity by improving lesion characterization accuracy. Table 1 summarizes the differences between bpMRI and mpMRI.

Computed Diffusion-Weighted Imaging

Some centers may not have the technology to acquire high-b DWI series. The SNR decreases at high b-values, and longer acquisition times may be required to increase SNR. For these reasons, computed DWI may enable faster prostate MR imaging and improved evaluation in centers lacking sufficient technology (Figures 3 and 4) (25). The software is theoretically based on the the following formulation:

Signal of Computed Image = Signal of Acquired Image ×exp[(-1)×ADC×(B value of Computed Image -B value of Acquired Image)]

In phantom studies, noise decreased for the computed series, and lesion contrast-to-noise ratio increased with

Table 1. bpMRI versus mpMRI

	bpMRI	mpMRI
Sequences used	T2W, DWI	T2W, DWI, DCE
Contrast agent required	No	Yes
Acquisition time	~15-20 minutes	~30-45 minutes
Cost	Lower	Higher
Diagnostic accuracy (csPCa)	Similar in expert centers	Similar
Patient comfort	Higher	Lower due to contrast prep
Ideal settings	Screening, community use	Detailed staging, equivocal cases

bpMRI: Bi-parametric magnetic resonance imaging, mpMRI: Multi-parametric magnetic resonance imaging, T2W: T2-weighted imaging, DWI: Diffusion-weighted imaging, DCE: Dynamic contrast enhancement, csPCa: Clinically significant prostate cancer

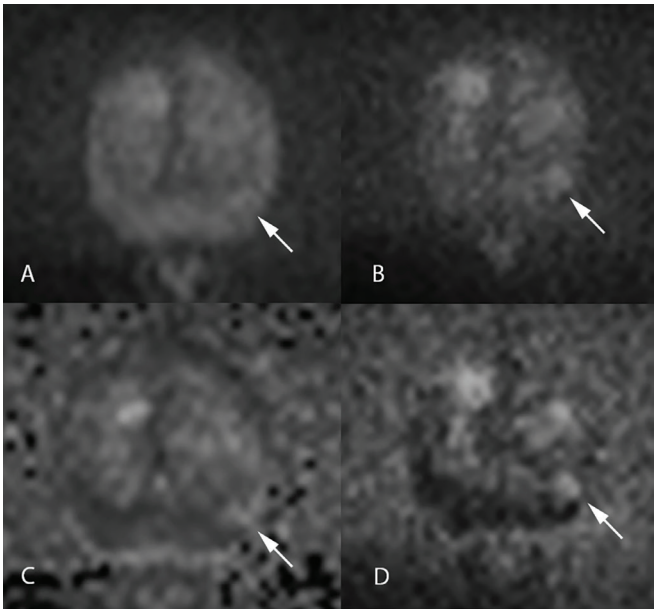

Figure 3. Figure A shows b800, B shows b1400 DWI, C shows computed b1400 and D shows computed b2000 DWI. Although the computed b1400 image is not as good as the original b1400, the computed b2000 DWI demonstrates the lesion better (arrow)
DWI: Diffusion-weighted imaging, 3D: Three-dimensional

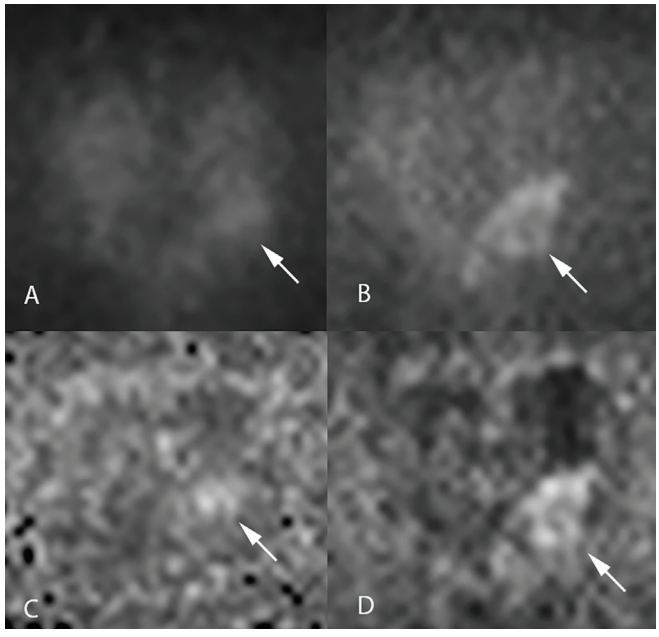

Figure 4. The lesion is not clearly demarcated on b800 DWI (A). In the computed b1400 DWI (C) and computed b2000 DWI (D), the tumour can be seen more clearly (arrow), and it is promising as a technology that can be used in prostate MRI imaging for centres with insufficient MR technology
DWI: Diffusion-weighted imaging, MRI: Magnetic resonance imaging

increasing b value (26). In support of the theory of computed DWI, Ueno et al. (27) found that noise was suppressed in computed images and that the lesion was more easily recognized. While obtaining computed DWI, Ogura et al. (28) showed that the image computed with low b values is not the same as the primary image obtained with high b-values. Therefore, it is recommended to evaluate combinations of b-values, such as 1500-2000 s/mm^2, 0-100 s/mm^2, or 500-1000 s/mm^2, in computed DWI images rather than the slow component of b-values (25). Rosenkrantz et al. (29) showed that a b value of 1500-2500 s/mm^2 is optimal for computed DWI. This occurs because values above 3000-5000 s/mm^2 significantly reduce the total signal. The aforementioned studies were performed using a mono-exponential model, and it is also possible to prepare computed DWI using a bi-exponential model. Computed DWI is a promising software tool particularly for centers with limited technological resources, and is expected to be further developed through additional studies in the field.

Prostate Imaging Quality for Prostate Magnetic Resonance Imaging Quality

Currently, the use of prostate MRI is increasing considerably and is not limited to academic or tertiary referral centers. Due to the issues described above and other imaging-related problems, prostate MRI may be of insufficient quality to contribute to the diagnosis, even if it is not biparametric. Moreover, determining which prostate MRIs cannot be evaluated may be problematic in less-experienced centers and among radiologists who are

not familiar with prostate MRI. For this reason, the prostate imaging quality (PI-QUAL) system was recommended in the multicenter PRECISION trial (30).

The PI-QUAL system can be summarized as follows: PIQUAL employs a 1-to-5 grading scale to evaluate the diagnostic quality of a scan. A score of 1 indicates that all sequences (such as T2W, DWI and DCE) fall below the minimum standard for diagnostic quality. A score of 3 suggests sufficient diagnostic quality, while a score of 5 signifies that all three sequences reach optimal diagnostic quality. Notably, a PI-QUAL score of 4 or higher signifies high MR quality, enabling confident identification or exclusion of all clinically significant lesions. The PI-QUAL score is determined by assessing the mpMRI against specific, objective quality criteria aligned with the PI-RADS v2 guidelines (31). These criteria encompass the adequacy of the execution of all three mpMRI sequences. It's worth noting that the PI-RADS v2.1 guidelines were not available during the PRECISION study, so the evaluation was based on an earlier version. A sheet on the score is also included in the PIQUAL publication; the relevant sheet can be found in the paper published by Giganti et al. (30).

The PI-QUAL system has been published for multiparametric MRI. The radiologist should be familiar with prostate MRI interpretation to evaluate the system. Although the objective criteria in PI-RADS v2 are taken as a reference here, a scoring system with simpler criteria that can be applied by those who are less familiar with prostate MR evaluation may yield more reliable prostate MR imaging in tertiary and non-referral centers. If the PI-QUAL system is applicable to bi-parametric MRI, its adoption may become widespread.

Short Magnetic Resonance Imaging Protocols

Given the increasing use of prostate MRI, abbreviated MRI protocols are being developed to improve patient access and reduce costs. These short protocols may also enhance patient throughput and reduce scheduling bottlenecks, particularly in high-volume institutions, and facilitate inclusion of MRI in population-level screening programs by lowering per-scan costs.

For T2W imaging, PI-RADS v2.1 recommends acquiring an axial image and at least one sagittal or coronal image. van der Leest et al. (32) reported that, when comparing single axial T2W and DWI (which they termed "fast bpMRI") with mpMRI, there was only a slight decrease in specificity for fast bpMRI. This study included 626 patients. In addition, this type of protocol may complicate the evaluation of "encapsulated BPH" in the transitional zone, making prostate MRI evaluation by an inexperienced radiologist even more challenging (Figure 5).

Another method is to acquire only the isotropic three-dimensional (3D) Turbo Spin Echo T2W sequence. In this way, work can be carried out according to the desired plan. Studies have not reported any significant difference in lesion diagnostic accuracy between this method and 2D sequences. In addition, it has been suggested that a 3D sequence may be more useful for assessing extraprostatic extension. However, the T1-weighting of the image may be affected when acquisition time is reduced, and the 3D sequence is more susceptible to motion artifacts (Figure 6) (33).

Recently, using machine learning models, Gassenmaier et al. (34) reduced the T2W acquisition time to almost one-third and did not observe significant changes in PI-RADS scores with these images.

In DWI, three b values (e.g., 50, 700, and 1400) are usually acquired at many centers, while PI-RADS considers it sufficient to acquire two b-values (e.g., 0-50 and 800-1000), provided that b1400 is calculated or obtained separately.

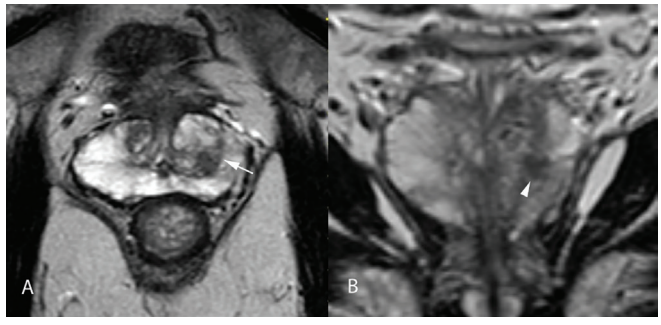

Figure 5. In the axial T2W image (A), a nodular lesion, which is not very suspicious and may belong to a BPH nodule (arrow). In the axial image, this nodule may be thought to be completely encapsulated and misinterpreted as PI-RADS 1 according to PI-RADS v2.1. However, it is clear that the lesion is not encapsulated in the coronal T2W image (B) in the same alignment (arrowhead). The biopsy result of this lesion was gleason 3+4

T2W: T2-weighted, BPH: Benign prostatic hyperplasia, PI-RADS: Prostate imaging reporting and data system

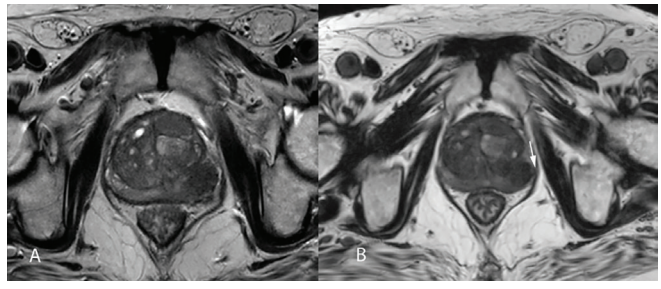

Figure 6. Figure 6 shows T2W series in both images and B was obtained as Isotropic (3D). Extraprostatic extension of the tumoural tissue is not visible in the non-volumetric axial T2W image, but clearly visible in the isotropic image (arrow). Note the increased T1 weighting in the isotropic sequence

T2W: T2-weighted, 3D: Three-dimensional

Recently, new techniques such as reduced field of view have been developed to provide better imaging, but this approach is known to increase acquisition time (Figure 7). In addition, the standard single-shot echo-planar imaging technique used in DWI is susceptible to artifacts, and patients may need to be recalled for DWI, which is a very important sequence in bpMRI. Although antispasmodic agents and enemas are recommended by some authors to reduce motion artifacts, results in the literature are controversial.

Prostate Magnetic Resonance Imaging as A Screening Tool

Given the growing role of MRI in early detection, a structured imaging pathway may aid in standardizing screening protocols. Figure 8 summarizes a proposed algorithm for imaging-based prostate cancer screening and diagnosis (35). A scanning program should be readily accessible, inexpensive, and safe. The screen should be easy to interpret within the program and not vary between observers. PSA testing has been a standard method for prostate cancer screening, but it lacks specificity, leading to overdiagnosis and unnecessary biopsies. As discussed in the background, PSA testing lacks specificity, often leading to unnecessary biopsies. An analysis of five randomized trials that used different biopsy thresholds found that PSA screening did not significantly affect all-cause mortality (36). Although there is no definitive cut-off value for the PSA testclinically significant prostate cancer may occur at PSA values of 3 ng/mL and above (37-39).

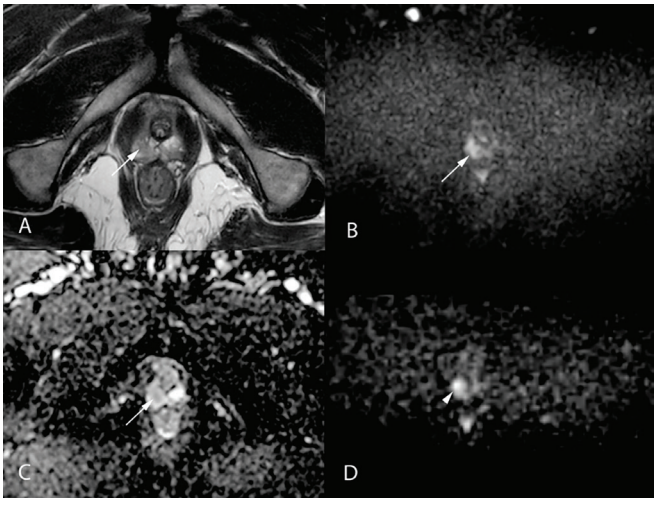

Figure 7. T2W (A), b1400 DWI (B), ADC (C) images of a patient with cancer in the right peripheral zone at the prostate gland apex show tumour tissue (arrows), however, tumour tissue is more prominent in reduced FOV DWI (D) (arrowhead)

T2W: T2-weighted, DWI: Diffusion-weighted imaging, ADC: Apparent diffusion coefficient, FOV: Field of view

Efforts are underway to assess the viability of employing MRI-only applications as a substitute for the PSA test in prostate cancer screening. Preliminary findings indicate a favorable inclination towards this paradigm shift. Despite the higher cost and more limited accessibility of bpMRI compared with the PSA test, particularly as a screening modality, it is imperative to recognize similar paradigms in other medical contexts. For instance, screening tests such as colonoscopy and sigmoidoscopy, which are conducted at longer intervals to optimize cost-effectiveness, have greater sensitivity than the fecal occult blood test (40). This underscores the complexity inherent in evaluating the cost, accessibility, and efficacy of transitioning from traditional screening methods to advanced imaging modalities for cancer detection.

A randomized trial comparing PSA with prostate MRI alone for screening found that prostate biopsy was less likely to be recommended in patients who underwent MRI alone, and that detection of clinically significant prostate cancer among those who underwent biopsy was slightly higher in the MRI-alone group (41). Prostate MRI overcomes this limitation by providing detailed anatomical and functional information, aiding in the identification and characterization of suspicious lesions. In the IP1-PROSTAGRAM trial, PSA and short non-contrast MRI were compared (37). Their results showed that positive MRI screening protocols alone detected more clinically significant prostate cancer than positive PSA examination alone. While this study reinforces the use of bpMRI for screening purposes, it is imperative to

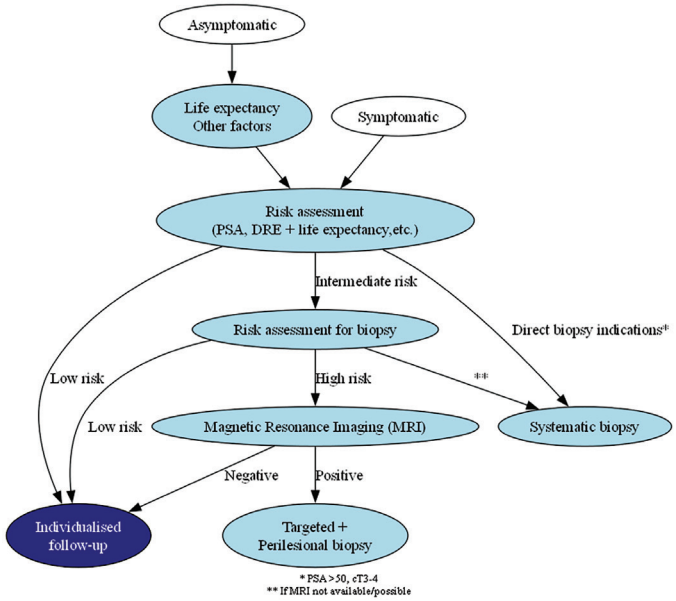

Figure 8. Algorithm for prostate cancer screening and diagnostic decision-making

PSA: Prostate-specific antigen, DRE: Digital rectal examination

acknowledge the need for additional evidence. The current dearth of comprehensive, long-term studies encompassing larger populations necessitates caution in drawing definitive conclusions. Nonetheless, the concurrent use of bpMRI and the PSA test is encouraging and suggests that bpMRI could be included in comprehensive screening programs. Further research is warranted to substantiate these preliminary findings and establish the robustness of bpMRI in the context of population-scale and extended-duration studies.

Radiomics in Prostate Magnetic Resonance Imaging

Radiomics studies in prostate imaging have been performed using many modalities, such as TRUS, computed tomography, and PET. However, most studies have been carried out using MRI. Initially, studies on the detection of prostate cancer were conducted to evaluate radiomics models on MRI for the diagnosis of any prostate cancer. Due to the biological diversity of prostate cancer, clinically significant prostate cancer (csPCa) receives greater focus. For both topics, manual or semi-automatic segmentation methods have been used in most studies. Since segmentation should be performed by a radiologist, its use in screening programs may be limited. However, studies show promise in improving the diagnostic accuracy for suspicious lesions. These algorithms may also allow a less experienced radiologist to interpret prostate MR more confidently.

Recently, the use of machine learning algorithms in bpMRI has increased. Gong et al. (42) reported an area under the curve (AUC) of 0.78, and Li et al. (43) reported an AUC of 0.98 for csPCa detection on bpMRI. Extraprostatic extension is also among the criteria for csPCa according to PI-RADS v2.1, and its detection on MRI may be challenging. Studies using mpMRI have been conducted in this area. Losnegård et al. (44) reported an AUC of 0.75 for radiology interpretation and 0.74 for radiomics. In the triple model combined with clinical nomograms, they obtained 0.79. Ma et al. (45) achieved an AUC of 0.906 for the training group and 0.821 for the internal validation group.

Radiomics studies using MRI are also advancing in the field of prediction. For example, scores such as the Prostate Cancer Risk Assessment score are used to predict biochemical recurrence. In radiomics studies in this area, Shiradkar et al. (46) reported an AUC of 0.84 in the training group and 0.73 in the validation group. Zhong et al. (47) also achieved an accuracy of 77.8% and reported an AUC of 0.73 in the test group.

Deep learning (DL) algorithms and convolutional neural networks enable more automated lesion detection. Ishioka et al. (48) pioneered the development of a DL model to identify biopsy-confirmed PCa. Their model was assessed in two distinct populations, resulting in AUC values of 0.636 and 0.645 for the detection of PCa. Winkel et al. (49) showed that commercial use of the DL algorithm, which has been approved in Europe and the United States of America, improved the radiologist's performance and shortened the reading time for lesions with PI-RADS scores greater than 3. Saha et al. (50) reported a sensitivity of up to 93% in their study of an algorithm developed for csPCa on bpMRI. The promise of artificial intelligence technologies in prostate MRI is becoming increasingly evident.

Despite promising results, radiomics and DL models often suffer from a lack of external validation, limited reproducibility across institutions, and segmentation variability. Many algorithms are trained on single-center datasets, which raises concerns regarding generalizability. Moreover, differing MRI parameters and preprocessing steps affect radiomics feature extraction, highlighting the need for standardization and robust multi-institutional trials. A major barrier remains: the reproducibility of radiomics features across MRI vendors, protocols, and institutions. Automated segmentation, while promising, still faces challenges due to interobserver variability and anatomic ambiguity. Standardization of preprocessing and feature extraction pipelines is lacking. Additionally, very few studies have undergone external validation or prospective evaluation, which raises concerns about overfitting and model robustness. Addressing these issues through transparent reporting standards, multicenter trials, and harmonization initiatives is essential for safe and effective clinical translation.

CONCLUSION

Prostate MRI has significantly evolved, becoming a crucial tool in the diagnosis and management of prostate cancer. While PSA testing remains prevalent, the integration of mpMRI offers a more detailed and functional assessment, enhancing the detection of csPCa. The refinement of techniques, such as bpMRI and computed DWI, provides faster, more cost-effective alternatives without compromising diagnostic accuracy. Additionally, the implementation of standardized systems such as PI-RADS and PI-QUAL ensures consistency and quality in imaging across various centers. Advances in artificial intelligence and radiomics further enhance the potential of prostate MRI, promising improved diagnostic accuracy and better patient outcomes. Continued advancements will likely solidify the role of MRI as a primary screening and diagnostic tool in prostate cancer care.

ETHICS

Ethics Committee Approval and Informed Consent: Not applicable. This article is a narrative review and does not involve original research with human participants. All clinical images are anonymized, and no identifiable patient information is presented.

FOOTNOTES

Authorship Contributions

Concept: H.A., A.T., Ş.M.E., Design: H.A., A.T., Ş.M.E., Data Collection or Processing: H.A., B.E., Analysis or Interpretation: H.A., Literature Search: H.A., B.E., Writing: H.A., A.T., Ş.M.E.

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Research

The Effect of Soft Tissue Mobilization and Kinesio Taping on Sportive Performance in Athletes: A Randomized Controlled Trial

Yumuşak Doku Mobilizasyonu ve Kinesio Bantlamanın Sporcularda Sportif Performans Üzerine Etkisi: Randomize Kontrollü Bir Çalışma

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ABSTRACT

Objective: Instrument-assisted soft tissue mobilization (IASTM) and Kinesio tape (KT) applications were suggested in the context of athlete rehabilitation. This study aimed to examine the impact of IASTM and KT on the bilateral hamstring muscles of athletes' balance, agility, and lower extremity explosive power.

Methods: A total of 45 athletes who met the inclusion criteria participated in the study. The participants were allocated to the exercise or the control group using simple randomization with a sealed envelope method. The athletes were divided into three groups. All three groups' balance, agility, and jump-lower extremity explosive strength performances were evaluated in a single session using the single foot stance test, agility t-test, and standing long jump test, respectively, before, immediately after, and one month after the intervention.

Results: There was a significant difference between the IASTM and KT groups for the agility t-test ($p<0.05$). In the IASTM group, an important difference was observed in the duration of the single foot stance test ($p<0.05$). There was no statistically significant difference between the groups in the scores of the single foot stance test, agility t-test, and standing long jump test ($p>0.05$).

Conclusion: The application of IASTM has been demonstrated to enhance balance and agility, while KT has been shown to improve agility in athletes. However, no significant differences were identified between the two methods. IASTM and KT may be useful as complementary methods to existing training programs for athletes, but further research is recommended to determine which is more effective.

Keywords: Therapy, soft tissue, athletes, balance, Kinesio tape

ÖZ

Amaç: Alet destekli yumuşak doku mobilizasyonu (ADYDM) ve Kinezyo bant (KB) uygulamaları sporcu rehabilitasyonu bağlamında önerilmiştir. Bu çalışmanın amacı, ADYDM ve KB'nin bilateral hamstring kaslarına uygulanmasının sporcuların denge, çeviklik ve alt ekstremite patlayıcı gücü üzerindeki etkisini incelemektir.

Gereç ve Yöntem: Çalışmaya dahil edilme kriterlerini karşılayan toplam 45 sporcu katılmıştır. Katılımcılar kapalı zarf yöntemiyle basit randomizasyon kullanılarak egzersiz veya kontrol grubuna ayrıldı. Sporcular üç gruba ayrılmıştır. Her üç grubun denge, çeviklik ve sıçrama-alt ekstremite patlayıcı kuvvet performansları sırasıyla tek ayak duruş testi, çeviklik t-testi ve durarak uzun atlama testi kullanılarak müdahaleden önce, hemen sonra ve bir ay sonra tek bir seansta değerlendirilmiştir.

Bulgular: Çeviklik t-testi için ADYDM ve KB grupları arasında anlamlı bir fark vardı ($p<0,05$). ADYDM grubunda tek ayak duruş testi süresi içinde önemli bir fark gözlendi ($p<0,05$). Tek ayak duruş testi, çeviklik t-testi ve durarak uzun atlama testi puanlarında gruplar arasında istatistiksel olarak anlamlı bir fark yoktu ($p>0,05$).

Sonuç: ADYDM uygulamasının denge ve çevikliği artırdığı, KB'nin ise sporcularda çevikliği geliştirdiği gösterilmiştir. Ancak, iki yöntem arasında anlamlı bir fark tespit edilmemiştir. ADYDM ve KB, sporcular için mevcut antrenman programlarını tamamlayıcı yöntemler olarak faydalı olabilir ancak hangisinin daha faydalı olduğunu belirlemek için daha fazla araştırma yapılması önerilmektedir.

Anahtar Kelimeler: Terapi, yumuşak doku, sporcular, denge, Kinezyo bant

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INTRODUCTION

Athletics is the most prevalent sport in both the Olympic and Paralympic Games (1). As is the case in all branches of sport, optimal sporting performance is a prerequisite for success in athletics. The optimal development of several physiological systems is necessary for successful performance in sports. These include the aerobic and anaerobic metabolic systems, muscle strength, endurance, mobility, balance, speed, and agility (2).

In athletes, balance refers to the ability to maintain postural control during dynamic movements (3). The capacity to maintain equilibrium is a fundamental prerequisite for numerous activities of daily living, including ambulation and functional mobility (3). It has been demonstrated that balance disorders are directly associated with sports-related injuries and reductions in overall athletic performance. The capacity to alter one's trajectory rapidly is a crucial determinant of success in the majority of field and court sports (4). It has been demonstrated that sports that demand a high degree of agility necessitate a change in movement approximately every two seconds. The ability to brake, change direction, and accelerate again is a prerequisite for agility (5). Agility represents one of the most significant physical factors influencing the performance of athletes. The discrepancy in agility test performance can significantly impact the outcomes of athletes in sports where agility is a crucial element (4). The standing long jump is a valuable indicator of lower limb muscle strength and is widely used because it is time-efficient and resource-efficient (6). During jumping activities, several muscle groups are engaged to varying degrees, with the hamstring muscle being one of the most significant contributors to overall performance (7).

One of the most frequently employed therapeutic interventions for the prevention and rehabilitation of sports-related overuse injuries, as well as for the facilitation of optimal warm-up, is instrument-assisted soft tissue mobilization (IASTM). However, despite the widespread use of these techniques by sports therapists, the effectiveness of IASTM remains unclear due to conflicting research findings (8). IASTM represents a widely utilized treatment modality for myofascial limitation. Its principles are derived from those espoused by James Cyriax. This treatment technique is specifically designed to act on the body's deeper tissues (9). The IASTM technique uses instruments, which have been specifically designed to identify and treat myofascial restrictions. The diversity of instruments permits using disparate techniques for instrument movement, employing distinct treatment surfaces, and administering varying intensities of treatment (9).

Among the various techniques for improving athletic performance, Kinesio tape (KT) is a notable intervention method. The breathability, freedom of movement, and a smooth feel are specific features of KT that make it a popular choice for athletes (10). The application of an elastic band in a manner that stimulates the proprioceptors can facilitate improvements in range of motion and thigh muscle function during exercise (10). The potential benefits of elastic banding may include increased body or extremity stability, joint support or protection, correction of body or limb alignment, modification of biomechanics of movement, and support of sensor-motor functions such as proprioception and inhibition of irrelevant sensory input (11). It has been demonstrated that KT is an effective intervention for the prevention of injuries, facilitation of rehabilitation, and improvement of performance. Furthermore, it has been shown to decrease pain, facilitate joint exercises, increase muscle activation, and enhance muscle strength (12). Therefore, we hypothesized that the application of IASTM and KT to track and field athletes would result in improvements in balance, agility, and the explosive power performance of the lower extremity during jumps.

The objective of this study was to examine the impact of IASTM and KT, the bilateral hamstring muscles on balance, agility, and lower extremity explosive strength in track and field athletes.

METHODS

Study Design

This randomized controlled study was conducted between May and July 2024 at the İstanbul Provincial Directorate's of Youth and Sports-affiliated sports health center. Before commencement, ethical approval was obtained from the Üsküdar University Non-Interventional Research Ethics Committee (approval no: 2023-22, date: 31.10.2023) following the Helsinki Declaration. This study was conducted and reported following the Consolidated Standards of Reporting Trials statement. The protocol is registered with http://clinicaltrials.gov/ (NCT06407466). All participants provided written informed consent.

Determination of Sample Size

The statistical power of the sample size was calculated using G*Power version 3.1.9.6 (Heinrich Heine University, Düsseldorf, Germany). It was determined that a sample size of at least 30 is required, with an effect size of 0.95, a significance level of 0.05, and a power of 0.81. Although the minimum required sample size was 30, 45 participants were included to increase statistical power and account

for possible dropouts. The research was conducted as a single-blind, randomized controlled study, following the ethical principles outlined in the Declaration of Helsinki and approved by the relevant ethics committee.

Randomization and Blinding

The study was conducted as a single-blind randomized controlled trial following the established principles of research design. The evaluation was conducted in a single-blind manner. Initially, 51 participants were assessed for eligibility. After exclusion due to not meeting the inclusion criteria, a total of 45 athletes, comprising short- and long-distance runners, long jumpers, and shot putters, were randomly assigned to one of three groups: IASTM group (n=15), KT group (n=15), and control group (n=15). This was accomplished using simple randomization. The concealment and randomization were carried out using the sealed envelope method. The physiotherapist recorded the names of all participants on individual pieces of paper and placed them in separate envelopes. Participants were randomly selected, and they were then assigned to either the exercise or control group following the order of selection by the physiotherapist. The study was ultimately concluded with 45 participants (Figure 1).

Participants

The following inclusion criteria were applied: participants must have been engaged in athletic activities for at least six months. They must have participated in regular training (at least three days per week). Additionally, participants must have been between the ages of 10 and 40 years and have volunteered to participate in the study. Informed consent was obtained from the participants above 18 years of age and legal guardians of participants under 16 years of age. Individuals who met any of the following criteria were excluded from participation: a history of injury or acute infection, systemic and metabolic diseases, chronic pain, unhealed or unstable bone fractures, allergies, illnesses, and open wounds on the skin.

Intervention and Procedure

The participants were randomly assigned to one of three groups, with stratification according to gender. All 3 groups continued a systematic training protocol consisting of warm-up, loading, and cool-down phases designed by their club or individual trainers, performed for at least 3 days a week for at least 60 minutes. The first group received IASTM, while the second group received KT. Group 3, the control group, did not receive any additional treatment. The balance, agility, and lower extremity explosive strength performance of all three groups were evaluated before, immediately after, and one month after the intervention in a single session using the single foot stance test, agility t-test, and standing long jump test, respectively. A three-minute rest period was allowed between the tests to prevent fatigue. All treatment procedures were performed by a relevant certified physiotherapist.

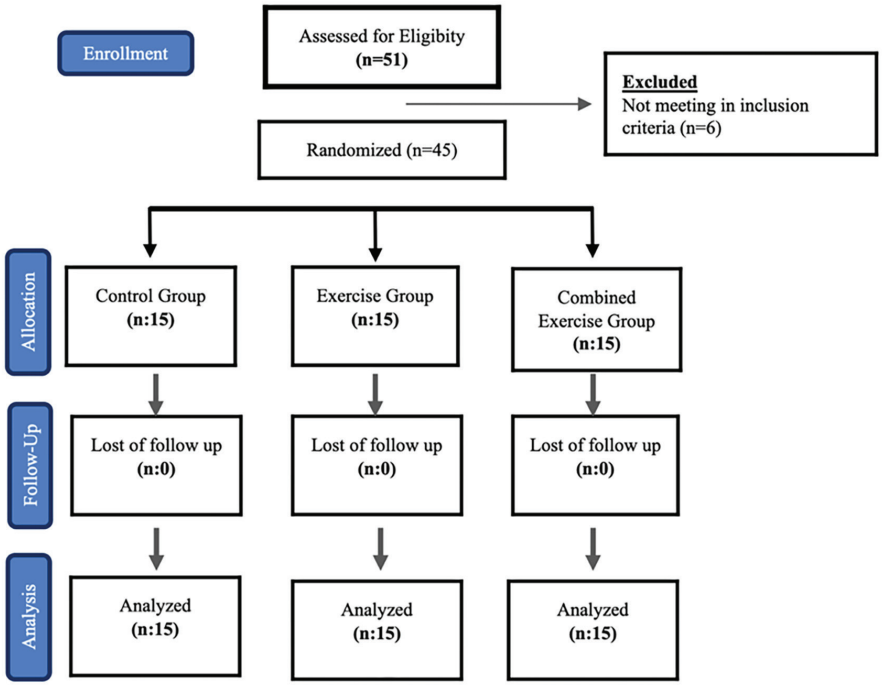

Figure 1. CONSORT flowchart of the study

IASTM (Graston Technique) Application

IASTM application was performed before training on a bed with the athlete in a prone position, with the lower extremities in a neutral position. A hazelnut-sized lubricant was applied to the working surface; and a muscle-appropriate shaped tool was selected and applied to the skin on the back of both upper legs for 5 minutes, targeting tissue structures (hamstring and deep fascia covering this muscle). The instrument was used at a 30° to 45° angle using sweeping strokes in all directions with moderate pressure. The pressure and speed were adjusted according to the participant's tolerance levels to avoid causing discomfort (Figure 2).

KT Application

The athletes were instructed to clean the area to be treated with KT and to refrain from using any topical substances, including creams, on the treated area for at least 24 hours prior to the application of the tape.

To induce both hamstring muscles before training in the group with KT application, both iliotibial bands (Kindmax Inc., Irvine, CA, USA) were applied to both legs, with 30% stretching from the medial and lateral sides, starting from the ischial tuberosity to the border of the popliteal fossa. This was done while the participant was standing and the trunk was flexed to ensure hip flexion (Figure 3).

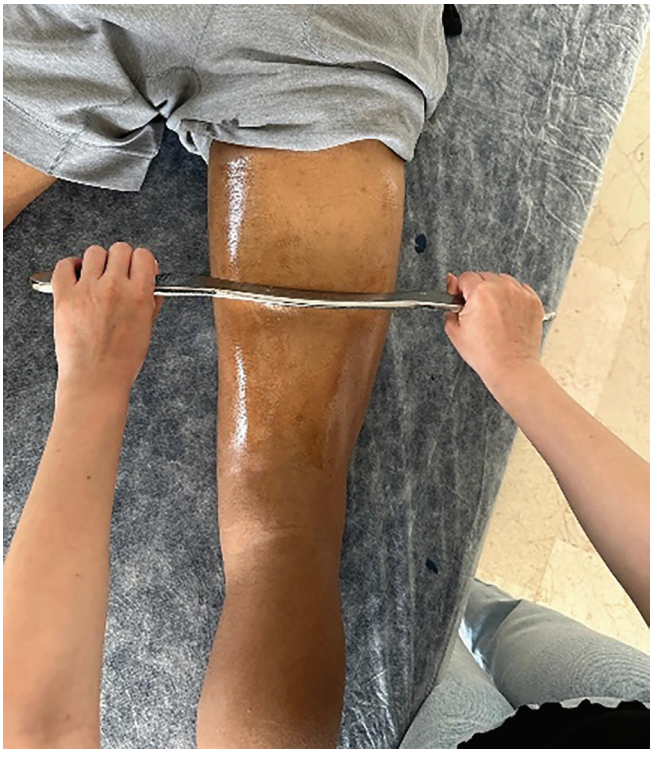

Figure 2. IASTM application to hamstrings
IASTM: Instrument assisted soft tissue mobilization group

Outcome Measurements

The primary outcome measure of this study was the examination of the impact of IASTM and KT applications on athletes' balance. The secondary outcome measures assessed the effect of these treatments on athletes' agility and lower extremity explosive power. These outcomes were measured at the outset and conclusion of the study using the following questionnaires.

The Unipedal Stance Test

It is a static balance test. To complete the test, participants were required to adopt a unipedal stance, with one foot selected as the point of support. The other foot was raised, with minimal contact between the ankle and the floor, and the arms were crossed over the chest. During the test, the subject was instructed to focus on a point at eye level. Once the participant had lifted their foot off the floor, the time was recorded using a stopwatch. The time was calculated until the participant exhibited one of the following behaviors: using their arms (i.e., not crossing the arms), the raised foot, or the weight-bearing foot to maintain balance. The procedure was repeated on three occasions, and the best result from the three trials was recorded. A five-minute

Figure 3. KT application to hamstrings
KT: Kinesio tape group

interval was permitted between each set of trials to prevent the onset of fatigue (13).

Agility T-test

The agility t-test comprises four contact points arranged in a t-shape within an area measuring 10 meters in length and 10 meters in width. The objective is to complete a series of movements in different directions between the contact points in the shortest possible time. The distinguishing feature of this test is that the subject is required to maintain a fixed direction of gaze throughout. The subject may change direction by sliding steps to the right or left or by running backward. The test necessitates the completion of one 90° turn and one 180° turn, in addition to traversing a total distance of 40 meters (10 meters in a forward direction, 10 meters to the right, 10 meters to the left, and 10 meters in a backward direction) (14). If the subject failed to make contact with any of the designated cones, execute the required sideways movement, or change direction at the appropriate time, the trial was not recorded, and the subject was required to repeat the trial. The data were analyzed using the mean value derived from the three trials.

Standing Long Jump Test

The standing long jump test is an assessment of lower extremity explosive strength. The individual is instructed to jump from a bipedal standing position as far as possible in a forward direction (i.e., horizontally in the sagittal plane), and to maintain this position for functional purposes (15). The participant conducted the test at the designated starting point with both feet planted firmly on the ground and propelling themselves with a thrust of both legs. The distance from the front of the jump line to the final point of body contact was measured in centimeters and recorded. The feet must remain in contact with the ground until the jump is initiated. The optimal score was achieved by performing a minimum of three repetitions for evaluation purposes.

Statistical Analysis

All data were recorded and analyzed using the IBM SPSS Statistics 22 software package for Windows (Armonk, NY, USA). Due to the limited sample size (n=15), non-parametric tests were employed for the data analysis. In this context, the Kruskal-Wallis H test was employed for comparing more than two independent groups, while the Friedman test was utilized for comparing more than two dependent measurements. A significance level of 0.05 was employed to determine statistical significance. Bonferroni tests were employed as multiple comparison tests, and the statistical significance level was determined to be 0.017.

RESULTS

This was a randomized clinical study with 45 athletes conducted between May and July 2024. Following the group allocation, all participants engaged in the exercise programs throughout the study period. Table 1 presents the variables—gender, age, age at the commencement of participation in sports, height, and body weight—by group. No statistically significant difference was observed between the gender, age, age at the commencement of participation in sports, height, and body weight variables of the 45 participants included in the study ($p>0.05$) (Table 1).

The results of the single-foot stance test for the control and KT groups indicate no statistically significant difference between the intra-time measurements ($p>0.05$). A statistically significant difference was observed between the intra-time measurements of the single-foot stance test in the IASTM group ($p<0.05$). The Bonferroni multiple comparison test was employed to ascertain the specific time points at which the observed difference occurred. The results indicated that the single-foot stance test values obtained following the application were significantly higher than those recorded before the application (Table 2).

Table 1. Socio-demographic information of the participants

Variables		IASTM (n=15)	KT (n=15)	C (n=15)	p[a]
		n (%)	n (%)	n (%)	
Sex	Female	8 (53.33)	8 (53.33)	7 (46.67)	0.91
	Male	7 (46.67)	7 (46.67)	8 (53.33)	
		X±SD	X±SD	X±SD	
Age (years)		17.53±2.77	17.6±2.92	19.6±3.14	0.10
Age of starting sport (years)		11.73±2.79	10.87±2.88	11.47±2.95	0.70
Height (cm)		170.93±11.22	170.2±1.47	174.8±7.95	0.43
Weight (kg)		59.2±15.61	58.13±12.56	65.0±12.99	0.35

$p<0.05$, [a]: Chi-square test, X: Mean, SD: Standard deviation, n: Number of people, cm: Centimeter, kg: Kilogram, IASTM: Instrument assisted soft tissue mobilization group, KT: Kinesio tape group, C: Control group

There is no statistically significant difference between the intra-time measurements of the agility t-test in the control group (p>0.05). There is a statistically significant difference between the intra-time measurements of the agility t-test in the IASTM group (p<0.05). When the difference was analyzed by the Bonferroni multiple comparison test, it was found that the agility t-test values measured after the application were significantly lower than the values measured before the application; they were also significantly lower than the values measured 1-month after the application. There is a statistically significant difference between the measurements taken during the agility t-test in the KT group (p<0.05). When the difference was analyzed by the Bonferroni multiple comparison test, it was found that the agility t-test values measured after the intervention were significantly lower than the values measured before the intervention (Table 2).

The results of the standing long jump test in the control group demonstrated no statistically significant difference between the intra-time measurements (p>0.05). No statistically significant difference was observed between the repeated measurements of the standing long jump test in the IASTM and KT groups (p>0.05) (Table 2).

No statistically significant difference was observed between the groups in the scores of the single foot stance test, agility t-test, and standing long jump test (p>0.05).

The results of the IASTM group single-leg stance test over time, as well as the associated statistical information, are presented in Figure 4.

The results of the IASTM group agility t-test over time, as well as the associated statistical information, are presented in Figure 5.

The results of the agility t-test, which provides statistical information about changes in time within the KT group, are presented in Figure 6.

DISCUSSION

The objective of this study was to examine the impact of IASTM and KT on bilateral hamstring muscles, balance, agility, and jump-lower extremity explosive power performance in track and field athletes. The findings of the study indicated that IASTM enhanced balance and agility, while KT was associated with improved agility in track and field athletes. Nevertheless, no discernible difference was noted between the two intervention methods.

One of the areas in which IASTM is applied to the lower extremity is the hamstring muscle group. Tension in the hamstrings affects the biomechanics of the lower extremities, reducing the efficiency of movements and disrupting the load balance on the lower extremity joints.

Table 2. Findings related to single foot stance test, agility t-test, and standing long jump test measurements

Variables		IASTM (n=15)	KT (n=15)	C (n=15)	p[b]
		X±SD (min-max)	X±SD (min-max)	X±SD (min-max)	
Unipedal stance test (sec)	BI	149.80±96.70 (25-335)	180.47±111.42 (5-430)	210.73±74.82 (60-347)	0.14
	AI	194.07±96.77 (57-400)	211.07±131.60 (18-444)	198.53±79.82 (70-310)	0.96
	1-month later	171.20±75.49 (70-343)	177.93±100.98 (20-338)	192.60±91.37 (65-332)	0.84
	p[c]	**0.03 difference =1<2**	**0.42**	**0.42**	
	AI-BI	21.40±72.16 [(-89)-201]	-2.53±93.39 [(-215)-190]	-18.13±67.07 [(-168)-131]	0.24
Agility t-test (sec)	BI	11.75±1.58 (10-15)	11.78±1.54 (9-14)	11.49±0.85 (10-14)	0.94
	AI	11.09±1.42 (9-14)	11.28±1.46 (9-15)	11.54±0.89 (10-14)	0.54
	1-month later	11.62±1.67 (9-15)	11.81±1.73 (9-15)	11.42±0.60 (11-12)	0.87
	p[c]	**0.00 difference =2<1.3**	**0.02 difference =2<1**	**0.77**	
	AI-BI	-0.13±0.48 [(-1)-1]	0.03±0.63 [(-1)-1]	-0.07±0.66 [(-2)-1]	0.56
Standing long jump test (cm)	BI	246.47±42.22 (174-302)	234.27±43.70 (160-316)	242.07±21.22 (216-277)	0.44
	AI	246.33±44.16 (163-313)	230.27±45.54 (157-311)	240.47±23.22 (212-281)	0.33
	1-month later	240.67±43.63 (176-305)	229.07±44.33 (163-322)	237.80±24.28 (195-275)	0.6
	p[c]	**0.77**	**0.48**	**0.38**	
	AI-BI	-5.80±15.59 [(-52)-11]	-5.20±11.31 [(-33)-7]	-4.27±9.34 [(-23)-11]	0.98

p<0.05, [b]: Kruskal-Wallis H test. [c]: Friedman test, X: Mean, SD: Standard deviation, n: Number of people, cm: Centimeter, sec: Second, min: Minimum, max: Maximum, BI: Before intervention, AI: After intervention, IASTM: Instrument assisted soft tissue mobilization group, KT: Kinesio tape group, C: Control group, pb: Intra-group comparison, pc: Intra-group comparison

Additionally, it causes an increased load on the knee joint. The application of IASTM has been demonstrated to be an efficacious approach in the management of hamstring tension (16). This physiological mechanism may explain the observed increase in balance scores following IASTM application in our sample.

In a study, it was reported that the application of IASTM to the gastrocnemius, soleus, and Achilles tendon for four sessions per week for eight weeks (17). Furthermore, it has been documented that IASTM can be employed in the context of sports preparation with the objective of enhancing muscle response and explosive force production, improving neuromuscular efficiency, and optimizing athletic performance (18). The results of our study align with existing literature on balance in the IASTM group. We hypothesized that IASTM improves balance indirectly through enhancement of proprioceptive sensations. Agility is regarded as a crucial component of physical fitness in sports that necessitate a diverse range of movements.

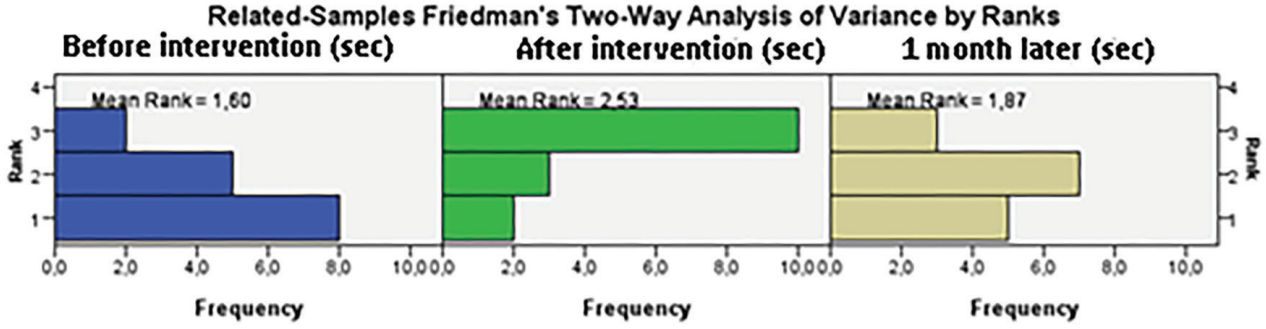

Figure 4. IASTM group single-foot stance test changes over time
IASTM: Instrument assisted soft tissue mobilization group

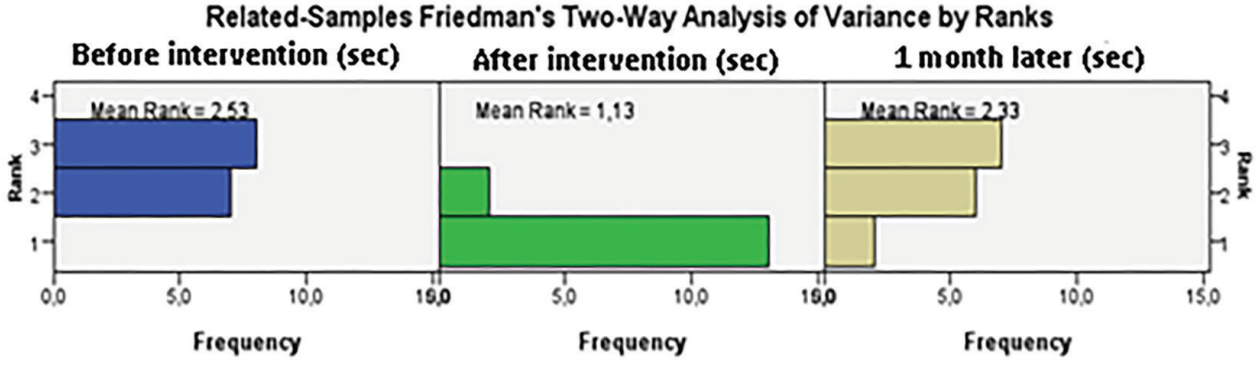

Figure 5. IASTM group agility t-test changes over time
IASTM: Instrument assisted soft tissue mobilization group

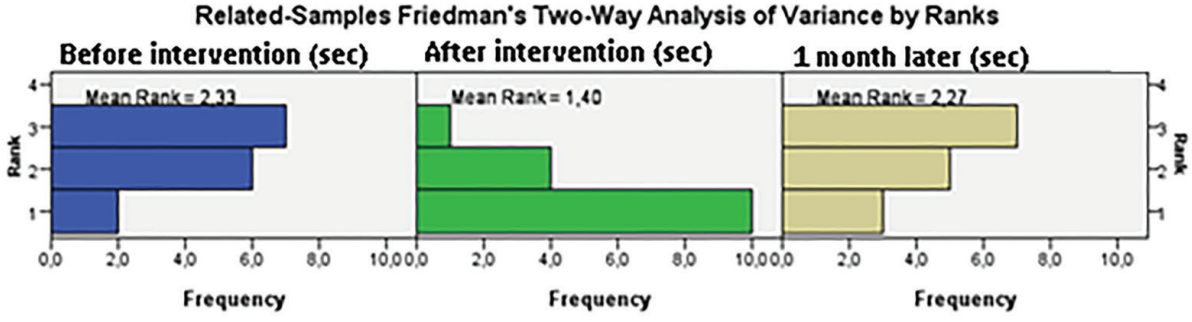

Figure 6. KT group agility t-test changes over time
KT: Kinesio tape group

A reduction in agility is a contributing factor to injuries sustained during competitive events. The enhancement of flexibility can improve agility and maintain technical fitness (19). In a study, it was demonstrated that the application of IASTM to bilateral hamstring muscles five minutes resulted in a favorable acute impact on agility (20). The results of our study align with existing literature on agility in the IASTM group. The observation that IASTM has the same effects as warm-up exercises may be indicative of enhanced agility. The results substantiated Laudner's assertion that IASTM rehabilitation impacts physical activity performance by stimulating the muscular and nervous systems (9) and soft tissues. Given that diminished flexibility and muscle strength can impede agility, it is imperative to maintain flexibility and muscle strength throughout the seasons to prevent a decline in agility (21). In a single study, the impact of IASTM, applied for a period of three minutes, on muscle performance was evaluated through the measurement of vertical jump height, peak power, and peak velocity. The findings indicated that there was no statistically significant difference between the IASTM group and the control group (22). The results of our study on jump performance in the IASTM group are in accordance with the findings of previous research in this field. It was highlighted that IASTM may necessitate a longer treatment duration, augmented pressure during application, or multiple treatments to achieve a significant improvement in measures such as vertical jump performance (22). We believe that further research is needed to determine the effect of IASTM on muscle performance.

In light of the various factors that may influence the athletic performance of professional athletes, it can be posited that even minor alterations may confer a competitive advantage to athletes. A review of the literature reveals a divergence of opinions regarding the impact of KT application on performance. It is hypothesized that these effects may vary depending on the specific muscles to which the tape is applied and differences in application techniques (23). The results of a study conducted on athletes specializing in jumping events revealed that the application of KT to the gastrocnemius muscle, using facilitation and inhibition techniques, did not result in any discernible acute effects on vertical jump height and lower extremity explosive power (24). In a separate investigation, no notable discrepancy was observed in jump height between the KT and control groups. However, an increase in ground reaction force was noted in the KT group, along a vertical trajectory (25). In a study conducted on healthy athletes, Nunes et al. (26) found that KT did not affect balance performance. The results of our study are in accordance with the existing literature concerning the relationship between balance and jump performance in the KT group. In light of the assertion that, thus far, there is no evidence to suggest that KT exerts any influence on motor control, this may help elucidate the absence of an effect of KT on balance and jump performance in the present study. It has been documented that KT can elevate body temperature, thereby enhancing neuromuscular function and, subsequently, agility (27). In a single study, an enhancement in agility was documented in track and field athletes following the administration of KT (20). The results of our study on agility performance in the KT group are in accordance with the findings of previous research in this field.

In their study on the effect of KT and IASTM, Grase et al. (28) found no significant difference between the groups in terms of pain, pain pressure threshold, range of motion, and function. Gandhi et al. (29) identified a statistically significant discrepancy in maximum grip strength when comparing the IASTM and KT groups with the control group. However, no significant divergence was observed between the IASTM and KT groups. The findings of Kurt et al. (20) indicated that both IASTM and CT applications yielded favorable acute outcomes with respect to balance and agility. Furthermore, no discernible superiority was observed between the two techniques (20). The findings of our study indicate that IASTM enhances balance and agility performance, while KT has a positive impact on agility performance in track and field athletes. Our results suggest that the two interventions have comparable effects, although further research is necessary to substantiate these observations. Improvements in fascial layer slippage, increased skin temperature, and decreased collagen resistance may be observed following IASTM treatments (8). The favorable effects of IASTM on balance and agility can also be attributed to neurophysiological mechanisms, as it has been demonstrated to stimulate intra-fascial mechanoreceptors, resulting in altered proprioceptive input to the central nervous system, and a global reduction in muscle tone of the affected muscle groups (30). The beneficial impact of KT on agility can be attributed to the enhancement of functional performance through the optimization of neuromuscular and joint capabilities (8).

Study Limitations

Should our findings be corroborated by future studies, they would represent a significant contribution to the fields of athlete preparation and sports injury prevention. This is because balance, agility, and jumping are prerequisites for optimal performance and injury prevention in athletics. The observed non-significant effects may also be explained by the relatively small sample size of the study. Additionally, the

outdoor setting in which the assessments were conducted may have resulted in inconsistencies in the environmental factors (air temperature, wind, humidity, sunlight and brightness, noise, etc.) to which the participants were exposed, potentially affecting the reliability of the results. Moreover, the dynamic application of these techniques during functional movements may result in neurophysiological adaptations that enhance functional performance. Therefore, we recommend that future studies evaluate dynamic and functional applications in different sports disciplines using larger samples of athletes.

CONCLUSION

IASTM can effectively enhance balance and agility, while KT can improve the agility of track and field athletes. Nevertheless, no notable discrepancies were discerned between the two methodologies. In light of the findings presented here, it is recommended that IASTM and KT be employed as supplementary interventions in conjunction with existing training programs for athletes.

ETHICS

Ethics Committee Approval: Before commencement, ethical approval was obtained from the Üsküdar University Non-Interventional Research Ethics Committee (approval no: 2023-22, date: 31.10.2023) following the Helsinki Declaration.

Informed Consent: All participants provided written informed consent.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: D.K., Ö.Ş., Consept: D.K., Ö.Ş., Design: D.K., B.D.H., Ö.Ş., Data Collection or Processing: D.K., B.D.H., B.B., Analysis or Interpretation: D.K., B.D.H., B.B., Literature Search: D.K., B.D.H., Ö.Ş., B.B., Writing: D.K., B.D.H., B.B.

Conflict of Interest: No conflict of interest was declared by the authors.

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Research

Correlation of Urine Haptoglobin and Albumin Levels in Predicting Early Nephropathy in Individuals with Obesity

Obezitesi Olan Bireylerde Erken Nefropatiyi Öngörmede İdrar Haptoglobin ve Albümin Düzeylerinin Korelasyonu

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ABSTRACT

Objective: Urine haptoglobin, an alpha-2 sialoglycoprotein, is associated with renal failure even in the early stages. We aimed to determine the correlation between the urinary haptoglobin-to-creatinine ratio (HCR) and the albumin-to-creatinine ratio (ACR) in diabetic, prediabetic, and non-diabetic obese patients without chronic renal failure.

Methods: A total of 102 obese individuals aged ≥18 years, including diabetic patients, normoglycemic patients, and patients with impaired fasting glucose disorders, were included in this cross-sectional study. Biochemical and urine parameters, including fasting blood glucose, glycated hemoglobin, renal and liver function tests, and spot urine ACR and HCR, were analyzed.

Results: Among study participants, 17.6% (n=18) had impaired fasting glucose, 46.1% (n=47) had type 2 diabetes mellitus, and 36.3% (n=37) were normoglycemic. Urinary ACR was significantly higher and urinary HCR was significantly lower in the diabetic group compared with the other two groups. A moderate, significant positive correlation was observed between ACR and HCR in the diabetic group (r=0.454; p=0.001). Although HCR was significantly higher in non-diabetic individuals with obesity (p=0.011) compared with other groups, no significant relationship was found between ACR and HCR.

Conclusion: We determined a relationship between HCR and ACR levels in diabetic patients with obesity. As a result, evaluation of urinary haptoglobin may be useful for predicting nephropathy related to diabetes mellitus and obesity. Further large-sample prospective studies are warranted to reach more precise conclusions regarding variations in HCR in the obese population.

Keywords: Haptoglobinuria, albuminuria, renal function, obesity, type 2 diabetes

ÖZ

Amaç: Bir alfa-2 sialoglikoprotein olan haptoglobinin idrardaki düzeyi, erken evrelerde bile böbrek yetmezliği ile ilişkilidir. Biz bu çalışmada, tümü obeziteli olan diyabetik, prediyabetik ve normoglisemik hastalarda idrar haptoglobin/kreatinin oranı (HKO) düzeylerini ölçmeyi ve albümin/kreatinin oranı (AKO) ilişkisini değerlendirmeyi amaçladık.

Gereç ve Yöntem: Diyabetik, normoglisemik ve bozulmuş açlık glukozu olan 18 yaş üstü toplam 102 obeziteli hasta kesitsel çalışmaya dahil edildi. Açlık kan şekeri, glikozillenmiş hemoglobin, böbrek ve karaciğer fonksiyon testleri, spot idrar AKO ve spot idrar HKO içeren biyokimyasal ve üriner parametreler analiz edildi.

Bulgular: Katılımcılar arasında %46,1'inde (n=47) tip 2 diyabet, %36,3'ünde (n=37) normoglisemik ve %17,6'sında (n=18) bozulmuş açlık glukozu olan obeziteli hasta mevcuttu. Diyabetik grupta AKO diğer 2 gruba kıyasla anlamlı derecede yüksek, HKO anlamlı derecede düşüktü. AKO ile HKO arasında ise sadece diyabetik grupta istatistiksel olarak orta derecede anlamlı bir korelasyon gözlendi (r=0,454; p=0,001; p<0,01). Diyabetik olmayan obeziteli bireylerde HKO diğer gruplara göre anlamlı olarak yüksek olmasına rağmen (p=0,011; p<0,05), AKO ile HKO arasında anlamlı bir ilişki saptanmadı.

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ÖZ

Sonuç: Çalışmamızda obeziteli diyabetik hastalarda HKO ve AKO düzeyleri arasında istatiksel olarak anlamlı bir ilişki saptandı. Sonuç olarak idrar haptoglobin düzeyinin değerlendirilmesinin diyabet ve obeziteye bağlı nefropatiyi öngörmede faydalı olabileceğini düşünüyoruz. Obeziteli popülasyonda haptoglobin varyasyonları açısından daha kesin sonuçlara varmak için daha büyük örneklemli prospektif çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Haptoglobinüri, albüminüri, renal fonksiyon, obezite, tip 2 diyabet

INTRODUCTION

Diabetes mellitus (DM) is a significant public health problem, with its prevalence steadily rising (1). The most common cause of end-stage renal disease in developing countries is diabetic nephropathy. Early diagnosis of diabetes and management of blood pressure and glucose levels can prevent or delay its progression (2). Obesity, defined as a body mass index (BMI) of 30 kg/m^2 or higher, is among the leading metabolic risk factors for global disease burden, and its prevalence has continued to increase in recent decades (3-5). It is also a recognized risk factor for the development of chronic kidney disease (CKD) (6,7). It is associated with an increased total glomerular filtration rate (GFR) (8,9), suggesting a potential direct pathogenic relationship with kidney disease such that long-term kidney damage may ensue without intervention.

Urinary albumin-to-creatinine ratio (ACR) is a well-established marker of diabetic nephropathy. However, microalbuminuria (30-300 mg albumin/gram creatinine) is neither a specific nor a sensitive predictor of renal progression, as it does not always precede macroalbuminuria (10,11). Moreover, studies have shown that diabetic nephropathy can develop in individuals with normal albuminuria (12-14).

Haptoglobin is an acute-phase reactant which, beyond its role in hemolysis, contributes to inflammation and immune responses (15). A two- to fivefold increase in haptoglobin occurs in response to inflammatory stimuli (16). Recent studies have linked urinary haptoglobin levels to clinical outcomes in both individuals with and without type 2 DM. Elevated urinary haptoglobin has been identified as a potential predictor of kidney disease progression in patients with type 2 DM (17-19). However, the relationship between urinary haptoglobin and kidney disease in individuals with obesity without DM remains unexplored.

This study aims to evaluate the potential of haptoglobinuria as an alternative to albuminuria for predicting nephropathy by comparing urinary haptoglobin and albumin levels among individuals with diabetes and obesity, obese individuals with normal glucose levels, and individuals with impaired fasting glucose (IFG).

METHODS

A cross-sectional study was performed in the internal medicine outpatient service of our hospital between February and May 2017. Participants aged 18 years or older with a BMI >30 who volunteered were included in the study. Exclusion criteria included estrogen treatment, hepatocellular disease, nephrotic syndrome, active infection, malignancy, and CKD (GFR <60).

Recruited participants were stratified into diabetic, prediabetic, and normoglycemic groups based on their glycemic status. The participants' weight and height were measured with the assistance of the physician, and their BMI was calculated. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2) (3). Fasting blood glucose (FBG), glycated hemoglobin (HbA1c), aspartate aminotransferase (AST), alanine aminotransferase (ALT), urea, creatinine, C-reactive protein, sodium, potassium, uric acid, calcium, phosphorus, and complete blood count were collected. Spot urine samples were subjected to a complete urine examination and analyzed for creatinine, albumin, and haptoglobin levels. Blood samples were collected after an eight-hour fast and centrifuged at 4,000×g for eight minutes. The ACR and the haptoglobin-to-creatinine ratio (HCR) were calculated. "IGF was defined as FBG levels from 100 to 125 mg/dL (from 5.6 to 6.9 mmol/L)" (20). "The abbreviated MDRD equation is: GFR=186×Scr (serum kreatinine) (-1.154)×age(-0.203)×(0.742 if female)×(1.210 if African-American), where Scr is measured in mg/dL and age in years" (21). We compared the biochemical parameters, ACR, and HCR between groups and evaluated the relationship between the ACR and the HCR within groups.

The University of Health Sciences Türkiye, Bağcılar Training and Research Hospital Non-Interventional Clinical Research Ethics Committee (approval number: 2016-554, date: 27.12.2016) approved the study, and all participants gave written informed consent.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including mean, standard

deviation, median, minimum, maximum, first quartile, and third quartile, were calculated for quantitative variables. Frequency and percentage distributions were used for categorical variables. The Shapiro-Wilk test and box plots were employed to assess data normality. For comparisons among three or more groups, one-way analysis of variance was used for data that were normally distributed, followed by the Games-Howell test for pairwise comparisons.

Kruskal-Wallis test and Dunn's test were used for anomalously distributed data. Associations between categorical variables were assessed using the chi-square test. Spearman's correlation analysis was conducted to examine relationships between variables. The results were evaluated at the 95% confidence level, and statistical significance was defined as $p<0.05$.

RESULTS

A total of 102 participants were enrolled in the study, with 84.3% (n=86) being female and 15.7% (n=16) being male. The age range was 18-74 years, with a mean age of 51.66±10.36 years. BMI values ranged from 27.4 to 66.9 kg/m^2, with a mean of 36.45±5.52 kg/m^2 (Table 1). Regarding glycemic status, 17.6% (n=18) had IFG, 46.1% (n=47) had DM, and 36.3% (n=37) were normoglycemic (Figure 1).

No significant gender differences were observed (p>0.05), but age differed significantly among groups (p=0.001). Specifically, the normoglycemic group was significantly younger than both the IFG and DM groups (p=0.035 and p=0.001, respectively) (Table 2). The groups were homogeneous in terms of sex and anthropometric measurements.

Table 1. Distribution of descriptive features

		n (%)
Sex	**Female**	86 (84.3)
	Male	16 (15.7)
Age	Mean±SD	51.66±10.36
	Median (min-max)	52 (18-74)
Height	Mean±SD	158.23±8.31
	Median (min-max)	157 (140-183)
Weight	Mean±SD	90.98±14.89
	Median (min-max)	88.8 (64.4-160)
BMI	Mean±SD	36.45±5.52
	Median (min-max)	36.1 (27.4-66.9)
Groups	**IFG**	18 (17.6)
	DM	47 (46.1)
	NG	37 (36.3)

SD: Standard deviation, IFG: Impaired fasting glucose, DM: Diabetes mellitus, NG: Normoglycemic, BMI: Body mass index

HbA1c levels differed significantly among groups (p=0.001), with the DM group exhibiting higher values compared to both the IFG and normoglycemic groups (p=0.001 for both comparisons). No significant differences in urea, creatinine, GFR, AST, or ALT levels were observed among groups (p>0.05) (Table 3).

ACR levels differed significantly among groups (p=0.016); the DM group showed higher values than the normoglycemic group (p=0.013) (Table 4). HCR levels also differed significantly among groups (p=0.014), with the normoglycemic group exhibiting higher values than those in the IFG group (p=0.011) (Table 4).

No significant correlation was found between ACR and HCR in the IFG or normoglycemic groups (p>0.05). However, a positive, moderate, and significant correlation was observed between ACR and HCR in the DM group (r=0.454; p=0.001) (Table 5).

DISCUSSION

In the present study, ACR was significantly elevated in the DM group compared to the other two groups, whereas HCR was significantly lower in the DM group. A moderate correlation between ACR and HCR levels was observed in the DM group. Although the presence of DM did not increase haptoglobinuria in individuals with obesity, it was more pronounced in albuminuric diabetic patients.

Previous research has investigated the role of urinary haptoglobin in diabetic nephropathy. Bhensdadia et al. (17) identified elevated haptoglobinuria as a strong predictor of early renal functional decline among normoalbuminuric patients with type 2 DM. Yang et al. (18) proposed urinary haptoglobin as a novel biomarker, complementary to

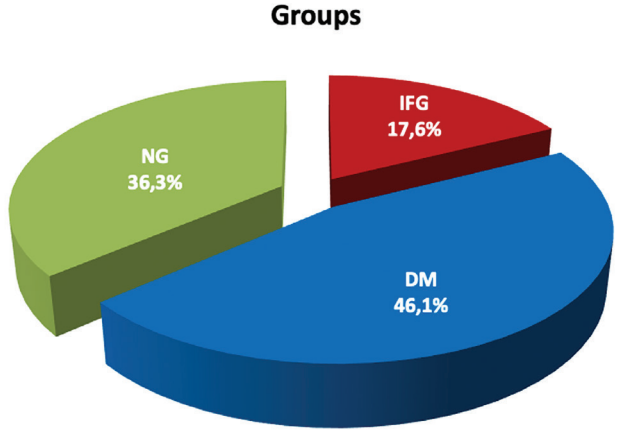

Figure 1. Distribution of the groups
NG: Normoglycemic, IFG: Impaired fasting glucose, DM: Diabetes mellitus

Table 2. Comparison of descriptive characteristics by groups

		Groups			p-value
		IFG (n=18)	DM (n=47)	NG (n=37)	
Sex	Female	16 (88.9)	38 (80.9)	32 (86.5)	[a]**0.656**
	Male	2 (11.1)	9 (19.1)	5 (13.5)	
Age	Mean±SD	53.28±8.72	55.40±8.12	46.11±11.38	[b]**0.001****
	Median (min-max)	55 (29-67)	53 (39-74)	49 (18-67)	
Height	Mean±SD	153.28±6.34	158.32±8.86	160.51±7.53	[b]**0.009****
	Median (min-max)	153 (140-162)	158 (145-183)	158 (149-177)	
Weight	Mean±SD	86.77±13.30	91.67±16.53	92.14±13.34	[b]**0.417**
	Median (min-max)	84.8 (67.3-120)	88.9 (64.4-160)	89.4 (70.8-137)	
BMI	Mean±SD	36.94±5.22	36.58±6.32	36.04±4.62	[b]**0.834**
	Median (min-max)	36.5 (30.5-48.9)	35.7 (27.4-66.9)	36 (30-52.3)	

[a]: Pearson chi-square, [b]: One-way ANOVA test and Games-Howell test, **: p<0.01, SD: Standard deviation, IFG: Impaired fasting glucose, DM: Diabetes mellitus, NG: Normoglycemics, BMI: Body mass index, ANOVA: Analysis of variance

Table 3. Comparison of biochemical parameters in blood by groups

		Total	Groups			p-value*
			IFG (n=18)	DM (n=47)	NG (n=37)	
FBG	Mean±SD	145.78±74.02	103.39±7.84	203.15±75.66	93.54±5.06	[c]**0.001****
	Median (Q1-Q3)	106 (96-168)	104.5 (101-106)	176 (137-257)	95 (92-97)	
HbA1c	Mean±SD	7.21±2.24	5.95±0.27	8.94±2.28	5.62±0.27	[c]**0.001****
	Median (Q1-Q3)	6.1 (5.8-8)	6 (5.8-6.1)	8.4 (7.2-9.7)	5.7 (5.4-5.8)	
Urea	Mean±SD	26.88±6.76	26.72±7.47	27.77±7.43	25.84±5.41	[b]**0.433**
	Median (Q1-Q3)	27 (23-31)	24.5 (22-33)	28 (22-32)	25 (23-28)	
Creatinine	Mean±SD	0.69±0.12	0.64±0.11	0.7±0.12	0.7±0.11	[b]**0.170**
	Median (Q1-Q3)	0.7 (0.6-0.8)	0.6 (0.6-0.7)	0.7 (0.6-0.8)	0.7 (0.6-0.8)	
GFR	Mean±SD	100.08±12.52	101.98±10.16	96.91±11.51	103.19±14.04	[b]**0.056**
	Median (Q1-Q3)	100.5 (91.9-108.3)	103.5 (96-108.3)	98.9 (89.6-104.2)	101.7 (94.8-113.9)	
AST	Mean±SD	21.75±12.1	22.17±18.87	23.34±12.54	19.51±5.77	[c]**0.452**
	Median (Q1-Q3)	19 (15-23)	17.5 (16-20)	19 (15-27)	19 (15-23)	
ALT	Mean±SD	23.58±16.98	23.5±26.06	26.53±16.54	19.86±10.65	[c]**0.092**
	Median (Q1-Q3)	18 (13-26)	16 (13-25)	22 (15-34)	18 (13-23)	
NA	Mean±SD	140.51±3.31	140.61±2.59	139.34±3.36	141.95±3.05	[b]**0.001****
	Median (Q1-Q3)	141 (138-143)	140.5 (139-142)	139 (137-142)	142 (140-144)	
K	Mean±SD	4.57±0.37	4.49±0.36	4.59±0.40	4.60±0.34	[b]**0.554**
	Median (Q1-Q3)	4.6 (4.3-4.8)	4.5 (4.3-4.7)	4.6 (4.3-4.9)	4.5 (4.4-4.8)	
Uric asid	Mean±SD	4.20±1.14	4.43±1.07	4.18±1.12	4.10±1.21	[b]**0.611**
	Median (Q1-Q3)	4.2 (3.3-5)	4.3 (3.5-5.1)	4 (3.3-4.8)	4.2 (3.1-5)	

[b]: One-way ANOVA test and Games-Howell test, [c]: Kruskal-Wallis test and Dunn-Bonferroni test, Q1: First quartile, Q3: Third quartile, SD: Standard deviation, IFG: Impaired fasting glucose, DM: Diabetes mellitus, NG: Normoglycemics, FBG: Fasting blood glucose, HbA1c: Glycated hemoglobin, GFR: Glomerular filtration rate, AST: Aspartate aminotransferase, ALT: Alanine aminotransferase, Na: Sodium, K: Potassium, *:p<0.05, **: p<0.01

albumin, for predicting kidney damage in patients with type 2 DM. Liu et al. (14) reported urinary haptoglobin as a predictor of renal progression and of rapid renal function decline in patients with type 2 DM. Consistent with these findings, our study demonstrated a correlation between increased haptoglobinuria and increased albuminuria in patients with diabetes. Unexpectedly, normoglycemic obese individuals exhibited higher HCR levels than those

Table 4. Comparison of biochemical parameters in urine by groups

		Total	Groups			p-value*
			IFG (n=18)	DM (n=47)	NG (n=37)	
Urine albumin (mg/L)	Mean±SD	5.12±12.19	2.32±2.55	7.70±16.45	3.21±7.20	[c]**0.032***
	Median (Q1-Q3)	1.7 (0.6-3.6)	1.5 (0.7-2.5)	2.2 (0.9-5.3)	1.1 (0.5-2.4)	
Albumin/creatinine ratio (mg/g)	Mean±SD	44.43±112.77	21.46±26.65	72.42±159.95	20.04±27.49	[c]**0.016***
	Median (Q1-Q3)	13.5 (6.3-31)	13.2 (7.8-20.2)	20 (6.9-60.4)	8.7 (4.5-24.7)	
Urine creatinine (mg/dL)	Mean±SD	86.5±70.17	68.55±45.06	95.6±82.38	83.67±62.51	[c]**0.587**
	Median (Q1-Q3)	67.8 (42.5-107.1)	58.1(30.2-92.3)	75.7 (42.8-128.8)	65.5 (43.5-93.5)	
Haptoglobin (ng/m)	Mean±SD	146.76±354.09	99.35±395.15	103.75±236.21	224.45±443.84	[c]**0.003****
	Median (Q1-Q3)	7.4 (2-37)	2.4 (0.7-6.2)	7.2 (2.3-37)	9.3 (6.7-130.9)	
Haptoglobin/creatinine ratio (ng/mg)	Mean±SD	30.02±95.34	30.84±126.12	19.05±61.96	43.56±112.88	[c]**0.014***
	Median (Q1-Q3)	1.4 (0.3-7.4)	0.3 (0.1-1.1)	1.4 (0.3-7.2)	2 (0.6-26.3)	

[b]: One-way ANOVA test and Games-Howell test, [c]: Kruskal-Wallis test and Dunn-Bonferroni test, Q1: First quartile, Q3: Third quartile, SD: Standard deviation, IFG: Impaired fasting glucose, DM: Diabetes mellitus, NG: Normoglycemic, ANOVA: Analysis of variance, *: p<0.05, **: p<0.01

Table 5. Relationship between albumin/creatinine ratio and haptoglobin/creatinine ratio in groups

Groups	ACR-HCR	
	r	p-value
IFG	-0.074	**0.769**
DM	0.454**	**0.001****
NG	0.183	**0.278**

ACR: Albumin/creatinine ratio, HCR: Haptoglobin-to-creatinine ratio, IFG: Impaired fasting glucose, DM: Diabetes mellitus, NG: Normoglycemics, **: p<0.01

in other groups, suggesting that haptoglobinuria may be a more sensitive marker of obesity-related nephropathy than albuminuria. The influence of haptoglobin genotypes, not assessed in our study, could be a contributing factor.

Obesity, independent of cardiometabolic disease, is a risk factor for renal injury (6,7,22), with glomerular hyperfiltration as a potential mechanism (9). Previous studies have linked albuminuria to obesity (23,24). Our study contributes to this body of knowledge by investigating haptoglobinuria in non-diabetic obese individuals for the first time.

Study Limitations

Small sample size and female-dominant population may limit generalizability. Haptoglobin genotypes, which influence clearance and expression, were not assessed. As well as potential confounding factors, such as smoking and medication use.

CONCLUSION

In conclusion, while urinary did not differ between diabetic and non-diabetic obese individuals, its correlation with ACR in diabetic patients warrants further investigation. Prospective studies that consider haptoglobin genotypes are necessary to elucidate the role of haptoglobinuria in obesity among individuals with and without diabetes.

ETHICS

Ethics Committee Approval: The University of Health Sciences Türkiye, Bağcılar Training and Research Hospital Non-Interventional Clinical Research Ethics Committee (approval number: 2016-554, date: 27.12.2016) approved the study.

Informed Consent: All participants gave written informed consent.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: M.G.A., A.Y., A.E.A., S.H.K., N.G., Concept: M.G.A., A.Y., A.E.A., S.H.K., N.G., Design: M.G.A., A.Y., A.E.A., S.H.K., N.G., Data Collection or Processing: M.G.A., A.Y., A.E.A., S.H.K., N.G., Analysis or Interpretation: M.G.A., A.Y., A.E.A., S.H.K., N.G., Literature Search: M.G.A., A.Y., A.E.A., S.H.K., N.G., Writing: M.G.A., A.Y., A.E.A., S.H.K., N.G.

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Research

Comparison of Neuromuscular Electrical Stimulation and Traditional Electrotherapy as Adjuncts to Standard Physiotherapy in Chronic Low Back Pain: A Randomized Controlled Trial

Kronik Bel Ağrısında Standart Fizyoterapiye Eklenen Nöromüsküler Elektriksel Stimülasyon ve Geleneksel Elektroterapinin Karşılaştırılması: Rastgele Kontrollü Bir Çalışma

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ABSTRACT

Objective: This study aimed to compare the effects of adding neuromuscular electrical stimulation (NMES) versus traditional electrotherapy, to standard physiotherapy on pain, function, sleep, and quality of life in patients with chronic low back pain (CLBP).

Methods: This prospective, two-arm randomized controlled trial included 30 adults with CLBP, assigned to receive either NMES or traditional electrotherapy alongside standardized physiotherapy (3 sessions/week for 12 weeks). Outcomes measured included pain (visual analogue scale), muscle strength (Medical Research Council Scale), hamstring length (active knee extension test), sleep quality (Pittsburgh Sleep Quality Index), and quality of life (World Health Organization Quality of Life-Short Form).

Results: Both groups demonstrated significant improvements in all outcomes following the intervention ($p<0.05$). However, the NMES group showed greater pain reduction compared to the traditional electrotherapy group ($p=0.009$, effect size $d=-1.03$). No significant between-group differences were observed for muscle strength, hamstring length, sleep quality, or quality of life.

Conclusion: NMES added to physiotherapy offers better pain relief and improves function, sleep, and quality of life in CLBP. It may be preferred for pain management, but further studies are needed to confirm this.

Keywords: Chronic low back pain, electrotherapy, neuromuscular electrical stimulation, pain management, physical therapy

ÖZ

Amaç: Bu çalışmanın amacı, kronik bel ağrısı hastalarında standart fizyoterapiye nöromüsküler elektriksel stimülasyon (NMES) ile geleneksel elektroterapinin eklenmesinin ağrı, fonksiyon, uyku ve yaşam kalitesi üzerindeki etkilerini karşılaştırmaktır.

Gereç ve Yöntem: Bu prospektif, iki kollu randomize kontrollü çalışmaya, kronik bel ağrısı olan ve standart fizyoterapinin yanı sıra (12 hafta boyunca haftada 3 seans) NMES veya geleneksel elektroterapi alan 30 yetişkin dahil edilmiştir. Ölçülen sonuçlar arasında ağrı (Görsel Analog Ölçeği), kas gücü (Tıbbi Araştırma Konseyi ölçeği), hamstring uzunluğu (aktif diz ekstansiyon testi), uyku kalitesi (Pittsburgh Uyku Kalitesi İndeksi) ve yaşam kalitesi (Dünya Sağlık Örgütü Yaşam Kalitesi-Kısa Form) yer almıştır.

Bulgular: Her iki grup da müdahalenin ardından tüm sonuçlarda anlamlı iyileşmeler göstermiştir ($p<0,05$). Ancak, NMES grubu geleneksel elektroterapi grubuna kıyasla daha fazla ağrı azalması göstermiştir ($p=0,009$, etki büyüklüğü $d=-1,03$). Kas gücü, hamstring uzunluğu, uyku kalitesi veya yaşam kalitesi açısından gruplar arasında anlamlı bir fark gözlenmemiştir.

Sonuç: Fizyoterapiye eklenen NMES, kronik bel ağrısında daha iyi ağrı kesici etki sağlar ve fonksiyon, uyku ve yaşam kalitesini iyileştirir. Ağrı yönetimi için tercih edilebilir, ancak bunu doğrulamak için daha fazla çalışmaya ihtiyaç vardır.

Anahtar Kelimeler: Kronik bel ağrısı, elektroterapi, nöromüsküler elektriksel stimülasyon, ağrı yönetimi, fizik tedavi

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INTRODUCTION

Individuals living with chronic low back pain (CLBP) frequently report challenges in performing daily activities, maintaining employment, and sustaining social participation, underscoring the multifactorial burden of this condition (1,2).

Current clinical guidelines emphasize structured exercise as the cornerstone of conservative management for CLBP, based on its benefits for physical function and pain modulation (3). Conventional physiotherapy approaches are commonly used to support symptom relief (4). However, evidence suggests that these interventions alone may provide only moderate improvements, particularly in individuals with persistent or recurrent symptoms (3,5).

Given the heterogeneous nature of CLBP and its recurrence rates, enhancing rehabilitation outcomes remains an important clinical goal (2). Accordingly, integrating adjunctive or technology-assisted approaches into physiotherapy programs has gained increasing clinical and scientific interest (6).

Neuromuscular electrical stimulation (NMES), a modality delivering medium-frequency electrical impulses to activate the deep paraspinal musculature, has emerged as a potential adjunct in rehabilitation protocols for CLBP (6). Preliminary studies indicate that NMES may facilitate deeper muscle engagement and enhanced pain modulation, potentially offering additional benefits when combined with traditional therapy (7,8). Despite these promising findings, high-quality comparative trials evaluating NMES alongside established electrotherapy techniques remain limited.

In this context, the present study aims to evaluate the therapeutic efficacy of adjunctive NMES delivered via the StimaWELL® BackUP system compared to traditional electrotherapy modalities, when both are incorporated into a standardized physiotherapy program for individuals with CLBP.

METHODS

Study Design and Ethics

This study was a randomized controlled clinical trial comparing two active electrotherapy modalities—adjunctive NMES and conventional electrotherapy—within a standardized physiotherapy program for individuals with CLBP. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and received approval from the Üsküdar University Non-Interventional Research Ethics Committee (approval no: 2023/73, date: 30.01.2023). The studies were conducted with institutional consent. The clinical trial was registered on clinicaltrials.gov on 17 August 2023 with the trial number NCT06006377.

Participants

Adults aged 20 to 60 years with non-specific CLBP (pain persisting for longer than 12 weeks without identifiable structural or neuropathic origin) were recruited. Pain was localized to the thoracolumbar region (T12-L5/S1) in accordance with established classification criteria (8,9). Individuals were excluded if they had received physical therapy within the previous month, presented with neurological symptoms or structural spinal abnormalities (e.g., scoliosis >10°, spinal stenosis), had undergone spinal surgery, had systemic diseases, were pregnant, used cardiac pacemakers or metallic implants, or had a body mass index (BMI) over 30.

Participants were screened and enrolled based on these criteria prior to randomization (Figure 1).

Randomization and Blinding

Eligible individuals were randomly assigned (1:1) to the NMES group [backup device group (BT-G)] or the conventional electrotherapy group (ET-G) using a computer-generated allocation sequence (www.random.org). The randomization sequence was prepared by an independent researcher not involved in the intervention or outcome assessment. Allocation concealment was maintained using sealed opaque envelopes. While participants and treating physiotherapists could not be blinded due to the nature of the interventions, outcome assessors were not informed of group assignments during post-intervention evaluations.

Sample Size and Power Analysis

The number of participants was determined using the G*Power 3.1 program (Heinrich Heine University, Düsseldorf, Germany). Based on prior clinical trials involving NMES in CLBP, a minimal clinically important difference (MCID) of 13 mm on the visual analogue scale (VAS) for pain intensity was used, with an assumed standard deviation of 15 mm (10). Using an alpha level of 0.05 and a power of 80%, a minimum sample size of 26 individuals was required. To accommodate potential dropouts (estimated at 15%), the final sample size was determined as 30 individuals (15 per group) (9).

Intervention

All participants received a standardized physiotherapy protocol consisting of manual therapy and supervised exercise. The program aimed to reduce pain, enhance spinal mobility, and improve postural control. Each session

lasted approximately 30 minutes and was delivered 3 times per week for 12 weeks by licensed physiotherapists with at least five years of clinical experience.

Electrotherapy group: Participants assigned to the ET-G received supplementary traditional electrotherapy interventions as part of their treatment protocol. These treatments include hot pack, transcutaneous electrical nerve stimulation (TENS), and ultrasound technology. The cumulative duration of these adjunctive electrotherapy modalities in the ET-G group was approximately 30 minutes per treatment session.

Backup device group: Participants in this group received adjunctive therapy using the StimaWELL® BackUP system (Hako Medical, Germany). This intervention comprised NMES delivered at a medium frequency of approximately 3 kHz, administered via segmental paraspinal electrode placement specifically targeting the thoracolumbar musculature. Additionally, local heat therapy was provided through the device's integrated thermal module, maintaining a stable surface temperature of up to 40°C throughout the application. Each StimaWELL® BackUP therapy session (Hako Medical, Germany) had a total duration of approximately 30 minutes.

Outcome Measures

Medical Research Council (MRC) Scale: Muscle strength was evaluated using the MRC scale, focusing specifically on the erector spinae muscles. Participants were evaluated in a prone position with resistance applied manually by a trained physiotherapist. Muscle strength was rated on a 6-point ordinal scale ranging from 0 (no contraction) to 5 (normal strength) (9).

Pittsburgh Sleep Quality Index (PSQI): The PSQI is a 19-item self-reported measure assessing sleep quality over the past month across seven components: latency, duration, disturbances, and daytime dysfunction. Global scores range from 0 to 21, with scores above 5 indicating poor sleep quality (11). The PSQI has demonstrated robust reliability and internal consistency in various populations (12).

World Health Organization Quality of Life-Short Form (WHOQOL-BREF): It is a 27-item quality of life scale encompassing general health, physical health, psychological health, social relationships, and the environment. The Turkish adaptation includes one additional national item, validated by Eser et al. (13), to capture sociocultural aspects specific to Türkiye. Domain scores were calculated according to WHO guidelines, with higher scores indicating better perceived quality of life (13,14).

Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics software (IBM Corp., Armonk, NY, USA). For inter-group comparisons, normally distributed variables were analyzed using the independent samples t-test, while non-normally distributed variables were analyzed using the Mann-Whitney U test. Intra-group (pre–post) comparisons were performed using the paired samples t-test or the Wilcoxon signed-rank test, as appropriate. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 40 individuals were screened for eligibility. Of these, 10 were not enrolled in the study: six did not meet the inclusion criteria (two had received physiotherapy within the previous three months, three presented with neurological symptoms, and one had a BMI greater than 30), while four declined participation due to time constraints or personal preferences. Ultimately, 30 individuals were randomized equally into the NMES group (BT-G) and the conventional ET-G. No participants withdrew or were lost to follow-up during the study period (Figure 1).

Baseline demographic and clinical characteristics of the two groups are presented in Table 1. No statistically significant differences were found between the groups in terms of age ($p=0.74$), BMI ($p=0.42$), gender distribution ($p=1.00$), educational level ($p=0.32$), or years of work experience ($p=0.29$).

Within-group Comparisons

Both groups demonstrated statistically significant improvements in all evaluated outcomes following the intervention ($p<0.05$ for all measures; Table 2). Pain intensity, measured by the VAS, showed a mean reduction of 61.2 mm in the BT-G, while the ET-G demonstrated a reduction of 46.0 mm. Both groups exceeded the established MCID threshold of 13 mm. The corresponding effect sizes indicated a large treatment effect for both groups (BT-G: $d=3.30$; ET-G: $d=2.70$).

Muscle strength, as measured by the MRC scale for the erector spinae muscles, demonstrated a statistically significant improvement in both groups (BT-G: $p<0.001$, $d=1.55$; ET-G: $p<0.001$, $d=1.39$). Hamstring muscle length scores improved significantly as well (BT-G: $p<0.001$, $d=2.12$; ET-G: $p=0.002$, $d=1.64$).

PSQI scores demonstrated significant reductions in both groups, corresponding to very large effect sizes (BT-G: $p<0.001$, $d=4.95$; ET-G: $p<0.001$, $d=2.88$), indicating improved sleep quality. Lastly, quality of life, assessed

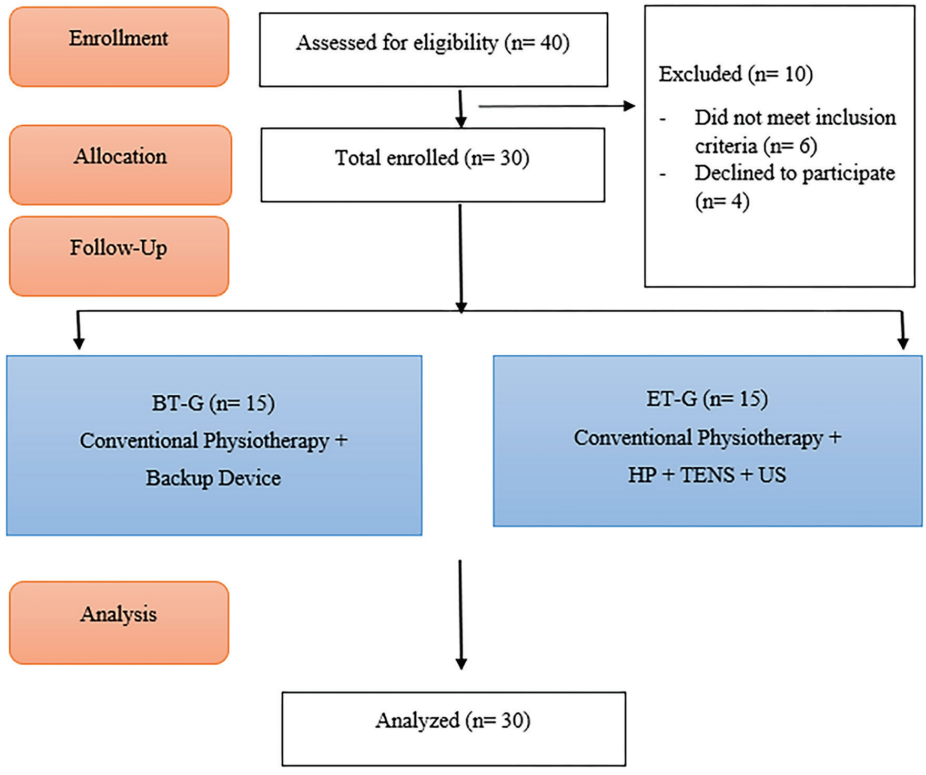

Figure 1. Flow chart of the study,
BT-G: Backup device group, ET-G: Electrotherapy group, US: Ultrasound therapy, HP: Hot pack, TENS: Transcutaneous electrical nerve stimulation

Table 1. Baseline demographic characteristics of the study groups

Variable	BT-G (n=15)	ET-G (n=15)	p-value
Age (years)	41.9±11.1	43.9±21.6	0.74
BMI (kg/m²)	23.5±3.3	24.7±4.6	0.42
Work experience (years)	18.3±7.9	22.1±11.4	0.29
Gender (male/female)	8 (53.3%)/7 (46.7%)	6 (40.0%)/9 (60.0%)	1.00
Education level (primary school/high school/ university)	2 (13.3%)/1 (6.7%)/12 (80.0%)	0 (0.0%)/4 (26.7%)/11 (73.3%)	0.32

BMI: Body mass index, BT-G: Backup device group, ET-G: Electrotherapy group

by the WHOQOL-BREF general health domain, showed statistically significant improvements in both groups, with large effect sizes reported (BT-G: $p<0.001$, $d=1.46$; ET-G: $p<0.001$, $d=1.03$).

Between-group Comparisons

Between-group analyses revealed a statistically significant difference in pain intensity change scores (VAS) in favor of the BT-G ($p=0.009$), with a large effect size ($d=-1.03$), indicating a greater reduction in pain compared to the ET-G.

No statistically significant differences were observed between groups for the remaining outcome measures. Specifically, changes in erector spinae muscle strength ($p=0.707$, $d=0.11$) and hamstring muscle length ($p=0.462$, $d=0.26$) demonstrated small effect sizes. Similarly, improvements in sleep quality, as assessed by the PSQI, did not significantly differ between groups ($p=0.155$), though the effect size suggested a moderate effect ($d=-0.56$). Lastly, between-group differences in quality of life, measured by the WHOQOL-BREF general health domain, were not statistically significant ($p=0.451$) and associated with a small effect size ($d=0.29$). Detailed between-group comparisons of change scores and effect sizes are presented in Table 3.

Table 2. Within-group comparisons of pre- and post-intervention outcomes with effect sizes

Measure	Group	Pre (Mean±SD)	Post (Mean±SD)	p-value	Effect size
VAS (mm)	**BT-G**	80.0±15.6	18.8±13.2	**<0.001**	3.30
	ET-G	69.3±17.1	23.3±16.8	**<0.001**	2.70
Erector spinae strength (MRC)	**BT-G**	4.13±0.83	4.93±0.25	**<0.001**	1.55
	ET-G	4.13±0.99	4.87±0.35	**<0.001**	1.39
Hamstring length	**BT-G**	135.0±7.0	145.5±6.0	**<0.001**	2.12
	ET-G	137.0±9.0	146.5±5.0	**0.002**	1.64
PSQI	**BT-G**	14.60±2.91	3.13±1.25	**<0.001**	4.95
	ET-G	13.80±3.73	4.60±2.63	**<0.001**	2.88
WHOQOL-BREF					
General health and quality of life	**BT-G**	42.33±23.26	68.87±15.41	**<0.001**	1.46
	ET-G	47.93±27.40	69.80±14.41	**<0.001**	1.03

VAS: Visual analogue scale, MRC: Medical Research Council, PSQI: Pittsburgh Sleep Quality Index, WHOQOL-BREF: World Health Organization Quality of Life-BREF, BT-G: Backup device group, ET-G: Electrotherapy group, SD: Standard deviation

Table 3. Between-group comparisons of change scores (Δ) and effect sizes

Measure	Δ BT-G (Mean±SD)	Δ ET-G (Mean±SD)	p-value	Effect size
VAS (mm)	-62.0±14.7	-46.0±16.4	0.009	-1.03
Erector spinae strength (MRC)	0.80±0.56	0.73±0.70	0.707	0.11
Hamstring length	10.5±5.5	9.5±6.0	0.462	0.26
PSQI	-11.47±3.48	-9.20±4.59	0.155	-0.56
WHOQOL-BREF				
General health and quality of life	26.53±15.34	21.87±16.68	0.451	0.29

VAS: Visual analogue scale, MRC: Medical Research Council Scale, PSQI: Pittsburgh Sleep Quality Index, WHOQOL-BREF: World Health Organization Quality of Life-BREF, BT-G: Backup device group, ET-G: Electrotherapy group, SD: Standard deviation

DISCUSSION

The present study aimed to compare the therapeutic efficacy of adjunctive NMES with the StimaWELL® BackUP spinal health device (BT-G) and traditional electrotherapy modalities (ET-G) in individuals with CLBP when both were integrated into a standardized physical therapy regimen. The findings revealed that while both interventions significantly improved pain intensity, muscle strength, hamstring flexibility, sleep quality, and overall quality of life, the BT-G demonstrated a greater reduction in pain intensity, indicating potential benefits of this modality in pain management.

The observed improvement in pain intensity in both groups aligns with findings from previous studies demonstrating the effectiveness of physiotherapy-based interventions in CLBP populations (15,16). Clinically significant analgesic outcomes, represented by larger effect sizes in the BT-G (d=3.30) versus the ET-G (d=2.70), highlight the effectiveness of NMES, consistent with previous studies reporting enhanced pain management through deeper muscle fiber recruitment and prolonged neuromodulatory effects (17). Fortin et al. (18) documented improvements in multifidus muscle function through NMES, suggesting potential mechanistic benefits of deep muscle activation. These mechanisms may contribute to more effective pain relief in individuals with chronic, non-specific low back pain. However, it is important to note that these findings represent preliminary evidence, given the modest sample size, and should be interpreted cautiously.

While traditional modalities (e.g., TENS, ultrasound, hot packs) achieved clinically meaningful (MCID) improvements, their effects were comparatively modest. TENS primarily reduces pain through gate control mechanisms and opioid receptor activation (19). Nonetheless, its effectiveness may diminish in chronic pain conditions characterized by central sensitization (20), suggesting the potential benefit of alternative neuromodulatory approaches such as NMES in such cases.

Both intervention groups exhibited significant improvements in erector spinae muscle strength and hamstring flexibility, with no statistically significant differences between groups.

This convergence in functional outcomes may reflect the shared benefits of supervised exercise therapy, which is a cornerstone of CLBP rehabilitation (3). While NMES exerts its effects through direct muscle activation (21,22), traditional modalities such as TENS and ultrasound contribute to motor learning, reduction of muscle guarding, and local tissue healing (5,23). These complementary mechanisms could explain the similar functional gains observed. Therefore, clinicians should consider patient-specific factors, including tolerance, accessibility, and clinical presentation, when selecting appropriate therapeutic modalities for rehabilitation programs aimed at biomechanical optimization.

Additionally, both groups demonstrated meaningful improvements in sleep quality and quality of life. Given the well-established bidirectional relationship between chronic pain and sleep disturbances, these improvements are likely secondary to effective pain management and enhanced physical function (24,25). Indeed, previous research confirms that physical therapy interventions can significantly enhance sleep quality by alleviating nocturnal pain and inflammation-induced disturbances (26). This underscores the importance of holistic rehabilitation strategies that address multiple dimensions of patient well-being.

Importantly, the observed improvements across groups also reflect the fundamental role of physiotherapist-supervised exercise programs in managing CLBP. Regular, structured exercise has been consistently shown to reduce pain, improve functional capacity, and enhance quality of life in this population (3). Therefore, while adjunctive modalities like NMES may offer additional benefits, the core component of effective rehabilitation remains the exercise intervention itself.

From a clinical perspective, NMES may be particularly beneficial for patients with pronounced central sensitization, neuromuscular inhibition, or limited tolerance to voluntary exercise due to pain. Conversely, traditional electrotherapy modalities might remain appropriate for managing superficial or acute pain presentations. Device selection should thus be individualized, considering patient-specific factors such as symptom profile, accessibility, and treatment goals.

The generalizability of these findings is limited by the inclusion of relatively young and non-obese participants (BMI≤30). It remains uncertain how these results translate to older populations, individuals with obesity, or those with comorbid chronic pain syndromes. Particularly, populations with pronounced multifidus atrophy might demonstrate enhanced responsiveness to NMES interventions. Clinically, NMES could be preferable in patients exhibiting prominent central sensitization, muscular inhibition, or limited response to prolonged manual therapies. Conversely, traditional modalities like TENS may be more practical and cost-effective in acute exacerbations or superficial pain scenarios.The reliance on subjective assessment tools (MRC scale, self-reported questionnaires) could limit sensitivity in detecting nuanced intergroup differences. Future studies should incorporate objective measurement techniques, such as isokinetic dynamometry or imaging modalities (magnetic resonance imaging ultrasound elastography), to provide more precise insights into muscular adaptations.

Finally, the study's modest sample size, lack of participant blinding, and absence of objective muscular assessments represent additional limitations. Future research should focus on multicenter randomized controlled trials with larger, diverse cohorts, objective muscular assessments, and extended follow-up periods to better evaluate long-term effectiveness and sustainability. Exploring combined NMES and advanced exercise interventions may further clarify potential additive benefits, informing more comprehensive and individualized rehabilitation strategies for CLBP.

CONCLUSION

The present study demonstrates that incorporating adjunctive NMES using the StimaWELL® BackUP device into conventional physiotherapy protocols provides superior analgesic effects compared to traditional electrotherapy modalities in patients with CLBP. While both treatment modalities equally improved muscle strength, hamstring flexibility, sleep quality, and overall quality of life, NMES may offer distinct clinical advantages for patients primarily seeking significant pain relief. Future research with larger participant samples, longer intervention durations, and incorporation of objective measurement tools is essential to further validate these results and refine individualized treatment protocols.

ETHICS

Ethics Committee Approval: Received approval from the Üsküdar University Non-Interventional Research Ethics Committee (approval no: 2023/73, date: 30.01.2023).

Informed Consent: The clinical trial was registered on clinicaltrials.gov on 17 August 2023 with the trial number NCT06006377.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: E.E.B., B.B., Consept: E.E.B., B.B., Design: E.E.B., A.Ö., B.B., Data Collection or Processing: E.E.B., A.Ö., Ö.Ş., Analysis or Interpretation: E.E.B., A.Ö., Ö.Ş., Literature Search: E.E.B., A.Ö., Ö.Ş., Writing: E.E.B., A.Ö., Ö.Ş.

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Research

Bone Health Following Pelvic Radiotherapy: Incidence of Pelvic Insufficiency Fractures and Evaluation of Prognostic Factors

Pelvik Radyoterapi Sonrası Kemik Sağlığı: Pelvik Yetmezlik Fraktürlerinin Sıklığı ve Prognostik Faktörlerin Analizi

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ABSTRACT

Objective: Pelvic radiotherapy (RT) can reduce bone strength, leading to pelvic insufficiency fractures (PIFs). This study evaluates the incidence of PIFs and associated risk factors among patients undergoing pelvic RT.

Methods: The study included cervical and endometrial cancer patients without pre-existing PIFs who received 3D-conformal RT (45-50.4 Gy). Trabecular bone Hounsfield unit (HU) values in the 4th lumbar vertebra and sacrum were measured on planning computed tomography (CT) scans using a 1-cm region of interest. The diagnosis of PIF was confirmed on follow-up magnetic resonance imaging evaluated by experienced radiologists. Statistical analyses were performed using IBM SPSS Statistics® 25, including the Mann-Whitney U test, multivariate logistic regression, and receiver operating characteristic (ROC) analysis ($p<0.05$).

Results: A total of 128 patients (69 with cervical cancer and 59 with endometrial cancer) were included; the median age was 68 years. The PIF incidence was 35.2% (n=45), with a median time to diagnosis of 19 months. Most PIFs (76.2%) occurred in the sacrum. Pain was present in 53.3% of cases; symptomatic patients received one or more of the following: non-steroidal anti-inflammatory drugs, vitamin E, pentoxifylline, or vertebroplasty. PIFs were significantly associated with low sacral HU ($p=0.012$), cervical cancer diagnosis ($p=0.033$), and concurrent chemotherapy ($p=0.023$). ROC analysis identified a sacral HU cut-off of ≤-8 ($p=0.011$; area under the curve=0.634). In multivariate logistic regression, sacral HU (≤-8) was the only independent risk factor for PIF (odds ratio: 3.04; 95% confidence interval: 1.36-6.83; $p=0.007$).

Conclusion: A simple bone mineral density assessment method can predict PIF risk. In patients receiving pelvic RT, a diagnosis of cervical cancer, concurrent chemotherapy, and low sacral HU values increase the risk of fracture. Early identification of high-risk patients and timely preventive measures may improve clinical outcomes.

Keywords: Pelvic insufficiency fractures, radiotherapy, bone mineral density, Hounsfield unit, osteoporosis

ÖZ

Amaç: Pelvik radyoterapi (RT), kemik dayanıklılığını azaltarak pelvik yetmezlik fraktürlerine (PIF) yol açabilir. Bu çalışmada, pelvik RT uygulanan hastalarda PIF sıklığı ve ilişkili risk faktörleri değerlendirilmiştir.

Gereç ve Yöntem: Çalışmaya, tedavi öncesi PIF olmayan, 3D-konformal RT (45-50,4 Gy) almış serviks ve endometrium kanserli hastalar dahil edilmiştir. Planlama bilgisayarlı tomografilerinde 4. lomber vertebra ve sakrum bölgesinin trabeküler kemik Hounsfield ünitesi (HU) değerleri 1 cm çapında ilgi bölgesi kullanılarak ölçülmüştür. Yetmezlik fraktürü tanısı, takip manyetik rezonans görüntülemeleri ile deneyimli radyologlar tarafından konulmuştur. İstatistiksel analizler IBM SPSS Statistics® 25 kullanılarak Mann-Whitney U testi, çok değişkenli lojistik regresyon ve alıcı işlem karakteristiği eğrisi (ROC) analizi ile yapılmıştır ($p<0,05$).

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ÖZ

Bulgular: Toplam 128 hasta (69 serviks kanseri, 59 endometrium kanseri) dahil edilmiş olup medyan yaş 68'dir. PIF insidansı %35,2 (n=45) olup medyan tanı süresi 19 aydır. PIF'lerin %76,2'si sakrumda görülmüştür. Hastaların %53,3'ünde ağrı mevcut olup, semptomatik hastalara non-steroid anti-enflamatuvar ilaçlar, E vitamini, pentoksifilin veya vertebroplasti uygulanmıştır. PIF gelişimi, düşük sakrum HU (p=0,012), serviks kanseri tanısı (p=0,033) ve eş zamanlı kemoterapi (p=0,023) ile anlamlı ilişkili bulunmuştur. ROC analizinde, sakrum HU için cut-off ≤-8 olarak belirlenmiştir (p=0,011, eğri altındaki alan=0,634). Çok değişkenli lojistik regresyonda, sakrum HU (≤-8) PIF için tek bağımsız risk faktörü olarak bulunmuştur (olasılık oranı: 3,04; %95 güven aralığı: 1,36-6,83; p=0,007).

Sonuç: Basit bir kemik mineral yoğunluğu değerlendirme yöntemiyle PIF riski öngörülebilir. Pelvik RT alan hastalarda serviks kanseri tanısı, eş zamanlı kemoterapi ve düşük sakrum HU değerleri fraktür riskini artırmaktadır. Yüksek riskli hastaların erken tespiti ve zamanında önlem alınması, klinik sürece katkı sağlayabilir.

Anahtar Kelimeler: Pelvik yetmezlik fraktürleri, radyoterapi, kemik mineral yoğunluğu, Hounsfield ünitesi, risk faktörleri

INTRODUCTION

Radiotherapy (RT) is essential for gynecological cancers, playing a key role in tumor control and organ preservation. However, the impact of pelvic RT on bone health and the associated risk of RT-induced bone damage remain underexplored. Pelvic insufficiency fractures (PIFs) are a common complication of pelvic RT, occurring in one in five patients (1).

Radiation-induced bone damage primarily results from the cytotoxic effects of ionizing radiation on osteoblasts and osteoclasts and from vascular injury in irradiated areas (2,3). These changes lead to a decrease in bone mineral density (BMD) and formation of weakened areas within the bone matrix, significantly increasing fracture risk, even with minimal trauma or during routine activities. The incidence of PIFs reported in the literature varies widely, from 9.7% to 89% (1,4-8). Moreover, recent series report higher detection rates than in the past, likely due to stricter follow-up and increased use of imaging techniques (6). Despite advancements in RT techniques that minimize radiation exposure to healthy tissues, such as intensity-modulated RT (IMRT) and volumetric-modulated arc therapy, the incidence of PIFs remains high, particularly in post-menopausal women and patients with predisposing risk factors such as low body mass index (BMI) or osteoporosis (9-11). Furthermore, systemic therapies, particularly chemotherapy administered concurrently with RT, can exacerbate bone weakening, further increasing fracture risk. Additionally, differentiating PIFs from metastatic bone lesions is crucial for proper treatment planning and management. Therefore, a multidisciplinary approach is essential to develop preventive strategies for PIFs.

This study aims to determine the frequency of PIFs in patients with endometrial and cervical cancer who have undergone pelvic RT, to investigate the relationship between CT-derived Hounsfield unit (HU) values and PIF occurrence, and to examine the prognostic factors influencing this condition.

METHODS

Patient Selection

Our study included patients who were diagnosed at our center between 2020 and 2024 and underwent pelvic RT and intracavitary high-dose-rate brachytherapy for cervical or endometrial cancer. Eligible patients had no history of PIF prior to treatment, had an Eastern Cooperative Oncology Group performance status of 0 or 1, were aged 18 years or older, and had a minimum follow-up of four months. Patients with a prior cancer diagnosis or a history of RT were excluded from the study. Ethical approval was obtained from the University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital Clinical Research Ethics Committee (approval no: 2023-24-33, date: 18.12.2023). Written informed consent was obtained and was available in the patient files.

Staging and Treatment Planning

Staging and treatment decisions were established through multidisciplinary tumor board discussions. Patients were staged using contrast-enhanced pelvic magnetic resonance imaging (MRI), thoraco-abdominal computed tomography, and positron emission tomography-computed tomography (PET-CT) when necessary. Diagnosis was based on tumor biopsy, with lymph node biopsy and final pathology performed when indicated. Staging was performed according to the 8th edition (2018) of the American Joint Committee on Cancer TNM staging system (12).

Patients were immobilized supine, with arms raised, on a lung board with knee support, and with a full bladder. Contrast-enhanced CT scans were obtained from the carina to the upper femur at 3 mm slices. The images were transferred to the Monaco 5.11 treatment planning system (TPS; Elekta AB PUBL, Stockholm, Sweden). The clinical target volume (CTV), the planned target volume (PTV), and the organs at risk (OARs)—rectum, sigmoid colon, femoral heads, bowel, bladder, and kidneys—were contoured by a radiation oncologist. All patients underwent three-dimensional

conformal RT (3D-CRT). Total prescribed doses were 45-50.4 Gy (1.8-2 Gy per fraction per day) for PTV-pelvis, and 54-56 Gy (1.8 Gy per fraction per day) for metastatic lymph node PTV, delivered 6- and 18-MV-X beams. QUANTEC dose constraints were used for OAR dose tolerances (13). Plans required 95% of the PTV to be covered by the prescribed dose, with <2 cc receiving >107% of the isodose. Intracavitary brachytherapy planning was performed using CT imaging and the Gamma Med Plus iX® v 15.1 TPS (Varian Medical Systems) prior to each fraction. The treatment aimed to deliver 90% of the prescription dose to at least 90% of the high-risk CTV (HR-CTV). The OAR limits were 70 Gy for the rectum and sigmoid colon and 90 Gy for the bladder (14).

Bone Density Measurement

Bone density was measured on CT simulation images. A 1 cm region of interest (ROI) was defined to measure the mean trabecular bone density of the 4th lumbar (L4) vertebra in HU (15). Additionally, two 1 cm ROIs were placed in the trabecular bone of the right and left sacrum (Figures 1 and 2). Bone density values below 100 HU were classified as indicating osteoporosis (16-18).

Follow-up and Detection of Pelvic Insufficiency Fracture

The patients were followed with MRI and/or PET-CT scans every 3 months during the first 2 years, every 6 months until year 5, and annually thereafter. Insufficiency fractures, evaluated on follow-up MRI by experienced radiologists, were characterized by low-signal (hypointense) changes on time T1-weighted images and high-signal (hyperintense) changes with surrounding edema on T2-weighted images.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics® version 25 (IBM Corp, Armonk, NY, USA). The distributions of the variables were assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Patient characteristics were summarized using descriptive statistics. The chi-square test was used to compare qualitative variables and to evaluate the factors influencing PIFs. The Mann-Whitney U test was applied to compare quantitative variables between groups defined by a two-category qualitative variable. The effectiveness of HU values as cut-off points for insufficiency fractures was analyzed using receiver operating characteristic (ROC) analysis. Multivariate logistic regression analysis was performed. A p-value <0.05 was considered statistically significant.

RESULTS

The study included 128 patients, of whom 69 had cervical cancer and 59 had endometrial cancer. The median age was 68 years (range: 36-85 years). Post-menopausal women comprised 77.3% (n=99) of the cohort, while premenopausal women comprised 22.7% (n=29). The median BMI was 29.1

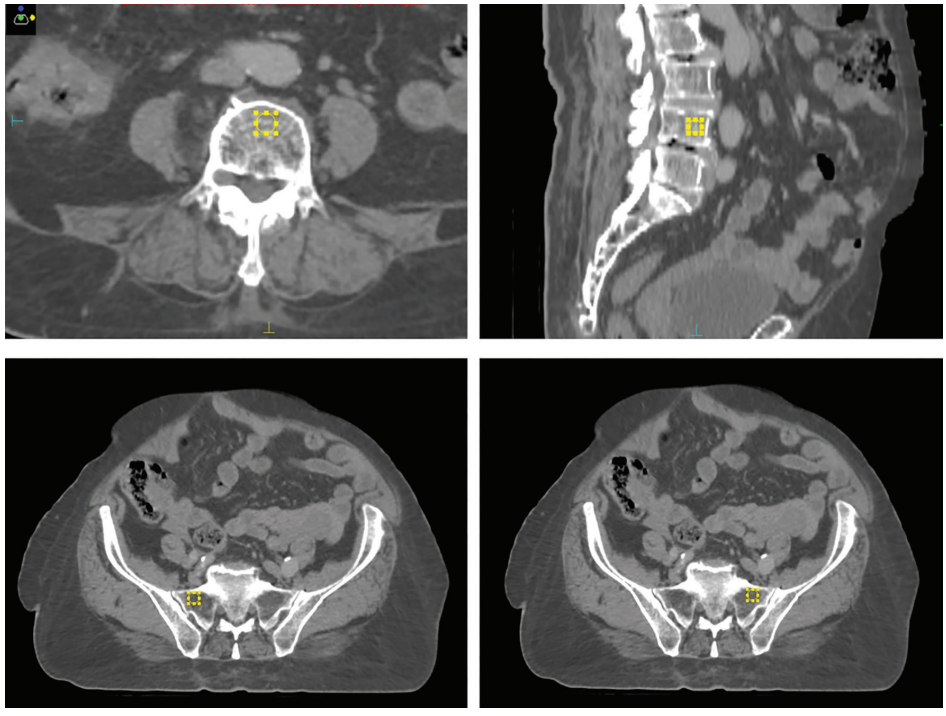

Figure 1. Measurement of bone density in Hounsfield units over bilateral sacral ala and L4 trabecular bone
L4: 4th lumbar vertebra

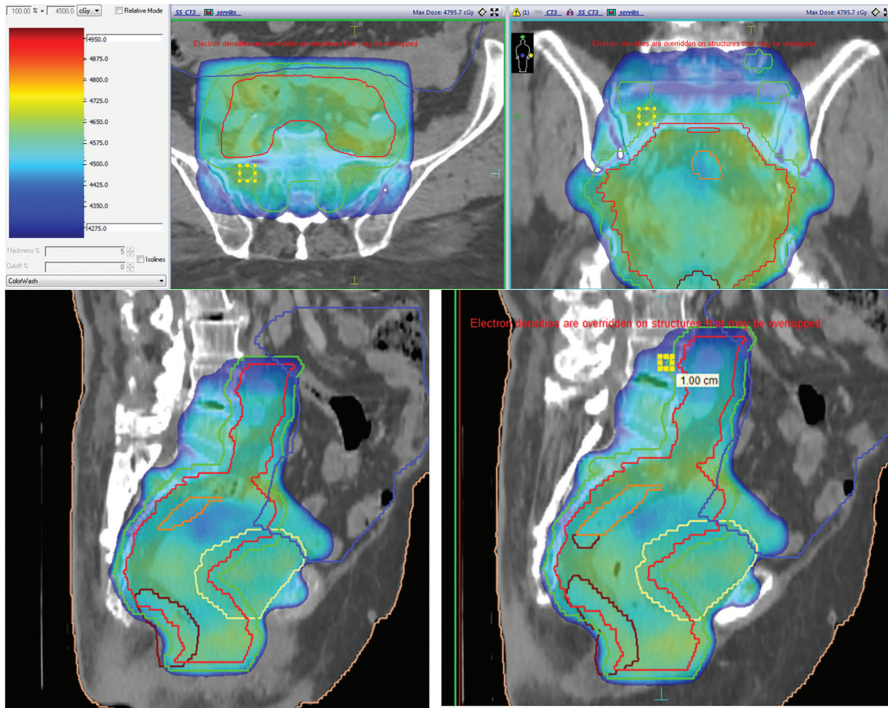

Figure 2. Radiotherapy plan views and ROI's for BMD measurements
ROI: Region of interest, BMD: Bone mineral density

(16.8-42) for cervical cancer patients and 30.8 (18-52.5) for uterine cancer patients (p=0.184). The median BMI for the entire group was 33.3 (range: 16.8-52.5). Comorbidities were present in 51.6% (n=66) of patients. The most common comorbidities included hypertension (16.4%; n=21), diabetes (9.4%; n=12), cardiovascular diseases (7.8%; n=10), and chronic obstructive pulmonary disease/asthma (8.6%; n=11).

Among cervical cancer patients, 5.8% (n=4) underwent pelvic MRI, 2.9% (n=2) had PET-CT, while the majority (91.3%; n=63) underwent both imaging modalities. The most common histologic subtypes were squamous cell carcinoma in cervical cancer (89.9%; n=62) and endometrioid adenocarcinoma in uterine cancer (84.7%; n=50). Among patients with cervical cancer, 13.0% (n=9) were stage 1, 15.9% (n=11) were stage 2, 40.6% (n=28) were stage 3, and 30.4% (n=21) were stage 4. Among patients with uterine cancer, 50.8% (n=30) were stage 1, 22% (n=13) were stage 2, 25.4% (n=15) were stage 3, and 1.7% (n=1) were stage 4. Total doses of 45-50.4 Gy (1.8-2 Gy per fraction) for PTV-pelvis and 54-56 Gy (1.8 Gy per fraction) for metastatic lymph node PTV were delivered using 3D-CRT. The median HR-CTV D90 was 89.1 Gy (range, 69-107 Gy) for cervical cancer patients and 75.5 Gy (range, 68.3-97.2 Gy) for uterine cancer patients.

Chemotherapy was administered concurrently with RT in 92.8% (n=64) of cervical cancer patients. Among patients with uterine cancer, 52.5% (n=31) received chemotherapy; only 1.7% (n=1) received it concurrently, and 50.8% (n=30) underwent adjuvant or neoadjuvant therapy. Overall, 7.2% (n=5) of cervical cancer patients and 47.5% (n=28) of uterine cancer patients did not receive chemotherapy. The median L4-HU value was 119 (range -9 to 306), while the median sacrum HU value was 19 (range -130 to 168). Using 100 HU as the osteoporosis threshold (16-18), 66.7% (n=46) of cervical cancer patients and 55.9% of uterine cancer patients had HU-L4 values exceeding this threshold, with no significant difference between the groups (p=0.213). For HU-sacrum values, no significant difference in osteoporosis risk was found between the two groups (p=0.133). In the total population, osteoporotic changes were detected in 38.3% of patients in the L4 region, while 61.7% had no osteoporosis. However, in the sacral region, osteoporosis was significantly more common: 90.6% of patients were below the 100 HU threshold, indicating a high risk of osteoporosis. Descriptive data are presented in Table 1.

The median follow-up time was 29 months (range, 9-79 months). The median time from RT completion to PIF detection was 19 months (range, 2-49 months), and the overall incidence of PIF was 35.2% (n=45) (Figure 3). For PIF diagnosis, MRI alone was used in 82.2% (n=37) of cases, while MRI+PET-CT was used in 17.8% (n=8). The median standardized uptake value (SUV) of PIF was 4.0 (2.7-5.9).

Table 1. Baseline characteristics for endometrial and cervical cancer groups

	Cervical cancer, n (%)	Uterine cancer, n (%)	p	
Age	57 (36-85)	65 (39-85)	-3.025*	0.002
BMI	29.1 (16.8-42)	30.86 (18-52.58)	-1.328*	0.184
Menopausal status				
Pre-menopausal	24 (34.8)	5 (8.5)	12.562**	<0.001
Post-menopausal	45 (65.2)	54 (91.5)		
Comorbidity				
Absent	25 (36.2)	34 (57.6)	5.859**	0.015
Present	44 (63.8)	25 (42.4)		
Chemotherapy (yes/no)				
No	5 (7.2)	28 (47.5)	26.876**	<0.001
Yes	64 (92.8)	31 (52.5)		
Chemotherapy type				
Concurrent with RT	64 (92.8)	1 (1.7)	109.512**	<0.001
Other (adjuvant/neoadjuvant/no chemotherapy)	5 (7.2)	58 (98.3)		
HU-L4-osteoporosis-100 HU				
Absent	46 (66.7)	33 (55.9)	1.551**	0.213
Present	23 (33.3)	26 (44.1)		
HU-sacrum-osteoporosis-100 HU				
Absent	4 (5.8)	8 (13.6)	2.256**	0.133
Present	65 (94.2)	51 (86.4)		

*: Mann-Whitney U test, **: Chi-square test, BMI: Body mass index, HU: Hounsfield unit, L4: 4th lumbar vertebra, RT: Radiotherapy

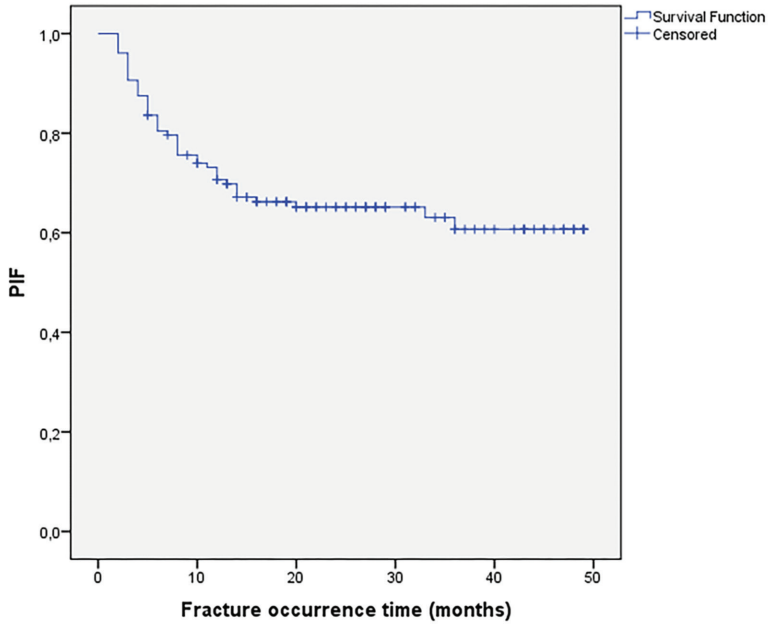

Figure 3. Follow-up duration (months) and incidence of PIF
PIF: Pelvic insufficiency fracture

Table 2. Evaluation of prognostic factors affecting pelvic insufficiency fractures

	PIF status		Chi-square	p
	Absent, n (%)	Present, n (%)		
Age group				
<65 years	47 (68.1)	22 (31.9)	0.703	0.402
≥65 years	36 (61.0)	23 (39.0)		
Disease				
Cervical cancer	39 (56.5)	30 (43.5)	4.548	0.033*
Uterine cancer	44 (74.6)	15 (25.4)		
Menopausal status				
Pre-menopausal	17 (58.6)	12 (41.4)	0.637	0.425
Post-menopausal	66 (66.7)	33 (33.3)		
BMI	29.1 (16.8-42)	30.86 (18-52.58)	-0.806	0.420
BMI group				
Normal and overweight	24 (60)	16 (40)	0.487	0.485
Obese	27 (67.5)	13 (32.5)		
Comorbidity				
Absent	40 (67.8)	19 (32.2)	0.419	0.518
Present	43 (62.3)	26 (37.7)		
Chemotherapy (yes/no)				
No	23 (69.7)	10 (30.3)	0.459	0.498
Yes	60 (63.2)	35 (36.8)		
Chemotherapy type				
Concurrent with RT	36 (55.4)	29 (44.6)	5.183	0.023*
Other (adjuvant/neoadjuvant/no chemotherapy)	47 (74.6)	16 (25.4)		
HU-L4	146 (-4-306)	105 (-9-222)	-0.200	0.842
HU-Sacrum	31.5 (-130-168)	6 (-103-162)	-2.498	0.012*

PIF: Pelvic insufficiency fracture, BMI: Body mass index, RT: Radiotherapy, HU: Hounsfield unit, L4: 4th lumbar vertebra, *: P significant

The most common fracture site was the sacrum (76.2%; n=32), followed by the pubis (14.3%; n=6), the sacroiliac region (7.1%; n=3), the lumbar spine (7.1%; n=3), and the iliac region (2.4%; n=1). Among patients diagnosed with PIF, 53.3% (n=24) experienced pain, while 46.7% (n=21) were asymptomatic. In 23 symptomatic patients, treatment included non-steroidal anti-inflammatory drugs, vitamin E, and pentoxifylline; vertebroplasty was performed in one patient.

Age, cancer type, menopausal status, BMI, presence of comorbidities, and HU-L4 and HU-sacrum values were analyzed as potential factors influencing PIFs. The analyses revealed significant differences associated with low HU-sacrum values (p=0.012), cervical cancer type (p=0.033), and receipt of CRT (p=0.023) (Table 2). In the ROC analysis for HU-sacrum values, the area under the curve was 0.634 (95% CI: 0.545-0.718). The cut-off value was determined to be ≤-8 and was statistically significant (p=0.011). For this cut-off value, sensitivity was 48.89%, and specificity was 78.31% (Figure 4). In the multivariate logistic regression analysis, sacral HU (≤-8 vs. >-8) was identified as an independent risk factor for PIF (OR: 3.04; 95% CI: 1.36-6.83; p=0.007). Patients in the low HU category had an approximately threefold higher risk of developing PIF. In contrast, chemotherapy type (p=0.407) and diagnosis (p=0.908) were not statistically significant independent predictors (Table 3).

DISCUSSION

PIF fractures were previously considered a rare complication of pelvic RT; however, with the widespread use of advanced imaging techniques, they are now more frequently detected. In older studies, the incidence of PIFs was reported as 5-10% (19,20), whereas modern studies have reported rates as high as 20-40% (1,5). The routine use of MRI has played a crucial role in this increase by revealing asymptomatic fractures (21). However, studies on PIF incidence show wide

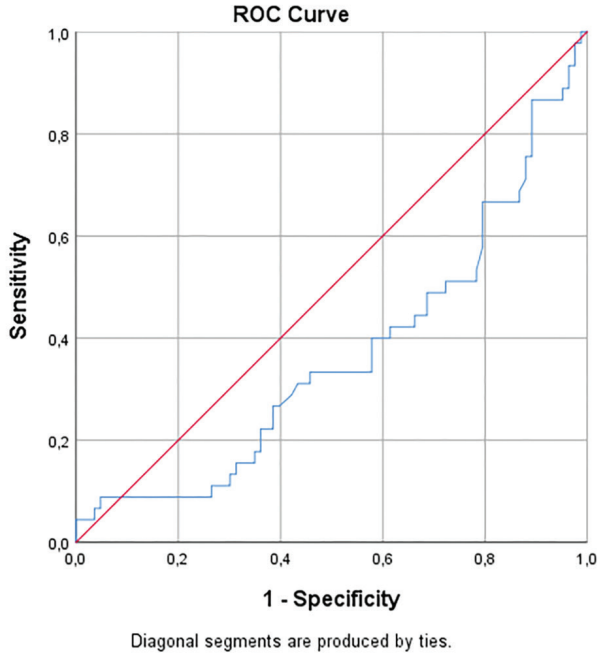

Figure 4. ROC analysis for HU-sacrum values
ROC: Receiver operating characteristic, HU: Hounsfield unit

Table 3. Multivariate logistic regression analysis for predictors of pelvic insufficiency fractures

Variable	B	S.E.	Wald	df	p-value	OR [Exp (B)]	95% CI (lower-upper)
Chemotherapy type	0.758	0.915	0.687	1	0.407	2.134	0.355-12.822
Diagnosis	-0.108	0.930	0.013	1	0.908	0.898	0.145-5.555
Sacrum HU* (≤-8 vs. >-8)	1.112	0.412	7.274	1	0.007	3.042	1.355-6.827

HU: Hounsfield unit, S.E.: Standard error, OR: Odds ratio, CI: Confidence interval, *: Sacrum HU cut-off value (≤-8) was determined using receiver operating characteristic analysis

variation, and there is no standardized risk assessment model currently available. In our study, we analyzed factors influencing PIF development after pelvic RT in 128 patients and evaluated the role of HU values obtained from CT images in predicting PIF risk.

The effects of RT on bone are dose-dependent. Pathophysiological studies suggest that osteoblast function begins to deteriorate at radiation doses of approximately 30 Gy, with cell death evident at approximately 50 Gy (22). Although advanced RT techniques have the potential to reduce radiation exposure to bone, Rijpma-Jacobs et al. (8) found that these techniques may not provide adequate protection in areas subject to high mechanical load, particularly in the sacrum. In a study of 27 anal cancer patients, the incidence of PIF was 50%, despite the use of rotational RT techniques in all cases (7). Similarly, Duranson et al. (1) reported a 5-year cumulative incidence of PIF of 22% among patients with cervical cancer treated with IMRT. In our clinic, 3D-CRT was used for all patients, and PIF occurred in 35.2% of cases. Although we could not evaluate pelvic-bone dose-volume parameters because the standard RT technique was used for all patients, several relevant studies have addressed this topic. For instance, Kronborg et al. (7) demonstrated that dose-volume parameters such as V30 Gy and V40 Gy for sacral bones were effective predictors of PIF risk. Ramlov et al. (23) reported that reducing the sacral D50% dose from 40 Gy to 35 Gy could decrease PIF incidence from 45% to 22%. A study by Mori et al. (24) examined the effects of carbon ion RT on PIF risk and investigated the relationship between dose and linear energy transfer (LETd) parameters. Their findings indicated that the D50% relative biological effectiveness-weighted dose to the sacrum was an important risk factor for PIF, whereas LETd and physical dose parameters were not significant predictors of PIF. Similarly, Huang et al. (25) found that BMD loss due to RT was reduced by 43% in patients who underwent pelvic bone marrow-sparing IMRT (PBMS-IMRT), compared with a 53% reduction in the control group.

PBMS-IMRT showed potential to reduce PIF incidence by 5% through minimizing BMD loss by 10%. In patients with low BMD, advanced RT techniques such as PBMS-IMRT may serve as a preventive strategy. Nevertheless, some studies have not found a significant correlation between RT dose parameters and PIF incidence (1,6). The current literature provides only limited evidence regarding the impact of modern RT techniques on PIF risk; our findings based on 3D-CRT highlight the need for caution in generalizing these results. While preliminary data (e.g., PBMS-IMRT) suggest potential dosimetric advantages and a possible reduction in the risk of PIF, larger comparative studies across cancer types and populations are required to determine whether these benefits translate into clinically meaningful improvements in practice.

The prognostic significance of advanced age, post-menopausal status, and low lumbar and sacral BMD in the development of PIFs has been well established in numerous studies (1,2,5,6,8). In our study, osteoporosis status was assessed based on HU values. Among patients with PIF, 90.6% had a sacral HU value <100, reinforcing the strong association between BMD loss after RT and PIF development. Similarly, Duranson et al. (1) demonstrated that BMD measurements from planning CT scans were strong predictors of PIF development, with lower sacral BMD values significantly increasing PIF risk ($p<0.001$). In our cohort, the statistically significant HU cut-off value (≤-8) was determined through a ROC analysis focusing exclusively on trabecular bone in the sacral region. Although low sacral BMD values are associated with increased PIF risk, the cut-off value may be specific to our population and measurement method and may vary across CT protocols and patient populations. Our findings indicate that sacral HU ≤-8 may be an independent risk factor for PIF, conferring approximately a threefold increase in risk. In contrast, chemotherapy type and diagnosis were not significant predictors. These results highlight the potential of HU-based sacral bone density assessment as a practical and clinically relevant parameter for early risk stratification in patients undergoing pelvic RT.

Patients receiving pelvic RT face a greater risk of PIF than non-irradiated counterparts. An analysis of Surveillance, Epidemiology, and End Results Program data from 6,428 patients aged 65 and older, including patients with anal canal, cervical, and rectal cancers, revealed that fracture incidence was significantly higher among patients who underwent pelvic RT. Specifically, in a cohort of 1,605 cervical cancer patients, the five-year fracture rate was 5.9% in the non-RT group compared to 8.2% in the RT group (26). Moreover, Huang et al. (25) demonstrated that systemic bone density loss can occur after RT, even in areas outside the radiation field. Similarly, Haque and Hossen (27) reported that bone loss following RT is not limited to the irradiated sites but may also have systemic effects on the entire skeletal system. This suggests that radiation-induced PIFs may result not only from localized BMD loss but also from systemic osteoporotic processes, emphasizing the need for bone-protective measures in high-risk patients.

The ROI technique used to determine HU values in our study focused exclusively on trabecular bone density. Therefore, direct comparisons with studies such as Huang et al. (25), which evaluated both cortical and trabecular density through contoured whole-bone assessments, may not be appropriate. PIF incidence rates in the literature range widely, from 1.7% to 89% (1,4-6,11,20,26-28). One of the highest reported rates comes from Mir et al. (5), who performed post-RT MRI examinations on 266 patients and detected PIFs in 37.4% of patients. The prevalence of PIF in our study was 35.2%, which is among the highest reported in the literature. This high incidence may be attributed to the high baseline prevalence of osteoporosis in our patient population. The prevalence of osteoporosis in Turkish women aged 50 years and older has been reported as 30-50%, which is higher than the 20-40% observed in European and U.S. populations (29,30). This could explain the higher PIF incidence (35.2%) in our study compared with those reported in the literature, where rates ranged from 9.7% (6) to 22% (1).

Huang et al. (25) reported that BMD loss following pelvic RT peaked within the first month of treatment and subsequently stabilized. Similarly, Rijpma-Jacobs et al. (8) reported that the mean time to PIF diagnosis was 17 months, with most fractures occurring within the first year. In Mir et al.'s (5) study, where the median follow-up was 12 months, 93% of fractures were detected within the first year. In our study, the median time from RT completion to PIF diagnosis was 19 months; however, 80% of fractures occurred within the first year, a discrepancy that warrants verification. Although some studies have reported earlier onset (6.5 months) (6), our findings align with the 11.5-19-month median latency period reported in other studies (1,3,7,8,28). The sacral bone and sacroiliac joints are the most common PIF locations, as documented in multiple studies, including ours (1,3,5-8,23). The lateral sacral wings are major weight-bearing structures, making them the most frequently affected sites. In our study, 82.2% of PIFs were detected by MRI. Although MRI remains the primary diagnostic modality, PET-CT has also demonstrated high sensitivity in detecting PIFs. PET-CT findings typically reveal diffuse or linear metabolic activity along the sacroiliac joint (21). In our study, the SUV for

PIFs in patients undergoing PET-CT was 4 (2.7-5.9), which is consistent with the SUV range of 1.7-5.9 reported in the literature (21,31). These findings suggest that PET-CT can serve as a complementary diagnostic tool for PIF detection. Another important consideration is the underdiagnosis of insufficiency fractures and their potential misidentification as metastatic lesions. Rijpma-Jacobs et al. (8) reported that in a cohort of 300 rectal cancer patients, only 12 PIFs were initially diagnosed, but this number increased to 32 upon detailed imaging review. This finding underscores the importance of systematic imaging to ensure early and accurate diagnosis of PIF.

Management of PIFs should be individualized according to the patient's condition and symptom severity. However, most cases can be effectively managed with conservative treatment without requiring hospitalization. Pain management is a critical component of the care of symptomatic patients, in which anti-inflammatory drugs can be used alongside analgesics for effective relief. In our study, 53% of patients reported pain, similar to the 56% reported Rijpma-Jacobs et al.'s (8) series, while other studies reported prevalences as high as 70% and 86% (7,25,31). A meta-analysis by Sapienza et al. (3), which included 3,929 patients, reported that 61% of the 504 PIF cases were symptomatic. In cases of bone fractures, surgical interventions such as vertebroplasty may be necessary. In Rijpma-Jacobs et al.'s (8) study, hyperbaric oxygen therapy was administered to only one patient. Another important consideration is that even asymptomatic patients should receive bone-strengthening interventions to improve BMD and prevent future fractures. Post-menopausal patients or those with low BMD may require a multidisciplinary approach, including prophylactic treatments (e.g., bisphosphonates or denosumab) and lifestyle modifications. Additionally, optimizing RT planning with bone-sparing techniques for high-risk patients and reducing sacral dose exposure may help lower fracture risk.

In routine clinical practice, pelvic bone density is not incorporated into RT planning, despite its strong association with PIF risk. Given the marked variability in osteoporosis prevalence across populations and the wide range of PIF incidences reported in the literature, there is a need for simple, standardized tools for risk stratification. HU-based BMD assessment derived from planning CT scans represents such a tool, as it is cost-free and readily accessible. Our findings, demonstrating a strong correlation between low sacral HU values and PIF risk, support its potential clinical utility. Nevertheless, before this parameter can be routinely adopted into RT planning workflows, its predictive value should be validated in larger cohorts.

Study Limitations

Our study has some limitations. The exclusive use of 3D-CRT limits the generalizability of our findings to centers utilizing advanced RT techniques. Additionally, our study used HU values from planning CT images as a surrogate for BMD, employing 100 HU as a reference threshold based on data from the Turkish population (18). Various HU cut-off values have been proposed in the literature for predicting osteoporosis across different populations. Further standardization of HU measurements and their integration into routine RT planning protocols are necessary to enhance their clinical applicability.

CONCLUSION

Our study demonstrates that PIF can be predicted using a simple BMD density assessment. In patients receiving pelvic RT, particularly those with cervical cancer, concurrent chemotherapy and low sacral HU values were identified as significant risk factors for fractures. Early identification of high-risk patients and timely preventive measures may significantly improve clinical outcomes.

ETHICS

Ethics Committee Approval: Ethical approval was obtained from the University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital Clinical Research Ethics Committee (approval no: 2023-24-33, date: 18.12.2023).

Informed Consent: Written informed consent was obtained and was available in the patient files.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: M.K.B., S.A., E.H., E.K.U., Concept: M.K.B., S.A., E.H., E.K.U., Design: M.K.B., S.A., E.H., Data Collection or Processing: M.K.B., S.A., O.Ö., F.B.G., B.H., B.G.T., Analysis or Interpretation: M.K.B., K.N.B., E.K.U., Literature Search: M.K.B., S.A., O.Ö., F.B.G., B.H., B.G.T., Writing: M.K.B., S.A., E.H., K.N.B., E.K.U.

Conflict of Interest: Esengül Koçak Uzel Prof. MD is a Editorial Member in Medical Journal of Bakırköy. She had no involvement in the peer-review of this article and had no access to information regarding its peer-review. The other authors declared no conflict of interest.

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Research

Use of Finger Tapping Test in Quantitative Evaluation of the Effectiveness of Rehabilitation Programs in Individuals with Chronic Hemiplegia

Kronik Hemiplejili Bireylerde Rehabilitasyon Programlarının Etkinliğinin Kantitatif Değerlendirilmesinde Parmak Vurma Testinin Kullanımı

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ABSTRACT

Objective: This study aimed to evaluate changes in upper extremity motor skills in individuals with chronic stroke using the finger tapping test (FTT) and clinical assessments.

Methods: This study was conducted between April 2019 and February 2021. Thirty volunteers with hemiplegia (mean age 61.7±7.22 years), in whom at least 6 months had passed since the first cerebrovascular accident, participated. A Bobath-based physical therapy program (45 minutes/day, 5 days/week, for 6 weeks) was applied to the affected hands. Pre- and post-treatment evaluations included a 20-second computer-based FTT and clinical tests, such as the Fugl-Meyer assessment upper extremity, the box and block test, the Duruöz hand index, and the functional independence measure.

Results: FTT showed an increase in tapping counts (from 58.8±20.52 to 75.5±19.31) and a reduction in mean inter-tapping intervals (ITI) (from 391.7±184.68 ms to 281.6±88.09 ms) ($p<0.001$). Clinical tests also revealed significant improvements in motor skills and reductions in disability ($p<0.001$). Both pre- and post-treatment ITI curves were described by linear equations with negative slopes; the slope before treatment (-2.1463) was steeper than that after treatment (-0.6286). Strong correlations were observed between FTT data and clinical test outcomes ($p<0.001$).

Conclusion: The ease of use and objective nature of the FTT highlight its potential for assessing motor recovery and prognosis in patients with hemiplegia, reducing errors associated with subjective assessments, and offering valuable insights for clinicians and researchers.

Keywords: Hemiplegia, motor performance, finger tapping test, temporal analysis

ÖZ

Amaç: Bu çalışmada kronik inme geçiren bireylerde, parmak vurma testi (PVT) ve klinik değerlendirmeler kullanılarak üst ekstremite motor becerilerindeki değişikliklerin değerlendirilmesi amaçlanmıştır.

Gereç ve Yöntem: Bu çalışma Nisan 2019-Şubat 2021 tarihleri arasında gerçekleştirilmiştir. Çalışmaya ilk serebral vasküler olayından sonra en az 6 ay geçmiş, hemiplejili 30 gönüllü (ortalama yaş 61,7±7,22 yıl) katıldı. Etkilenen ellere yönelik Bobath temelli fizik tedavi programı (günde 45 dakika, haftada 5 gün, 6 hafta boyunca) uygulandı. Tedavi öncesi ve sonrası değerlendirmeler, 20 saniyelik bilgisayar tabanlı PVT ile Fugl-Meyer üst ekstremite değerlendirmesi, kutu ve blok testi, Duruöz El İndeksi ve fonksiyonel bağımsızlık ölçümü gibi klinik testleri içerdi.

Bulgular: PVT sonuçlarında vuru sayılarında artış (58,8±20,52'den 75,5±19,31'e) ve ortalama vuru aralıklarında (OVA) azalma (391,7±184,68 ms'den 281,6±88,09 ms'ye) görüldü ($p<0,001$). Klinik testler, motor becerilerde önemli iyileşmeler ve engellilikte azalma olduğunu ortaya koydu ($p<0,001$). Hem tedavi öncesi hem de sonrası OVA eğrileri negatif eğimli doğrusal denklemlerle açıklanırken, tedavi öncesi eğim (-2,1463), tedavi sonrasına göre (-0,6286) daha dikti. PVT verileri ile klinik test sonuçları arasında güçlü bir ilişki bulundu ($p<0,001$).

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ÖZ

Sonuç: PVT'nin kullanım kolaylığı ve objektif yapısı, hemiplejik hastalarda motor iyileşmenin ve prognozun değerlendirilmesinde potansiyelini vurgulamakta, subjektif değerlendirme hatalarını azaltmakta ve klinisyenler ile araştırmacılar için değerli bilgiler sunmaktadır.

Anahtar Kelimeler: Hemipleji, motor performans, parmak vurma testi, zamanlama analizi

INTRODUCTION

Hemiplegia is a neurological condition characterized by paralysis (plegia) on one side of the body, typically resulting from damage to a specific area of the brain. Ischemic and hemorrhagic strokes are the most common causes of hemiplegia (1). Neurological disorders affecting the central nervous system, such as head injuries, brain tumors, multiple sclerosis, infections like meningitis or encephalitis, and vascular issues like stenosis of cerebral blood vessels, can also lead to hemiplegia. Treatment and support approaches used to enhance individuals' quality of life and aid in their functional recovery can vary based on the cause and severity of hemiplegia and patients' overall health condition (2).

In post-hemiplegic rehabilitation, various methods are employed, including conventional techniques (exercises for muscle strengthening and maintenance of normal joint range of motion; activities to enhance daily life skills; and balance and mobility exercises), neurophysiological treatment methods (such as Bobath, Rood, and Brunnstrom techniques and proprioceptive neuromuscular facilitation), biofeedback techniques, functional electrical stimulation, robot-assisted rehabilitation, constraint-induced movement therapy, and orthoses (3-6). Additionally, some other methods with different mechanisms of action, such as rehabilitation using sensory glove stimulation, virtual reality, and continuous passive motion devices, can be applied (7,8). Evaluating the effectiveness of rehabilitation is crucial for determining the patient's functional status, monitoring progress, setting treatment goals, and optimizing the rehabilitation process. Measurement tools with standardized scoring, such as the modified Ashworth scale (MAS), upper extremity Brunnstrom stage (UE-BS), box and block test (BBT), and Fugl-Meyer upper extremity motor assessment scale (UE-FMA), have been developed to assess an individual's functional status. These methods often involve scoring based on the therapist's observations during active or passive execution of motor movements (9). Treatment progress can be further evaluated quantitatively by tracking movement using electronic sensors (10,11). Another quantitative method used in rehabilitation assessment is the finger tapping test (FTT). FTT has long been used as a quantitative method to assess neuromotor function of the upper extremity (10). It has been frequently employed for the quantitative assessment of diseases such as Alzheimer's disease (12), ataxia (13), Parkinson's disease (14), and stroke (15). A longitudinal study by Chunyong et al. (16) used the FTT and functional magnetic resonance imaging to evaluate improvements in the hemiplegic hand during a three-month rehabilitation period. In monthly evaluations, they also observed significant increases in the average number of FTT taps. Térémetz et al. (17) used the BBT and the FTT in their pilot study to evaluate the effectiveness of "interactive manual dexterity training" therapy after stroke. They found an increase in BBT score and an acceleration in FTT in the training group.

Assessing rehabilitation programs typically relies on data collected from patients, their families, and caregivers. This assessment often hinges on self-reported outcomes and questionnaires. Nevertheless, these subjective approaches may lack precision and fail to accurately reflect the patient's current condition (9). This study aimed to evaluate upper-extremity function in adults with chronic hemiplegia before and after rehabilitation programs using clinical tests, including UE-FMA, Duruöz hand index (DHI), BBT, functional independence measure (FIM), and the novel computer-based test FTT. The study also aims to determine the potential relationship between FTT data and clinical tests to support the use of FTT as an objective assessment tool.

METHODS

The study was conducted in accordance with the Declaration of Helsinki and reviewed. Ethical approval for the study was obtained from the İstanbul Okan University Faculty of Health Sciences Ethics Committee (approval no: 6, date: 27.03.2019). This study was conducted between April 2019 and February 2021 and involved 30 patients who met the study criteria and presented to the Vision Physical Therapy and Rehabilitation Center. The sample size of the study was determined using the G*Power program. Based on the age-interaction relationship in the finger-tapping test reported by Özen et al. (8), a minimum of 28 participants would provide 81% statistical power at a 5% significance level. Considering a 10% attrition rate, the planned sample size was 30 participants.

Participants included individuals aged 18 or older who had experienced their first cerebrovascular accident (CVA) resulting in hemiplegia or hemiparesis, with at least 6 months elapsed since the CVA; who had a a Mini-Mental State Examination (MMSE) score of ≥16; who were in UE-BS stages 4-6; who had upper extremity spasticity ≤2 according to the Modified MAS (MMAS); and who had UE-FMA scores between 15 and 50 or who could perform a minimum of 10 degrees of extension or flexion in the wrist or fingers and could perform wrist extension and flexion five times consecutively without loss of range of motion. Individuals with two or more CVAs were excluded from the study. Participants with sensory aphasia, apraxia, hemianopia, rheumatoid arthritis, multiple sclerosis, Dupuytren's contracture, complete or incomplete spinal cord injury, Parkinson's disease, hand deformities resulting from fractures, and other medical conditions that could interfere with the tests were excluded. Those who had received botulinum toxin A injections in the affected upper extremity within the last 6 months were also excluded.

General Study Protocol

After obtaining written consent from the participants, detailed medical histories were taken, including height, weight, body mass index (BMI), age, occupation, education, date of stroke, dominant hand, etiology of hemiplegia, affected side, medications, and surgeries. Evaluations to determine eligibility were conducted using UE-BS, MMSE, and MMAS. Participants underwent a 6-week Bobath-based rehabilitation program, five days per week, 45-minute sessions, tailored to their needs. There were no interventions made in the patients' medical treatments.

Participants were assessed using UE-FMA, DHI, BBT, FIM, and FTT before (pre-treatment) and after (post-treatment) the 6-week rehabilitation program. FTT data—including mean tapping counts, mean inter-tapping intervals (ITIs, in milliseconds), and temporal variation patterns—were evaluated, whereas other clinical tests were assessed using standard scores.

Assessment Tools

UE-BS is a method used to assess the motor function and control of the upper extremity (arm, shoulder, hand, wrist) in individuals who have had a stroke. It categorizes seven stages ranging from stage 1, where muscles are completely flaccid and reflexes are absent, to stage 7, where all functions have returned to normal (18).

MMSE is a screening test developed in 1975 to assess cognitive impairment in adults. The test evaluates short-term memory, attention and calculation, language, orientation, and praxis. The evaluation is performed out of a total of 30 points. Scores below 10 indicate severe impairment; scores between 10 and 19 indicate moderate dementia; scores between 20 and 24 indicate early-stage dementia; and scores of 25 and above are considered normal.

Modified Modified Ashworth Scale

The scale, initially developed in 1964 to assess muscle spasticity in patients with multiple sclerosis, has been modified over the years, first into the MAS and then into the MMAS. The evaluation is based on range of motion and muscle tone during passive wrist movement. It is scored on a scale from 0 to 4, where 0 indicates no increase in muscle tone and 4 indicates stiff flexion or extension in the affected area (21).

Rehabilitation Protocol

All participants received Bobath-based physical therapy for six weeks, five days per week. This approach focuses on ensuring correct movement during activities to enhance proper functioning. The program includes exercises targeting different areas, such as the lower and upper extremities, the trunk, and postural control (22).

The computer-based FTT was used to evaluate the finger-tapping performance of hemiplegic patients. The system measures ITI with high temporal resolution and stores the data on the computer's hard disk. FTT was performed on the participants before and after the treatment. During the test, participants were seated comfortably, approximately 50 cm from the computer screen. They were instructed to tap a key on the computer keyboard using the index finger of their hemiplegic hand as quickly as possible for 20 seconds (10). The implementation of the test is shown in Figure 1.

Fugl-Meyer Upper Extremity Motor Assessment Scale

UE-FMA assesses sensorimotor recovery of the upper extremity. The method is based on the motor recovery stages described by Brunnstrom (18). The scale consists of five sections: motor function, joint range of motion, sensory function, balance, and joint pain. The motor function assessment is the most commonly used component and consists of 33 items assessing the upper extremity. Each item is rated on a scale: 0=unable to perform; 1=partially able to perform; 2=able to perform completely. The total score obtainable on the scale ranges from 0 to 66, and the assessment takes approximately 20 minutes (23).

The DHI, a Turkish-language validated tool, was used to assess participants' limitations in hand function. The test consists of 18 items assessing the individual's hand skills in self-care, work, kitchen activities, dressing, personal hygiene, and other general movements. Each item is scored

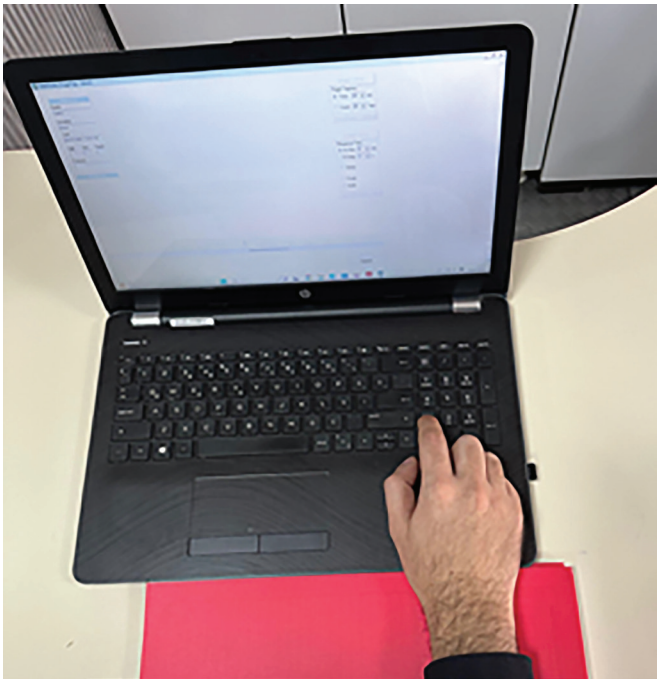

Figure 1. Procedure of the FTT test as applied to participants
FTT: Finger tapping test

from "0: no difficulty" to "5: impossible." A higher score indicates a greater activity limitation. The completion time for the index is approximately 3 minutes (24).

Box and Block Test

The test requires the patient to pick up a wooden block and place it into another section of the apparatus. The score is the number of wooden blocks placed in the other section within 60 seconds (25).

The FIM, developed in 1993 by Heinemann and colleagues, is a method used to evaluate physical disability. FIM, for which Turkish validity and reliability studies have been conducted, assesses physical and cognitive impairments, assistance needs, and caregiver burden in activities of daily living. FIM consists of 18 items, 13 for motor functions and 5 for cognitive functions. Each item is evaluated on a 7-point Likert scale indicating the level of assistance required (1=total assistance; 7=total independence). The evaluation is observation-based and takes, on average, 20 minutes (26). In this study, only the motor component of the FIM was used.

Briefly, the study standardized participants using MMSE to assess cognitive function, UE-BS to measure motor abilities, and MMAS to evaluate muscle spasticity. To assess the effectiveness of rehabilitation on motor skills, clinical tests including the UE-FMA, DHI, BBT, FIM, and FTT, a computer-based test, were administered.

Statistical Analysis

Descriptive statistics, including mean, standard deviation, count, and percentage, were provided for the study's categorical and continuous variables. The homogeneity of variances was checked using the Levene's test, a prerequisite for parametric tests. The normality assumption was assessed using the Shapiro-Wilk test. When it was desired to evaluate differences between two dependent groups, the dependent samples t-test was used when parametric test assumptions were met, and the Wilcoxon test was used when they were not. The relationship between two continuous variables was evaluated using the Pearson correlation coefficient when parametric assumptions were met; otherwise, the Spearman correlation coefficient was used. Regression analysis was applied to assess the relationships among the number of taps, ITI measurements, and other parameters. Statistical significance was considered at two levels: $p<0.05$ and $p<0.01$.

RESULTS

Of the 30 participants, 77% (n=23) were male and 23% (n=7) were female. The mean age of the participants was 61.7±7.22 years, with a mean height of 170±0.06 cm, mean weight of 82.7±9.78 kg, and mean BMI of 28.8±4.02 kg/m^2. Additionally, the participants had mean MMSE, MMAS, and UE-BS scores of 24.9±1.87; 1.2±0.46, and 4.7±0.52 points, respectively (Table 1).

Table 2 presents pre- and post-treatment values of tests and scales administered to volunteers before and after 6 weeks of rehabilitation. The data in the table indicate notable changes across various parameters. Specifically, post-

Table 1. Descriptive statistics of demographic data of participants (n=30)

Gender	**Male, n (%)**	**23 (77%)**
	Female, n (%)	7 (23%)
Age (year)		61.7±7.22
Height (cm)		170±0.06
Weight (kg)		82.7±9.78
Body mass index		28.8±4.02
Mini mental state examination score (MMSE)		24.9±1.87
Modified modified Ashworth scale (MAS)	**0 (%)**	1 (3%)
	1 (%)	23 (77%)
	2 (%)	6 (20%)
Upper extremity-Brunnstrom stages (UE-BS)	**4 (%)**	9 (30%)
	5 (%)	20 (67%)
	6 (%)	1 (3%)

Descriptive statistics are given as mean±standard deviation for continuous data and number (percentage) for categorical data

treatment the number of tappings increased from 58.8 to 75.5, while ITI durations decreased from 391.7 ms to 281.6 ms; similarly, UE-FMA score increased from 37.3 to 40.7; DHI value decreased from 56.3 to 50.9; BBT score increased from 30.6 to 36.5; and FIM measurements increased from 63.1 to 66.8. The statistical analysis revealed that all changes in the tests were significant (p=0.001).

When investigating the relationship between pre- and post-treatment clinical test results and FTT tapping performance, we observed a strong negative correlation between the number of taps and the DHI scores. Additionally, the number of tappings was strongly positively correlated with UE-FMA, BBT, and FIM scores (all p=0.001). The details are provided in Table 3.

Examining the temporal variation of FTT tapping performance in the pre- and post-treatment periods, it was noted that ITIs shortened as the test progressed. The slopes of the linear fits to the time course of ITIs were negative for both pre- and post-treatment data. Notably, the magnitude of the negative trend in the pre-treatment data was greater than that in the post-treatment data (slopes were -2.1463 and -0.6286, respectively; Figures 1 and 2).

Figures 2 and 3 graphically presents the temporal behaviors of the FTT tapping performances of three randomly selected participants.

DISCUSSION

The routine clinical tests, which often include scales and questionnaires used in the assessment of rehabilitation, may sometimes be associated with relatively low precision and may be insufficient for quantitative assessment to provide an accurate reflection of the patient's condition. Hence, the reliability and validity of these measurements

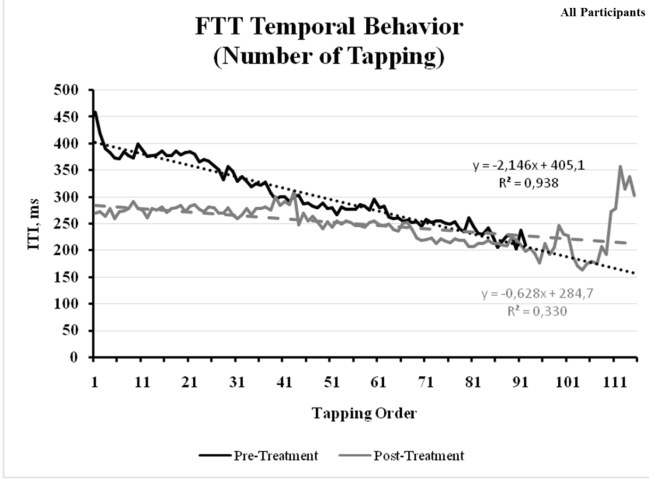

Figure 2. The temporal variation of FTT tapping performances in pre- and post-treatment period, linear regression equation and determination coefficient (R2) are given on thegraph (n=30)
FTT: Finger tapping test, ITI: Inter-tapping intervals

Table 2. Pre- and post-treatment values and significance levels of the tests and scales administered to the participants (n=30)

	Pre-treatment	Post-treatment	t	p-value
FTT # of tapping	58.8±20.52	75.5±19.31	-8.41	**<0.001**
FTT ITI, ms	391.7±184.68	281.6±88.09	5.33	**<0.001**
UE-FMA	37.3±3.93	40.7±4.73	-7.62	**<0.001**
DHI	56.3±6.95	50.9±7.62	6.49	**<0.001**
BBT	30.6±7.23	36.5±6.93	-8.18	**<0.001**
FIM	63.1±5.08	66.8±6.51	-6.71	**<0.001**

The table shows the mean±standard deviation values of the data
FTT # of tapping: Mean number of tapping, FTT ITI: Mean inter tapping interval, UE-FMA: Fugl-Meyer upper extremity motor assessment scale, DHI: Duruöz hand index, BBT: Box and block test, FIM: Functional independence measure scale, t: Paired-sample t-test

Table 3. Correlations and significance levels between pre- and post-treatment FTT mean number of tapping and the clinical tests (n=30)

		Pre-treatment	Post-treatment
UE-FMA	**r**	0.937	0.957
	p	**<0.001**	**<0.001**
DHI	**r**	-0.925	-0.945
	p	**<0.001**	**<0.001**
BBT	**r**	0.989	0.966
	p	**<0.001**	**<0.001**
FIM	**r**	0.814	0.907
	p	**<0.001**	**<0.001**

UE-FMA: Fugl-Meyer upper extremity motor assessment scale, DHI: Duruöz hand index, BBT: Box and block test, FIM: Functional independence measure scale, r: Pearson correlation coefficient

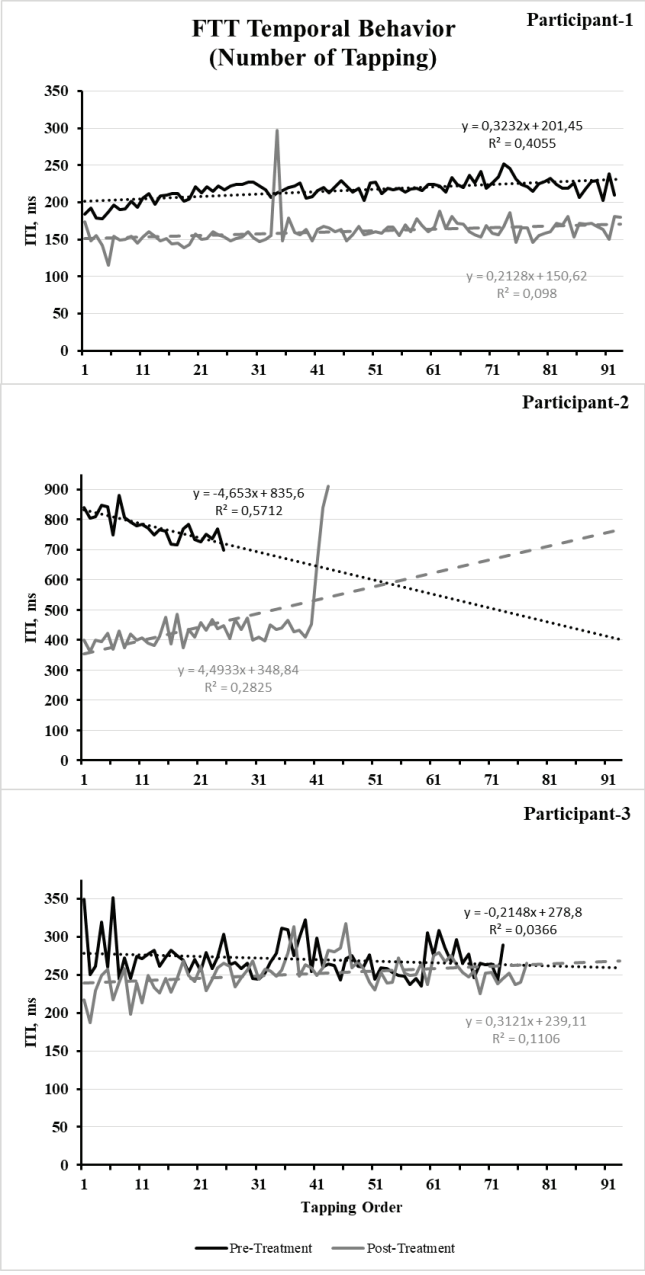

Figure 3. The temporal variation of FTT tapping performances in pre- and post-treatment period, linear regression equation and determination coefficient (R2) aregiven on the graph for three participations

FTT: Finger tapping test, ITI: Inter-tapping intervals

are limited, emphasizing the necessity for correlations with objective data obtained through technical systems that monitor movements (9). In this study, we conducted a quantitative evaluation of the impact of a rehabilitation program on the upper extremity motor skills of individuals with chronic hemiplegia. We administered standard clinical tests and the computer-based FTT. The FTT data, consistent with the clinical tests, indicated significant improvements in all measurements after six weeks of rehabilitation.

In our study, significant improvements were found in the UE-FMA, DHI, BBT, and FIM tests when comparing measurements performed before and after rehabilitation. These findings are similar to those of the following three studies. In a study by Lee at al. (27), 30 patients with hemiplegia received occupational therapy for eight weeks (five days per week). Sessions in the control group consisted of one hour of ergotherapy for the hemiplegic hand, whereas sessions in the experimental group comprised 30 minutes of ergotherapy for the hemiplegic hand followed by a 30-minute bilateral arm exercise session. Significant differences were found in the results of the UE-FMA, BBT, and modified Barthel index tests before and after treatment. Additionally, bilateral occupational therapy was more effective than unilateral occupational therapy. Kocyigit and Akaltun (28) conducted a study involving 51 stroke patients who underwent 30 sessions of rehabilitation therapy. They used various assessment tools, including the box and blocks test, Michigan hand assessment questionnaire (MHQ), dizziness handicap inventory (DHI), disabilities of the arm, shoulder, and hand (DASH) questionnaire, and ABILHAND questionnaire. They also observed significant improvements in the DHI, similar to improvements measured by other assessment methods (MHQ, DASH, and ABILHAND).

In the present study, we used a computer-based test (FTT) in addition to clinical tests, and found that the mean tapping counts on the FTT increased post-treatment. In a study by Özen et al. (8), FTT was performed on single and double fingers in patients with Parkinson's disease. They suggested that finger-tapping speed could be a practical, objective, and precise method for assessing upper extremity function and disease severity in patients with Parkinson's disease. Kang et al. (5) applied low-frequency repetitive transcranial magnetic stimulation combined with motor imagery and electrical stimulation to 20 stroke patients for two weeks. They evaluated upper-extremity motor functions subsequently. In contrast to our results, they found no significant changes in finger-tapping counts. Raghumahanti et al. (29) observed a statistically significant increase in finger-tapping counts in 15 hemiplegic patients after five weeks of combined modified constraint-induced movement therapy (COMBIT) and bimanual intensive training. We also found a significant increase in finger-tapping counts after 30 sessions of Bobath-based physiotherapy in patients with chronic hemiplegia, with the mean count rising from 58.8 to 75.5. While our results were similar to those reported in Raghumahanti et al.'s (29) study, they differed from those reported in Kang et al.'s (5) study. This difference can be explained by the varying efficacy of the applied treatment protocols.

Unlike the above-mentioned studies, our study included not only finger-tapping counts but also the time course of ITIs. Aydin et al. (10) suggested in their previous studies that temporal analysis of ITIs in healthy young adults could contribute to our understanding of motor skills, peripheral and central fatigue. The execution of maximum voluntary sequential movements results from a highly complex planning process that involves the formation of movement schemas in the central and peripheral nervous systems (10,30).

The temporal analysis of FTT data (Figure 1) in this study revealed that as the test progressed, ITIs shortened, indicating a decreasing trend in ITIs. This suggests adaptation to repetitive movements and the formation of movement schemas. Furthermore, as shown in the figure, the initial ITI values decreased from 459 ms before treatment to 270 ms after treatment, strongly supporting the effectiveness of the treatment. Moreover, the post-treatment trendline, which had a lower slope than the pre-treatment trendline, remained stable, implying that neurological recovery was approaching its upper limit. To facilitate clear interpretation, it would be advisable to repeat FTT at multiple intervals during treatment and to compare the results across different treatment durations in future studies.

While FTT may provide us with valuable information and interpretation about the neurological movement circuit, it does not provide a definitive answer as to whether the movement is functionally successful. For example, if an individual successfully completes the FTT using their index finger at a high tapping rate, it does not provide information about their functional ability to grasp a glass. Unlike other methods that involve multiple joints of the upper extremity, such as BBT, UE-FMA, DHI, and FIM, the application of FTT is limited to joints involved in movement of the index finger. However, the strong correlation we found between FTT and the other clinical methods in our study supports the utility of FTT for interim assessments, particularly in terms of ease of application.

Examination of the individual time courses of ITI derived from the FTT data (Figure 2) reveals that, although the overall trend aligns with performance based on average ITI values, significant interindividual variation exists in initial and final values. This variation can be attributed to clinical variables such as patients' pre-disease activity levels (sedentary versus active), gender differences, and neurological characteristics of the pathology causing hemiplegia, despite these patients having been subject to specific exclusion criteria. For instance, the pre-treatment ITI for participant 1 was 183.42 ms, whereas participant 2 had 840.08 ms, and participant 3 had 349.09 ms. Similarly, the post-treatment initial ITIs were 173.73 ms for participant 1, 400.38 ms for participant 2, and 216.69 ms for participant 3. Notably, participant 1, who began treatment with a higher score, exhibited an ITI change of 5.17%, whereas participants 2 and 3 showed changes of 52.34% and 37.92%, respectively. Based on this, narrowing the criteria for participant exclusion in future studies may lead to more reliable interpretations.

A wide variety of tools and measures are available to assess rehabilitation outcomes in patients with impaired upper-limb and hand function following stroke. However, this diversity can make it difficult for clinicians to select the most appropriate scales, tests, and instruments to assess therapy outcomes objectively (31). This is because the applications of these tools and the functions they assess can differ substantially. For example, the UE-FMA is a comprehensive test in which a health professional objectively assesses the patient's reflexes and upper limb function according to standardized instructions, whereas the DHI is a questionnaire in which the patient reports on various daily activities that require use of the hands, such as buttoning, writing, cutting food, opening doors, and lifting objects; the information is based on the patient's self-report (32,33). The BBT is a patient performance-based test that evaluates functions such as hand-eye coordination, fine motor skills, speed, and agility while the patient takes the blocks one by one from one box and moves them to another, whereas the motor-skill domain of the FIM is generally used to measure the level of functional independence of patients in activities of daily living, such as feeding, bathing, dressing, using the toilet, transferring, and walking, and the information is based on the patient's own or caregiver's statement (24,33). In this study, we aimed to evaluate the efficacy of computer-based FTT in rehabilitation. Rather than relying efficacy on a single assessment method, we sought to strengthen the evidence for its possible efficacy by examining its correlations with tests that clinically assess upper limb function in different ways (declarative scales: DHI, FIM; performance-based methods: UE-FMA, BBT) and that focus on different functional domains. We consider this to be the main of our study.

In this study, patients were standardized with respect to cognitive function and certain motor characteristics of the CVA-affected side. On the other hand, factors such as whether the patient's hemiplegic side was the dominant hand , gender, etiology of hemiplegia, and the degree of neurological damage were not taken into account, which can be considered weaknesses of our study.

Study Limitations

This study has some limitations. First, the relatively small sample size may limit the generalizability of the findings. Second, the study did not include a control group; therefore, the observed improvements cannot be attributed exclusively to the rehabilitation program. Finally, the FTT was administered for a relatively short period (20 seconds), and longer tapping durations or repeated measurements may provide additional information regarding the temporal characteristics of motor performance. Future studies with larger samples, control groups, and longer follow-up periods are warranted to further establish the clinical utility of FTT in individuals with chronic hemiplegia.

CONCLUSION

In this study, the combination of computer-based FTT with clinical evaluation methods such as UE-FMA, DHI, BBT, and FIM, together with temporal analysis of FTT, distinguishes our research. In conclusion, our study suggests that, compared with the clinical tests commonly employed to evaluate treatment effectiveness in hemiplegic individuals, FTT offers highly sensitive, quantitative measures in terms of both mean values and temporal aspects of movement.

Furthermore, because of its ease of administration and efficiency, FTT is regarded as a reliable tool for prognostic assessment of stroke patients. Being a computer-based test, it mitigates potential errors arising from subjective evaluations by caregivers, patients, and family members.

We believe that our findings are important for guiding future research objectives, particularly regarding homogenizing factors such as affected side, dominant hand, gender, etiology of hemiplegia, and the extent of brain damage.

ETHICS

Ethics Committee Approval: Ethical approval for the study was obtained from the İstanbul Okan University Faculty of Health Sciences Ethics Committee (approval no: 6, date: 27.03.2019).

Informed Consent: Informed consent was obtained from all study participants prior to their participation.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: T.K., E.A., L.A., E.K., Concept: E.A., L.A., E.K., Design: E.A., L.A., E.K., Data Collection or Processing: T.K., L.A., E.K., Analysis or Interpretation: T.K., E.A., L.A., E.K., Literature Search: T.K., E.A., L.A., E.K., Writing: T.K., E.A., L.A., E.K.

Conflict of Interest: No conflict of interest was declared by the authors.

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Research

Evaluation of Symptoms and Factors Associated with Symptom Severity in Children with Allergic Rhinitis

Alerjik Rinitli Çocuklarda Semptomların ve Semptom Şiddeti ile İlişkili Faktörlerin Değerlendirilmesi

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ABSTRACT

Objective: Allergic rhinitis (AR) is a common childhood disease characterized by immunoglobulin E (IgE)-mediated inflammation of the nasal mucosa. Manifesting with nasal and ocular symptoms, this condition also adversely affects quality of life. This study aimed to evaluate symptom severity and identify clinical and laboratory factors associated with it in children diagnosed with AR.

Methods: This cross-sectional study was conducted between August and October 2025 at the Pediatric Allergy Clinic of İzmir City Hospital. A total of 260 children aged 6-18 years who were followed up with a diagnosis of AR and had a positive skin prick test were included. Demographic characteristics, symptoms, Allergic Rhinitis and its Impact on Asthma-based classifications according to severity and duration, sensitization patterns, total IgE, and eosinophil levels were recorded. Symptom severity was assessed using nasal and ocular visual analogue scale (VAS). Data were analyzed using SPSS software (IBM SPSS Statistics, version 27). Appropriate statistical tests were used for group comparisons and correlation analyses. A p-value of <0.05 was considered statistically significant.

Results: Of the patients included, 62.7% were male, with a mean age of 11.7±4.8 years. The most common sensitization was to pollen (66.2%). Among the participants, 56.9% were polysensitized, 66.2% were classified as having moderate-to-severe AR, and 53.1% had the persistent type. The mean nasal VAS score was 5.55±2.17, and the mean ocular VAS score was 3.6±3.6. Nasal symptom scores were significantly higher than ocular symptom scores (p<0.001). VAS scores were also significantly higher in polysensitized, moderate-to-severe, and persistent AR patients (p<0.05).

Conclusion: In children with AR, symptom severity is closely associated with disease phenotype and sensitization patterns. The use of VAS scores in clinical evaluation may facilitate objective assessment of symptom burden and contribute to the individualization of treatment strategies.

Keywords: Allergic rhinitis, allergy, child, symptoms, visual analogue scale

ÖZ

Amaç: Alerjik rinit (AR), çocukluk çağında sık görülen burun mukozasının immünoglobulin E (IgE) aracılı enflamasyonu ile karakterize bir hastalıktır. Nazal ve oküler semptomlarla kendini gösteren bu hastalık, yaşam kalitesini de olumsuz etkilemektedir. Bu çalışmanın amacı, AR tanılı çocuklarda semptomların şiddetini değerlendirmek ve semptom şiddetiyle ilişkili klinik ve laboratuvar faktörleri belirlemektir.

Gereç ve Yöntem: Kesitsel nitelikteki bu çalışma, Ağustos-Ekim 2025 tarihleri arasında İzmir Şehir Hastanesi Çocuk Alerji Kliniği'nde gerçekleştirildi. Çalışmaya, 6-18 yaş arasında olan, AR tanısıyla izlenen ve deri prick testi pozitif 260 çocuk dahil edildi. Hastaların demografik özellikleri, semptomları Alerjik Rinit ve Astım Üzerindeki Etkileri sınıflamasına göre ağırlık ve süre dağılımları, duyarlanma örüntüsü, total IgE ve eozinofil düzeyleri kaydedildi. Semptom şiddeti nazal ve oküler görsel analog skala (GAS) ile değerlendirildi. Veriler SPSS (IBM SPSS Statistics, sürüm 27) yazılımı ile analiz edildi; uygun istatistiksel testler kullanılarak gruplar arası karşılaştırmalar ve korelasyon analizleri yapıldı. p<0,05 değeri istatistiksel olarak anlamlı kabul edildi.

Bulgular: Çalışmaya katılan hastaların %62,7'si erkekti ve ortalama yaş 11,7±4,8 yıl idi. En sık duyarlanma polen (%66,2) ile saptandı. Hastaların %56,9'u polisensitize, %66,2'si orta-ağır AR grubunda, %53,1'i persistan tipteydi. Ortalama nazal GAS skoru 5,55±2,17, oküler GAS skoru 3,6±3,6 bulundu. Nazal semptom skorları oküler semptom skorlarından yüksekti (p<0,001). Polisensitize, orta-ağır ve persistan tipteki hastalarda da GAS skorları anlamlı şekilde yüksek bulundu (p<0,05).

Sonuç: Alerjik rinitli çocuklarda semptom şiddeti, hastalığın fenotipi ve duyarlanma örüntüleriyle yakından ilişkilidir. GAS skorunun klinik değerlendirmede kullanılması, semptomlar, yükünün objektif olarak belirlenmesine ve tedavi stratejilerinin bireyselleştirilmesine katkı sağlayabilir.

Anahtar Kelimeler: Alerjik rinit, alerji, çocuk, semptomlar, görsel analog skala

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INTRODUCTION

Allergic rhinitis (AR) is an inflammatory disease of the nasal mucosa associated with hypersensitivity to environmental allergens mediated by immunoglobulin E (IgE) (1). While it is observed in 10-40% of the pediatric population worldwide, studies conducted across different regions of Türkiye show that the prevalence ranges from 18% to 43% (2-4).

Sneezing, nasal congestion, clear nasal discharge, nasal itching, and watery, itchy eyes are the most common symptoms in patients with AR (1). Among patients, the phenotype of symptoms and their timing and duration can vary. Studies have generally shown that nasal symptoms are more prominent than ocular symptoms (5,6). In some patients with AR, complaints occur seasonally, while in others, they are perennial; some of these patients with perennial complaints experience seasonal exacerbations. Additionally, symptom severity varies among patients with AR (7). Additionally, AR may be accompanied by other allergic diseases, such as atopic dermatitis and asthma, and comorbidities, including gastro-oesophageal reflux, sinusitis, and otitis media (8).

AR impairs quality of life and causes morbidity (9). To define the burden caused by AR, the Allergic Rhinitis and its Impact on Asthma (ARIA) classification has been introduced. AR is classified as mild or moderate-to-severe by symptom severity, and as persistent or intermittent by duration (10). Various scoring systems can be used to assess symptom severity in children. These scoring systems guide the objective recording of patients' subjective experiences and the monitoring of treatment effectiveness (7).

The sensitization patterns of children with AR vary regionally; however, sensitization to house dust mites, pollen, molds, and pet epithelia is most commonly detected (5,11,12). Additionally, the polysensitization rate among patients with AR exceeds 50% (5,13). Studies have shown that monosensitized patients have milder symptoms and a less impaired quality of life than polysensitized patients (14,15).

AR in children is a disease that varies widely in terms of sensitization profile, symptom distribution, and clinical severity. A better understanding of clinical diversity and symptom patterns is of great importance for disease management and for personalized treatment strategies (16). This study aims to evaluate the patterns and severity of symptoms, and the factors affecting symptoms in children diagnosed with AR.

METHODS

Our study was cross-sectional, conducted at the İzmir City Hospital Children's Allergy Clinic from August 2024 to October 2025. Ethical approval for the non-interventional study, planned in accordance with the Helsinki Declaration, was obtained from the Non-Interventional Ethics Committee of the İzmir City Hospital (approval no: 2025/390, date: 10.09.2025). The sample size was calculated for 80% power, α=0.05, and an effect size (d) of 0.80; the planned sample size was 260 patients.

The study included children aged 6-18 years who were being followed up for a diagnosis of AR and who presented during the period of peak symptom severity. Inclusion criteria were a positive skin prick test, no AR-specific treatment within the past three months, and agreement by both the children and their parents to participate in the study. Each patient was evaluated during the season associated with the allergen to which they were allergic. Children under 6 years of age, those who had received treatment for AR within the previous three months, and those who declined to participate were excluded from the study. Detailed information regarding the study was provided to all eligible patients and their parents, and written informed consent was obtained prior to enrollment. A structured case report form was used to record the patients' age, sex, duration of symptoms, age at symptom onset, current complaints, symptom period, ARIA classification group, physical examination findings, and laboratory results (serum total IgE, skin prick test results, and eosinophil counts). The visual analogue scale (VAS) was used for the evaluation of symptoms. In this scoring system, nasal symptoms (sneezing, nasal discharge, nasal itching, and nasal congestion) and ocular symptoms (watery, itchy, and red eyes) were assessed. For each symptom, patients were asked to rate the severity of their experience on a VAS ranging from 0 (no symptom) to 10 (most severe). The mean VAS scores were calculated both for each individual symptom and for grouped nasal and ocular symptoms, and the results were reported accordingly. The ARIA classification was used to assess the severity and duration of AR symptoms. According to this classification, symptoms lasting more than 4 days per week and persisting more than 4 weeks were classified as persistent, while shorter durations were classified as intermittent. In addition, patients with no sleep disturbance, no impairment in daily activities or school performance, and no bothersome symptoms were classified as having mild disease, whereas the presence of at least one of these features indicated moderate-to-severe disease. Symptoms occurring year-round were classified as

perennial, whereas those appearing during specific seasons were classified as seasonal. An eosinophil count greater than 500/mm³ was considered eosinophilia. The results of skin-prick tests performed with extracts of pollen (*Plantago lanceolata*, *Olea europaea*, grass mix, *Chenopodium album*, *Artemisia vulgaris*); mites (*Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*); molds (*Alternaria alternata*, *Cladosporium herbarum*, *Aspergillus fumigatus*); and animal epithelia (cat, dog, and cockroach) were recorded. A wheal diameter at least 3 mm greater than that of the negative control was considered positive.

Statistical Analysis

The data obtained from the study were analyzed using IBM SPSS Statistics, version 27 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as mean±standard deviation or median [interquartile range (IQR)] for continuous variables and as percentages for categorical variables. The normality of data distribution was assessed using the Kolmogorov-Smirnov or Shapiro-Wilk tests. For continuous variables with a normal distribution, group comparisons were performed using the Student's t-test or one-way analysis of variance (ANOVA). When ANOVA results indicated significant differences, pairwise comparisons between groups were conducted using the Tukey's honest significant difference post-hoc test. For continuous variables that were not normally distributed, the Mann-Whitney U test or the Kruskal-Wallis test was applied. Associations between categorical variables were analyzed using the chi-square test. The relationship between VAS scores and allergen sensitization profiles was evaluated using Spearman's correlation analysis. A p-value of <0.05 was considered statistically significant in all analyses.

RESULTS

A total of 260 patients with AR were included in the study. Of these, 163 were male (62.7%) and 97 were female (37.3%), with a mean age of 11.7±4.8 years. The mean age at symptom onset was 7.1±3.4 years, and the mean duration of symptoms was 4.3±2.9 years. According to the ARIA severity classification, 88 patients (33.8%) had mild AR and 172 (66.2%) had moderate-to-severe AR; based on symptom duration, 122 patients (46.9%) were classified as intermittent and 138 (53.1%) as persistent. Complaints were seasonal in 101 patients (38.8%), perennial in 41 (15.8%), and perennial with seasonal exacerbations in 118 (45.4%). The general characteristics of the patients are summarized in Table 1.

When the patients' laboratory findings were evaluated, the median total IgE level was 366.0 IU/mL (IQR: 358.5 IU/mL) and the mean eosinophil count was 382.7±449.1/mm³. Eosinophilia was present in 61 patients (23.5%). Among the patients, 112 (43.1%) were monosensitized, whereas 148 (56.9%) were polysensitized. Sensitization to pollens was the most common (172 patients, 66.2%), followed by sensitization to animal allergens (140 patients, 53.8%), molds (83 patients, 31.9%), and mites (101 patients, 38.8%) (Table 2).

Analysis of individual nasal symptom VAS scores revealed that nasal congestion was the most severe symptom (6.1±3.1), followed by nasal discharge (5.7±3.1), nasal itching (5.2±2.9), and sneezing (5.1±2.7). Among ocular

Table 1. Demographic and clinical characteristics of the patients

Sex (M/F), n (%)		163 (62.7) / 97 (373)
Age, years (mean±SD)		11.7±4.8
Age at symptom onset, years (mean±SD)		7.1±3.4
Duration of symptoms, years (mean±SD)		4.3±2.9
Family history of atopy, n (%)		145 (55.8)
Presence of pets at home, n (%)		65 (25)
Exposure to cigarette smoke, n (%)		145 (55.8)
Comorbid allergic diseases, n (%)		
Asthma		129 (49.6)
Atopic dermatitis		51 (19.6)
AR classification, n (%)		
By severity	Mild	88 (33.8)
	Moderate-to-severe	172 (66.2)
By duration	Intermittent	122 (46.9)
	Persistent	138 (53.1)
AR classification by symptom timing, n (%)		
Seasonal		101 (38.8)
Perennial		41 (15.8)
Perennial with seasonal exacerbations		118 (45.4)

SD: Standard deviation, AR: Allergic rhinitis, M/F: Male/female

Table 2. Laboratory characteristics of the patients

Total IgE [IU/mL, (IQR)]	366.0 (358.5)
Eosinophil count (cells/mm³, mean±SD)	382.7±449.1
Presence of eosinophilia, n (%)	61 (23.5)
Sensitization pattern, n (%)	
Monosensitization	112 (43.1)
Polysensitization	148 (56.9)
Allergen sensitization, n (%)*	
Pollens	172 (66.2)
Animal dander	140 (53.8)
Molds	83 (31.9)
House dust mites	101 (38.8)

*: Percentages for allergen sensitization may exceed 100% because some patients were sensitized to multiple allergens, SD: Standard deviation, IQR: Interquartile range, IgE: Immunoglobulin E

symptoms, ocular itching was the most prominent (3.9±3.4), followed by watery eyes (3.5±3.2) and ocular redness (3.3±3.3) (Figure 1).

Evaluation of VAS scores by grouping symptoms into nasal and ocular categories showed a mean VAS score for nasal symptoms of 5.5±2.1, whereas the mean VAS score for ocular symptoms was 3.6±3.6. VAS scores for nasal symptoms were significantly higher than those for ocular symptoms ($p<0.001$). Analysis of patients by sensitization pattern revealed that both nasal and ocular VAS scores were significantly higher in polysensitized than in monosensitized patients ($p<0.05$). Regarding AR severity, patients with moderate-to-severe AR exhibited higher nasal and ocular VAS scores than those with mild AR. Additionally, VAS scores were higher in patients with persistent AR. Overall, nasal symptom scores were higher than ocular symptom scores (Table 3).

DISCUSSION

Our study demonstrates that children with polysensitized, moderate-to-severe, persistent AR exhibit more severe nasal and ocular symptoms. Additionally, symptom scores were higher in children with perennial AR, particularly in those with seasonal exacerbations. Nasal congestion was the most prominent nasal symptom, whereas ocular itching was the most severe ocular symptom.

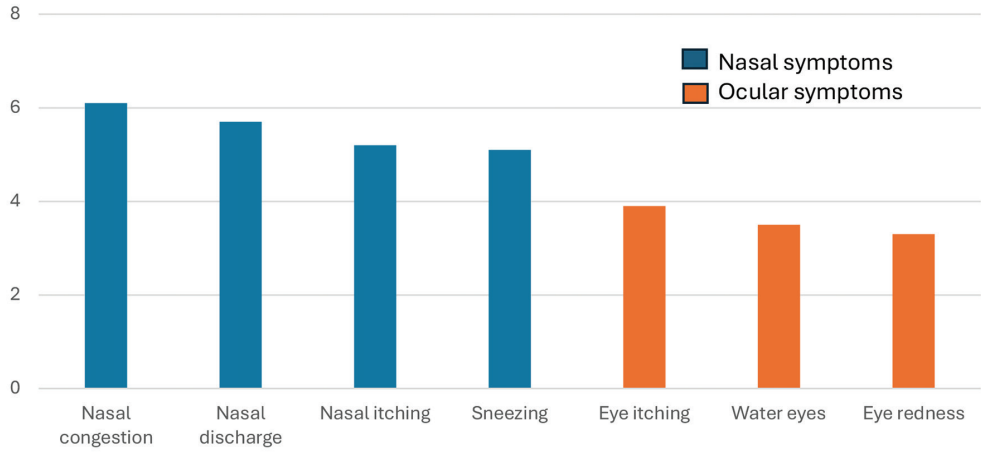

Figure 1. Nasal symptoms and ocular symptoms VAS scores of the patients
VAS: Visual analogue scale

Table 3. Evaluation of nasal and ocular symptom VAS scores according to clinical characteristics

	Ocular symptom-VAS results (mean±SD)		Nasal symptom-VAS results (mean±SD)	
Sensitization pattern				
Monosensitization	3.0±2.8	p=0.01	5.2±2.2	p=0.03
Polysensitization	4.1±4.0		5.7±2.0	
AR classification by severity				
Mild	2.5±2.8	p<0.001	4.7±2.1	p<0.001
Moderate-to-severe	4.2±3.8		5.9±2.0	
AR classification by duration				
Intermittent	3.0±2.9	p=0.005	4.8±2.1	p<0.001
Persistent	4.2±4.0		6.1±2.0	
AR classification by symptom timing				
Seasonal	2.8±2.9	p (ANOVA)=0.006*	4.8±2.0	p (ANOVA)=0.000**
Perennial	3.8±3.1		5.9±2.1	
Perennial with seasonal exacerbations	4.3±4.1		6.0±2.1	

*: Significant difference between the seasonal and perennial with seasonal exacerbations groups (Tukey post-hoc test, p=0.004), **: Significant differences were observed between the seasonal and perennial groups (Tukey post-hoc test, p=0.015) and between the seasonal and perennial with seasonal exacerbations groups (Tukey post-hoc test, p<0.001)
VAS: Visual analogue scale, ANOVA: Analysis of variance, AR: Allergic rhinitis

Ciğerci Günaydın et al. (17) reported in a study of 266 children with AR that the proportion of polysensitized patients was 45.1%. In a study conducted in China, including 4,279 patients with AR, the proportion of polysensitized patients was 60.11%, whereas another study in Greece, which involved 231 patients, reported 59.7% (5,18). In our study, consistent with the literature, polysensitized patients were more prevalent than monosensitized patients.

In a study by Filiz et al. (19) of children with AR, the mean nasal symptom score was 7.94±5.58, whereas the mean ocular symptom score was 2.23±1.75. Similarly, in our study, nasal symptoms were more prominent among the patients. A study of 1,054 children with AR found that nasal congestion affected approximately 70% of those with moderate-to-severe AR. This study also emphasized that nasal congestion is the most important symptom of AR (20). Similarly, in our study, the most severe symptom was found to be nasal congestion.

In a study of 619 children with asthma, 93.5% of whom also had AR, 37.8% experienced perennial symptoms with seasonal exacerbations, while 5.4% had purely perennial symptoms (21). In another study, 20% of symptoms were reported as seasonal, while 61.4% were perennial. In our study, 45.4% of patients had perennial symptoms with seasonal exacerbations, and 15.8% had exclusively perennial symptoms (22). A study of 75 children with AR found that VAS scores were higher in children with perennial symptoms than in those with seasonal symptoms. The same study also found that patients with moderate-to-severe AR had higher nasal and ocular VAS scores than those with mild AR (23). In our study, patients with AR who experienced perennial symptoms with seasonal exacerbations demonstrated higher nasal and ocular VAS scores than those with seasonal only or purely perennial symptoms. Furthermore, patients with moderate-to-severe AR had higher nasal and ocular VAS scores than those with mild AR. These findings are likely attributable to the high prevalence of polysensitization and pollen sensitization among the patients.

A multicenter study in Spain that included 1,269 children (aged 6-12 years) with AR reported that 59.5% of the children had intermittent AR and 89.9% had moderate-to-severe AR. The study also found that participants were most commonly sensitized to pollen (53.5%) (24). Another study conducted in China that included 1,054 children with AR reported that 19.2% of the children had intermittent AR and 57.3% had moderate-to-severe AR. In this study, sensitization to house dust mites was most common (20). In a study conducted in Greece that included 675 school-aged children, sensitization was most commonly to house dust and second most commonly to pollen (5). Sensitization was reported to be most common to pollen, with house dust mites the second most frequent, in a study conducted in Türkiye (25). In our study, 46.9% of patients had intermittent AR and 66.2% had moderate-to-severe AR; sensitization was most commonly observed to pollen (66.2%). These results support the notion that sensitization profiles vary between countries and even regions, and that the timing of symptom onset differs according to sensitization patterns.

Study Limitations

The limitations of our study include its single-center design and a relatively small number of patients. Additionally, because the number of monosensitized patients was low, nasal and ocular VAS scores could not be analyzed separately according to sensitization profiles. The patient group included seasonal cases, perennial cases, and perennial cases with seasonal exacerbations, and was therefore heterogeneous. Although this may be considered a limitation because it may affect the distribution of symptoms, it also provides insight into different AR types based on symptom timing. Nevertheless, the study is highly valuable as a prospective, real-life investigation evaluating VAS scores in children with AR according to the ARIA classification.

CONCLUSION

AR is a common condition that is often comorbid with other disorders and adversely affects quality of life. Our study is important because it evaluates symptoms in children with AR based on sensitization patterns and AR classifications and demonstrates that the phenotypic characteristics of AR significantly affect symptom severity.

ETHICS

Ethics Committee Approval: Ethical approval for the non-interventional study, planned in accordance with the Helsinki Declaration, was obtained from the Non-Interventional Ethics Committee of the İzmir City Hospital (approval no: 2025/390, date: 10.09.2025).

Informed Consent: Detailed information regarding the study was provided to all eligible patients and their parents, and written informed consent was obtained prior to enrollment.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: E.Ş.Y., İ.T., İ.A.H., R.Y., İ.N.Ş., T.T., Concept: E.Ş.Y., T.T., Design: E.Ş.Y., T.T., Data Collection

or Processing: E.Ş.Y., İ.T., İ.A.H., R.Y., İ.N.Ş., Analysis or Interpretation: E.Ş.Y., İ.T., Literature Search: E.Ş.Y., Writing: E.Ş.Y., T.T.

Conflict of Interest: No conflict of interest was declared by the authors.

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Research

Clinical Significance of Incidental Colorectal FDG-Avid Lesions on Oncologic 18F-FDG PET/CT: Colonoscopy and Pathology Correlation

İnsidental Kolorektal FDG-Avid Lezyonların Klinik Önemi: Onkolojik 18F-FDG PET/BT Bulgularının Kolonoskopi ve Patoloji ile Karşılaştırılması

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ABSTRACT

Objective: To evaluate the clinical significance of incidental focal colorectal fluorodeoxyglucose (FDG)-avid lesions detected on oncologic positron emission tomography/computed tomography (PET/CT) by correlating uptake intensity with colonoscopy and, when available, histopathology.

Methods: In this single-centre retrospective study, patients who underwent oncologic 18F-FDG PET/CT (October 2012-October 2025) and were referred for colonoscopy because of an incidental focal colorectal FDG-avid lesion were included if colonoscopy had been completed, forming a selected referral cohort (n=208). The lesion's maximum standardized uptake value (SUV_{max}) was recorded. Colonoscopy outcomes were classified as neoplastic lesion present (polyp or mass/tumour) versus no neoplastic lesion. Histopathology was available in 149 of 208 patients; pathology was grouped as cancer, high-grade dysplasia (HGD), or low-grade dysplasia or benign pathology, and advanced neoplasia was defined as cancer or HGD. Discrimination was assessed using receiver operating characteristic analysis for SUV_{max} alone and for simple covariate-adjusted models, with internal validation via stratified 5-fold cross-validation using out-of-fold predictions.

Results: The median age was 66 years; 59.6% were male. Colonoscopy identified neoplastic lesions in 133 of 208 patients (63.9%). In the histology subset (n=149), 44 cancers and 61 HGD lesions were found; advanced neoplasia was present in 105/149 (70.5%). SUV_{max} showed moderate discrimination for colonoscopy-defined neoplastic lesions [area under the curve (AUC): 0.724; 95% confidence interval (CI): 0.655-0.796], advanced neoplasia (AUC: 0.702; 95% CI: 0.605-0.785), and cancer (AUC: 0.729; 95% CI: 0.639-0.811). Covariate-adjusted models yielded only modest improvements for colonoscopy-based detection and no improvements for histology-verified endpoints.

Conclusion: Incidental focal colorectal FDG uptake prompting colonoscopy is frequently associated with clinically relevant findings. SUV_{max} provides moderate discrimination, whereas simple covariate-adjusted models add limited value for pathology-defined outcomes in this referred population.

Keywords: PET/CT, 18F-FDG, colon neoplasms, colon cancer, colonoscopy, colonic polyps

ÖZ

Amaç: Onkolojik pozitron emisyon tomografi/bilgisayarlı tomografide (PET/BT) insidental saptanan kolorektal florodeoksiglukoz (FDG)-avid lezyonların klinik önemini, tutulum şiddetini kolonoskopi ve mevcut olduğunda histopatoloji ile ilişkilendirerek değerlendirmek.

Gereç ve Yöntem: Ekim 2012-Ekim 2025 arasında onkolojik 18F-FDG PET/BT'de insidental kolorektal FDG-avid lezyon saptanıp kolonoskopi önerilen olgular arasından kolonoskopisi tamamlanan hastalar analize alındı; bu kriterlerle kolonoskopisi tamamlanmış seçilmiş bir sevk kohortu elde edildi (n=208). Lezyon maksimum standartlaştırılmış tutulum değeri (SUV_{maks}) kaydedildi. Kolonoskopi sonucu neoplastik lezyon var (polip/kitle) ve neoplastik lezyon yok (normal veya benign/enflamatuvar bulgular) olarak sınıflandırıldı. Histopatoloji mevcut hastalarda (n=149) patoloji; kanser, yüksek dereceli displazi (YDD) veya düşük dereceli/benign olarak gruplandı; ileri neoplazi kanser veya YDD olarak tanımlandı. Ayırıcı performans alıcı işletim karakteristiği eğrisi analizi ile değerlendirildi; iç doğrulama stratifiye 5-kat çapraz doğrulamada dış-kat tahminlere dayalı olarak yapıldı.

Bulgular: Medyan yaş 66 yıl olup hastaların %59,6'sı erkekti. Kolonoskopide 133/208 (%63,9) hastada neoplastik lezyon saptandı. Histopatolojisi olan 149 hastanın 44'ünde kanser, 61'inde YDD mevcuttu; ileri neoplazi 105/149 (%70,5) hastada görüldü. SUV_{maks}, kolonoskopi temelli neoplastik lezyon varlığını orta düzeyde ayırt etti [eğri altındaki alan (AUC): 0,724; %95 güven aralığı (GA): 0,655-0,796] ve ileri neoplazi (AUC: 0,702; %95 GA: 0,605-0,785) ile kanser (AUC: 0,729; %95 GA: 0,639-0,811) için de benzer performans gösterdi. Çok değişkenli modeller kolonoskopi temelli uç noktada sınırlı kazanım sağladı ve histoloji doğrulamalı uç noktalarda performansı artırmadı.

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ÖZ

Sonuç: PET/BT'de insidental saptanan ve kolonoskopi önerilen kolorektal FDG-avid lezyonlar, klinik açıdan sıklıkla anlamlı bulgularla ilişkiliydi. SUV_{maks} orta düzeyde ayırıcı performans sağlarken, bu popülasyonda patoloji temelli uç noktalarda basit çok değişkenli modellerin ek katkısı sınırlı görünmektedir.

Anahtar Kelimeler: PET/BT, 18F-FDG, kolon neoplazm, kolon kanseri, kolonoskopi, kolon polipleri

INTRODUCTION

18F-fluorodeoxyglucose positron emission tomography/computed tomography (18F-FDG PET/CT) is widely employed for staging, restaging, and assessing treatment responses in numerous malignancies. Incidental gastrointestinal findings, particularly unexpected focal or discrete FDG-avid colorectal lesions, become more common as the volume of oncologic PET/CT examinations increases. Some of these lesions represent clinically important neoplasia. Nevertheless, interpretation is often challenging because physiological bowel activity, benign polyps, diverticular disease, metformin use, and inflammatory conditions can also cause increased FDG uptake. This can lead to a potentially avoidable colonoscopy or, conversely, a delayed diagnosis if an abnormality is dismissed as nonspecific uptake (1,2).

Several single-centre series have shown that an incidental colorectal FDG-avid lesion on PET/CT carries a meaningful probability of clinically relevant pathology, including advanced adenoma and colorectal cancer, when correlated with colonoscopy and histopathology (2-6). At the same time, reported rates of malignancy and advanced neoplasia vary considerably across studies. This heterogeneity likely reflects differences in underlying patient populations; imaging and inclusion criteria such as focal versus segmental uptake and the extent of CT correlation; and verification strategies that depend on completion of colonoscopy and histology (7-12).

A practical clinical question is whether PET-derived quantitative metrics, particularly the maximum standardized uptake value (SUV_{max}), can help triage patients referred for colonoscopy after incidental focal colorectal FDG uptake on PET/CT. Prior work suggests that higher SUV_{max} values are more often associated with neoplastic pathology, but proposed thresholds and their clinical utility remain inconsistent across cohorts. In many settings, SUV_{max} alone may be insufficient for reliable discrimination (13-18). For this reason, multimodal approaches that incorporate CT correlations, including localised wall thickening and contrast-enhanced CT findings, have been evaluated to improve diagnostic confidence and reduce false-positive interpretations (1,3,17,19). In addition, dual-time-point and bowel-preparation PET/CT strategies, such as water-enema PET/CT, have been investigated; however, these methods may not be feasible in routine workflows and have not fully addressed the central triage problem in real-world practice (20,21).

Outcome definition is another important driver of variability. Clinically, it is not enough to report "any colonoscopic lesion." Separating histologically verified advanced neoplasia, such as high-grade dysplasia (HGD) and carcinoma, from invasive cancer has direct implications for prioritisation and patient counselling. Evidence from primary studies, systematic reviews, and meta-analyses indicates ongoing uncertainty about which endpoints should be emphasised and how to handle incomplete histologic verification when colonoscopy is normal or when biopsy or resection is not performed (8-10,22). These considerations support the need for transparent reporting and clinically interpretable analyses in diagnostic accuracy and prediction model studies (23,24).

In this context, we conducted a retrospective observational study to evaluate the clinical significance of incidental colorectal FDG-avid lesions detected on oncologic 18F-FDG PET/CT, correlating PET/CT findings with colonoscopy and, when available, histopathology. Our aims were to describe colonoscopy and pathology outcomes in a consecutive cohort undergoing colonoscopy after a PET/CT recommendation and to quantify the discriminative performance of SUV_{max}, both alone and as part of internally validated multivariable models, for clinically relevant endpoints. These endpoints included colonoscopy-detected lesions (polyp or mass/tumour), histologically verified HGD, and cancer. Reporting was guided by established recommendations for diagnostic accuracy studies and multivariable prediction models (23,24).

METHODS

Study Design and Setting

This retrospective observational study evaluated the clinical significance of incidental colorectal FDG-avid lesions detected on PET/CT by correlating PET/CT findings with colonoscopy and histopathology.

Study Period and Case Identification

Between October 2012 and October 2025, a total of 40,111 PET/CT examinations were reviewed. Among these, 1,151 examination reports included a recommendation for

colonoscopy. The final study cohort comprised 208 patients with completed colonoscopy results (Supplementary Figure S1).

Inclusion and Exclusion Criteria

Inclusion criteria were: an incidental colorectal FDG-avid focal or discrete lesion reported on PET/CT that prompted a colonoscopy recommendation, and a completed colonoscopy report available for review, thereby defining a referral cohort with completed colonoscopy.

Diffuse or segmental colorectal FDG uptake was excluded; the analysis was restricted to focal, discrete FDG-avid colorectal lesions that triggered a colonoscopy recommendation. Patients were excluded if a colonoscopy was not performed or if the report was missing or incomplete.

Reference Standards and Endpoint Definitions

Colonoscopy findings were categorised into five mutually exclusive classes: normal, polyp, mass/tumour, inflammatory/ulcerative, and diverticular disease. A polyp was defined as any mucosal polypoid lesion detected at colonoscopy and reported by the endoscopist, regardless of histology or size.

Lesion location was recorded from colonoscopy reports and categorised as the right colon (caecum to transverse colon), the left colon (splenic flexure to sigmoid colon), or the rectum.

The primary endpoint was the presence of lesions detected by colonoscopy, defined as polyp or mass/tumour versus normal. Inflammatory, ulcerative, and diverticular findings were not considered lesions in the definition of the primary endpoint. This classification was pre-specified because inflammatory or ulcerative changes and diverticular disease represent non-neoplastic conditions and do not constitute neoplastic lesions on colonoscopy in the absence of polypoid lesions or masses/tumours.

Histopathology was available only when tissue sampling was performed; therefore, histopathology was typically absent when colonoscopy showed no abnormalities. This introduces partial verification (work-up) bias for pathology-defined endpoints. Accordingly, pathology-defined endpoints (advanced neoplasia and cancer) were analysed primarily in the histology-verified subset. As a complementary sensitivity analysis, we also performed a full-cohort analysis classifying cases without histology as non-advanced neoplasia, reflecting the clinical scenario in which a normal colonoscopy generally does not require biopsy. Accordingly, this full-cohort classification should be interpreted strictly as a sensitivity analysis under a strong assumption, and may underestimate advanced neoplasia if any lesions were present but not sampled.

Histopathology was available for a subset of patients (n=149). Histology results were grouped into cancer (1), HGD (2), and low-grade/benign (3). Advanced neoplasia was defined as cancer or HGD.

For advanced neoplasia, two analyses were performed: (i) a verified analysis restricted to patients with available histology and (ii) a full-cohort sensitivity analysis in which missing histology was treated as non-advanced neoplasia under a strong assumption.

The cancer versus non-cancer distinction was evaluated as a secondary, histology-defined endpoint within the subset with available histology.

Image Acquisition and Quantitative Assessment

Patients underwent whole-body 18F-FDG PET/CT imaging after fasting for at least 6 hours. Imaging was performed 50-70 minutes after intravenous administration of 3.7 MBq/kg 18F-FDG, provided that blood glucose was <200 mg/dL. Scans were acquired supine on an integrated PET/CT system (Philips Gemini TF 64; Philips Medical Systems, The Netherlands). A low-dose CT was acquired for attenuation correction and anatomic localisation prior to three-dimensional PET acquisition, which used standard attenuation correction. SUV_{max} was measured for a lesion showing incidental colorectal FDG uptake (Figure 1). SUV_{max} was defined as the highest voxel value within a volume of interest, delineated using the 40% SUV_{max} isocontour on attenuation-corrected PET images, and normalised to body weight.

Ethical approval was obtained from the İstanbul Medeniyet University, Göztepe Training and Research Hospital Clinical

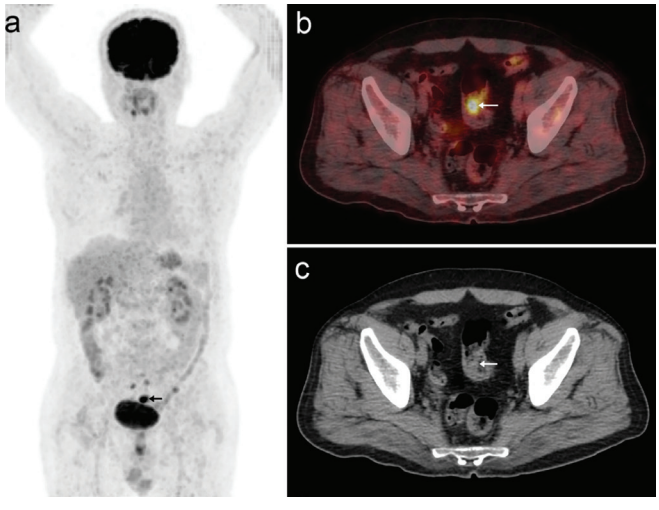

Figure 1. Representative example of incidental focal colorectal 18F-FDG uptake. Descriptions of Figure 1 are available in the Supplementary Material

18F-FDG: 18F-fluorodeoxyglucose

Research Ethics Committee (approval no: 2021/0595, date: 24.11.2021).

Statistical Analysis

Analyses were conducted in Python (Jupyter Notebook). Continuous variables are presented as median (IQR) and categorical variables as n (%). Diagnostic performance was assessed using receiver operating characteristic (ROC)/area under the curve (AUC) analysis, and secondary multivariable logistic regression models were evaluated with internal validation; full methodological details (bootstrap procedures, cut-off derivation, calibration assessment, and sensitivity analyses) are provided in the Supplementary Material.

RESULTS

Study Cohort

Between October 2012 and October 2025, 40,111 oncologic 18F-FDG PET/CT examinations were performed; of these, 1,151 examinations included a report recommending colonoscopy due to an incidental FDG-avid focal or discrete colorectal lesion. Of these, 208 patients who had completed colonoscopy and for whom a colonoscopy report was available were included in the analysis, forming a selected, colonoscopy-completed referral cohort.

The median age was 66.0 years (IQR: 58.0-74.0), and the median SUV_{max} was 9.1 (IQR: 6.7-13.1). In the cohort, 84 participants (40.4%) were female and 124 (59.6%) were male. Lesion location was classified as right colon in 56 (26.9%), transverse colon in 11 (5.3%), left colon in 96 (46.2%), and rectum/rectosigmoid in 45 (21.6%) (Supplementary Table S1). The median interval between PET/CT and colonoscopy was 23 days (IQR: 9-57 days).

On colonoscopy, findings were normal in 56 (26.9%), polyps in 88 (42.3%), masses/tumours in 45 (21.6%), inflammatory/ulcerative lesions in 13 (6.2%), and diverticular disease in 6 (2.9%) (Supplementary Table S1). Based on the prespecified definition, a neoplastic lesion on colonoscopy (lesion-any=1; polyp or mass/tumour) was identified in 133 (63.9%) patients, whereas lesion-any=0 indicated no neoplastic lesion on colonoscopy (normal, inflammatory/ulcerative, or diverticular findings), and these findings were classified as non-neoplastic for the colonoscopy-based endpoint.

Histopathology was available for 149 (71.6%) patients. Within this subgroup, histology showed cancer in 44 (29.5%), HGD in 61 (40.9%), and low-grade or benign pathology in 44 (29.5%). Advanced neoplasia (cancer or HGD) was present in 105 (70.5%) (Supplementary Table S1). Histology was unavailable primarily for cases with a normal colonoscopy because biopsies are not routinely obtained. Thus, missing pathology in the normal colonoscopy subgroup was largely structural and should not be interpreted as an independent negative verification.

Primary Endpoint: Neoplastic Lesion on Colonoscopy

SUV_{max} showed moderate discrimination for detecting a neoplastic lesion at colonoscopy (lesion-any) in the full cohort, with an AUC of 0.724 (95% CI: 0.655-0.796) (Figure 2a, Supplementary Table S2a). The Youden-optimal SUV_{max} cut-off was 8.7 (descriptive), yielding a sensitivity of 67.7% and a specificity of 70.7% (Supplementary Table S2), and should be interpreted as a descriptive, cohort-specific summary rather than a prescriptive clinical threshold. Prespecified thresholds are summarised in Supplementary Table S2.

Histology-Defined Advanced Neoplasia

In the histology-verified analysis (n=149), SUV_{max} discriminated advanced neoplasia with an AUC of 0.702 (95% CI: 0.605-0.785) (Figure 2b, Supplementary Table S2b). The Youden-optimal cut-off was 10.4 (Supplementary Table S3), but it should not be interpreted as a validated clinical decision threshold. In the full-cohort sensitivity analysis, under a strong assumption that missing histology indicates non-advanced neoplasia (n=208), discrimination was similar (AUC: 0.739; 95% CI: 0.667-0.807), with the same Youden-optimal cut-off (10.4) (Figure 2c, Supplementary Table S2c).

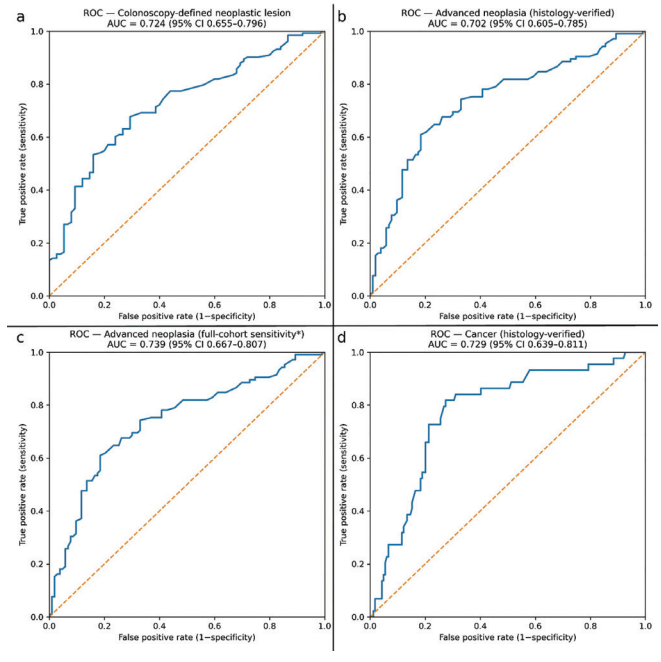

Figure 2. ROC curves of SUV_{max} for colonoscopy- and pathology-defined colorectal outcomes. Descriptions of Figure 2 are available in the Supplementary Material

ROC: Receiver operating characteristic, SUV_{max}: Maximum standardized uptake value, AUC: Area under the curve

Histology-Verified Cancer

Within the subgroup with available histology (n=149), SUV_{max} discriminated cancer from non-cancer histology with an AUC of 0.729 (95% CI: 0.639-0.811) (Figure 2d; Supplementary Table S2d). The Youden-optimal SUV_{max} cut-off was 10.5 (Supplementary Table S2d) but should not be interpreted as a validated clinical decision threshold.

Incremental Value of Simple Multivariable Models

Simple multivariable models provided internally validated discrimination estimates for the colonoscopy-based endpoint. For lesion-any, the multivariable model achieved an out-of-fold (OOF) AUC of 0.755 (95% CI: 0.687-0.821) (Supplementary Table S3). For histology-verified endpoints, the multivariable OOF AUC was 0.660 for advanced neoplasia (95% CI: 0.557-0.747) and 0.676 for cancer (95% CI: 0.577-0.767) (Supplementary Table S3). SUV_{max}-only ROC/AUC summaries are reported descriptively in Figure 2 and are not presented as directly comparable to cross-validated OOF AUCs from multivariable models.

Calibration of Multivariable Models (OOF)

Calibration summaries based on OOF predictions are presented in Figure 3 and Supplementary Table S3. For lesion-any, calibration was close to ideal (intercept 0.026; slope 0.939), indicating minimal systematic miscalibration (intercept near 0) and an appropriate dispersion of predicted risks (slope near 1). For histology-verified endpoints, calibration slopes were below 1, indicating that predictions were more extreme than the observed outcomes (advanced neoplasia: intercept 0.244, slope 0.712; cancer: intercept -0.339, slope 0.578), consistent with overfitting or overconfidence in the risk estimates. In addition, the positive intercept for advanced neoplasia suggests an overall underestimation of risk, whereas the negative intercept for cancer suggests an overall overestimation, as visualised in the calibration plots (Figure 3).

DISCUSSION

In this single-centre retrospective cohort study (October 2012-October 2025), incidental focal colorectal FDG-avid uptake on oncologic 18F-FDG PET/CT that prompted colonoscopy was associated with a high prevalence of clinically relevant findings: among 208 patients who completed colonoscopy, lesions were identified in nearly two-thirds of cases, and advanced neoplasia was common in the histology-verified subset (n=149). These findings support the practical message that such focal uptake should not be dismissed as physiological when it triggers endoscopic referral (2-6).

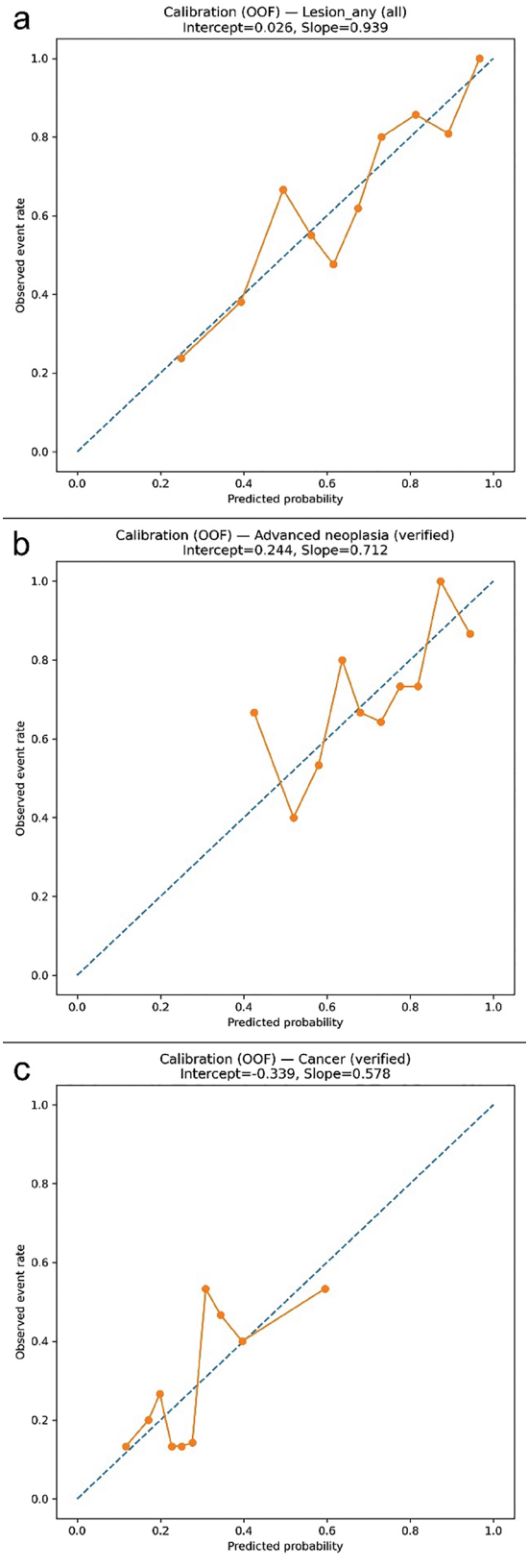

Figure 3. Calibration of multivariable models using out-of-fold (OOF) predictions. Descriptions of Figure 3 are available in the Supplementary Material

Principal Diagnostic Findings and Interpretation

Our discrimination analyses showed that SUV_{max} alone achieved moderate accuracy for detecting any colonoscopic lesion, and adding basic clinical/anatomic covariates provided only a small incremental gain for this broad endpoint. In contrast, for histology-verified endpoints (advanced neoplasia and cancer), SUV_{max} again demonstrated moderate discrimination, while multivariable models did not provide consistent improvement. This pattern suggests that in routine practice, SUV_{max} is a key quantitative signal for triage, whereas the incremental value of simple covariates (age, sex, coarse anatomic location) may be limited once colonoscopy referral has occurred. Similar heterogeneity in the incremental value of quantitative PET parameters and widely varying SUV_{max}-based thresholds have been reported across cohorts, likely reflecting differences in populations, referral criteria, and reference standards (13-18). Calibration was close to ideal for the colonoscopy-based endpoint (lesion-any), whereas histology-verified endpoints showed slopes <1, suggesting overfitting and indicating the need for external validation and, if required, recalibration before clinical use.

Several factors may explain why multivariable models provided little additional discrimination beyond SUV_{max} for histology-verified endpoints in our cohort. First, this pragmatic colonoscopy-completed referral cohort shapes the disease spectrum and may diminish the incremental value of simple clinical covariates while preserving the dominant effect of uptake intensity. Second, histology is outcome-dependent in routine practice: when colonoscopy is normal, tissue sampling is typically not indicated, and histopathology is therefore unavailable; accordingly, pathology-defined endpoints were analysed in the histology-verified subset, whereas "any colonoscopic lesion" was assessed across the full cohort. Finally, predictors that may add value elsewhere, particularly CT-based features (e.g., localized wall thickening or contrast-enhanced CT features), were not comprehensively captured in our dataset, thereby limiting gains beyond SUV_{max} (1,3,17,19).

Comparison with Prior Literature

Our findings are consistent with prior observational series and meta-analyses showing that incidental focal colorectal FDG uptake is associated with a meaningful prevalence of clinically significant lesions identified at colonoscopy and, when available, confirmed by histopathology, and therefore generally warrants endoscopic evaluation, although predictive values vary across settings and inclusion criteria (2-6,8-10,22). This variability cautions against using a single SUV_{max} threshold as a universal "rule-out" criterion. Consistent with this, our Youden-derived cut-offs should be viewed as cohort-specific statistical summaries rather than clinically generalisable decision thresholds. Studies that specifically addressed whether SUV_{max} can guide colonoscopy timing have reached mixed conclusions; some report a higher risk associated with greater SUV_{max} values, but the studies have not converged on a single, widely accepted cut-off (13-18). This supports a pragmatic approach in which SUV_{max} is interpreted alongside the qualitative uptake pattern and the available CT correlation, rather than being used in isolation (1,3,17,19). However, discrimination metrics such as AUC do not directly translate into clinical utility. In practice, the usefulness of SUV_{max}-based triage depends on the chosen referral threshold and the relative consequences of missed neoplasia versus unnecessary colonoscopies; therefore, thresholds should be selected within a decision-analytic framework and externally validated rather than inferred solely from the AUC.

Recent real-world data from Türkiye also indicate that incidental colorectal FDG uptake on PET/CT is often clinically relevant. In that cohort, incidental uptake was associated with endoscopic and pathologic abnormalities, and SUV_{max} was reported as a useful quantitative marker to support risk assessment (25). Taken together with prior literature, these findings reinforce the need for careful reporting and appropriate endoscopic work-up of incidental FDG-avid colorectal lesions detected on oncologic PET/CT (2-6,8-10,22,25).

From a clinical workflow perspective, our results support recommending colonoscopy for incidental focal colorectal FDG-avid uptake and reinforce that a substantial fraction of referred patients harbour clinically meaningful pathology. However, in this previously referred population, simple covariate-adjusted models did not demonstrate reliable added value over SUV_{max} for predicting advanced neoplasia or cancer. SUV_{max} may therefore serve as a supportive quantitative triage signal, but should not be used to downgrade the indication for colonoscopy when uptake is suspicious. In real-world oncologic settings, where competing risks and treatment timelines influence endoscopic workup, proposed refinements based on lesion location or referral context remain inconsistent and should therefore be applied cautiously (26-29). Our findings highlight that richer imaging correlations may be required to develop more robust triage tools beyond SUV_{max}.

Strengths

The strengths of this study include a clinically grounded cohort derived from routine PET/CT reporting and a clear endoscopic reference standard in all included patients,

with histopathology available for the majority. We also evaluated clinically relevant endpoints at different levels of stringency, including "any lesion on colonoscopy," histology-verified advanced neoplasia, and cancer, and reported discrimination using internal validation methods consistent with current reporting expectations (23,24).

Study Limitations

Several limitations merit emphasis. The retrospective single-centre design limits generalisability. Our cohort is enriched by design because it includes only patients for whom colonoscopy was recommended and completed. Therefore, our findings should be interpreted as performance estimates within a selected referral pathway rather than as prevalence estimates for all PET/CT patients. Histology was not uniformly available because tissue sampling occurs only when a biopsy or polypectomy is performed, which may introduce partial verification (work-up) bias for pathology-defined endpoints. Accordingly, we prioritised analyses of the histology-verified subset for advanced neoplasia and cancer, and we presented the classification of missing histology in the full cohort as non-advanced neoplasia, strictly as a sensitivity analysis under a strong, clinically motivated assumption. In addition, PET acquisition and reconstruction parameters, as well as uptake time variability, can influence SUV measurements. Although our institutional workflow follows a standard uptake time window, patient-level deviations were not explicitly modelled and may have introduced measurement noise (12). Finally, we did not incorporate more granular CT features, dual-time-point imaging, or dedicated bowel preparation protocols, all of which have shown promise in selected settings and could improve triage performance if available (20,21).

Future Directions

Future work should integrate imaging features beyond SUV_{max}, particularly CT correlates (e.g., focal wall thickening or morphologic abnormalities), and evaluate their added value for advanced neoplasia in externally validated, preferably multi-centre cohorts (1,17,19). Stratification by referral context and background malignancy status may help identify subgroups most likely to benefit from expedited colonoscopy, and harmonised endpoint definitions, with transparent handling of pathology-defined outcomes, will be essential for comparability across studies (23,24,27,29).

CONCLUSION

In a PET/CT-referred cohort undergoing colonoscopy, incidental colorectal FDG-avid lesions were frequently associated with clinically meaningful findings, including a high prevalence of advanced neoplasia among histology-verified cases. SUV_{max} provided moderate discrimination across endpoints, while simple multivariable models did not consistently add value for histologically verified advanced neoplasia or cancer. These results support prompt endoscopic evaluation of suspicious incidental colorectal FDG-avid lesions and suggest that improved triage tools will likely require incorporating richer imaging correlates beyond SUV_{max}.

ETHICS

Ethics Committee Approval: Ethical approval was obtained from the İstanbul Medeniyet University, Göztepe Training and Research Hospital Clinical Research Ethics Committee (approval no: 2021/0595, date: 24.11.2021).

Informed Consent: Retrospective study.

FOOTNOTES

Authorship Contributions

Concept: M.T.T., E.İ., Design: M.T.T., E.İ., Data Collection or Processing: M.T.T., E.İ., Analysis or Interpretation: M.T.T., E.İ., Literature Search: M.T.T., Writing: M.T.T.

Conflict of Interest: No conflict of interest was declared by the authors.

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Supplementary Material Links: https://d2v96fxpocvxx.cloudfront.net/68ab204c-182b-49da-b227-bc7efe058632/content-images/9db4d66b-4b8f-4358-a8b7-8d08220b423d.pdf

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Research

Evaluation of the Clinical and Endoscopic Characteristics of Duodenitis in Children

Çocuklarda Duodenitin Klinik ve Endoskopik Özelliklerinin Değerlendirilmesi

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ABSTRACT

Objective: Compared to gastritis and esophagitis, research on duodenitis in children remains limited. This study aimed to evaluate the etiological, endoscopic, and histopathological characteristics of biopsy-proven duodenitis in a large pediatric cohort.

Methods: The pathology reports of children who underwent upper gastrointestinal (GI) endoscopy at the pediatric gastroenterology department between January 2011 and December 2017 were retrospectively analyzed. Demographic data, complaints, endoscopic findings, and histopathological results were recorded and analyzed.

Results: Duodenitis was detected in 1,494 (24%) of 6,223 patients who underwent endoscopy, with a mean age of 9.1±3.2, and 53.3% were female. The most common symptoms were periumbilical pain (64.6%), vomiting (51.9%), epigastric pain (50.3%), and regurgitation (46.0%). Growth retardation was observed in 31.9% of cases, GI bleeding in 25%, and refractory iron deficiency anemia in 11.9%. Endoscopy revealed antral hyperemia (83.9%), antral nodularity (61.4%), corpus hyperemia (52.4%), esophageal hyperemia (46%), duodenal hyperemia (46%), and bulbar hyperemia (41.1%). Histopathological examination revealed acute inflammatory cells in 45.7% of cases, chronic inflammation in 54.2% of cases, *Helicobacter pylori (H. pylori)* in 46.0% of cases, and increased intraepithelial lymphocytes in 30.1% of cases. According to the Marsh classification, 13.5% of the patients were in stage 1, 7.5% in stage 2, and 4.7% in stage 3. The etiological factors were *H. pylori* gastritis (46%) and celiac disease (25.7%).

Conclusion: Duodenal biopsy is an important diagnostic tool in pediatric endoscopy, especially for detecting *H. pylori* gastritis, celiac disease, and *giardiasis*.

Keywords: Endoscopy, biopsy, duodenitis

ÖZ

Amaç: Gastrit ve özofajite kıyasla, çocuklarda duodenit üzerine yapılan araştırmalar sınırlıdır. Bu çalışmanın amacı, biyopsi ile doğrulanmış duodenitin etiyolojik, endoskopik ve histopatolojik özelliklerini geniş bir pediatrik kohortta değerlendirmektir.

Gereç ve Yöntem: Ocak 2011 ile Aralık 2017 tarihleri arasında çocuk gastroenterolojisi bölümünde üst gastrointestinal (Gİ) endoskopi uygulanan çocukların patoloji raporlarını geriye dönük olarak analiz edildi. Demografik verileri, şikayetleri, endoskopik bulguları ve histopatolojik sonuçları kaydedilerek analiz edildi.

Bulgular: Altın bin iki yüz yirmi üç endoskopiye alınan hastanın 1,494'ünde (%24) ortalama 9,1±3,2 yaşla duodenit tespit edildi; %53,3'ü kadındı. En sık semptomlar periumbilikal ağrı (%64,6), kusma (%51,9), epigastrik ağrı (%50,3) ve geğirme (%46) idi. Olguların %31,9'unda büyüme geriliği, %25'inde Gİ kanama, %11,9'unda refrakter demir eksikliği anemisi görüldü. Endoskopide antral hiperemi (%83,9), antral nodülarite (%61,4), korpus

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ÖZ

hiperemi (%52,4), özofagus hiperemi (%46), duodenal hiperemi (%46), bulbar hiperemi (%41,1) saptandı. Histopatolojik incelemede, olguların %45,7'sinde akut enflamatuvar hücreler, %54,2'sinde kronik enflamasyon, %46'sında *Helicobacter pylori (H. pylori)*, %30,1'inde artmış intraepitelyal lenfositler görüldü. Marsh sınıflandırmasında, olguların %13,5'i evre 1, %7,5'i evre 2 ve %4,7'si evre 3'tü. Etiyolojik faktörler *H. pylori* gastriti (%46), çölyak hastalığı (%25,7) idi.

Sonuç: Duodenal biyopsi, özellikle *H. pylori* gastriti, çölyak hastalığı ve giardiyazisi saptamak için çocuk endoskopisinde önemli bir tanı aracıdır.

Anahtar Kelimeler: Endoskopi, biyopsi, duodenit

INTRODUCTION

Children should undergo endoscopic evaluations in line with international guidelines, which emphasize standardized procedures and biopsy protocols (1,2). Upper gastrointestinal endoscopy with biopsy is a fundamental diagnostic tool in the assessment of pediatric patients presenting with gastrointestinal symptoms. Among the pathological findings detected, duodenitis is a relatively common condition with diverse etiologies, including infections, celiac disease, and other inflammatory disorders (3).

In contrast to pediatric esophagitis and gastritis, which have been extensively studied, duodenitis has received comparatively limited attention in the literature (3-5). A clearer understanding of its clinical presentation and histopathological spectrum is essential to improve diagnostic accuracy and to guide appropriate management strategies.

The aim of this study was to investigate the etiological factors, clinical features, endoscopic findings, and histopathological characteristics of biopsy-proven duodenitis in children who underwent upper gastrointestinal endoscopy at a tertiary pediatric gastroenterology center over a six-year period.

METHODS

Study Design and Population

This retrospective observational study was conducted at Clinic of Pediatric Gastroenterology, University of Health Sciences Türkiye, Şişli Hamidiye Etfal Training and Research Hospital and included pediatric patients who underwent upper gastrointestinal endoscopy with biopsy between January 2011 and December 2017. Patients were excluded from the study if they had incomplete medical records or no histopathological reports available. In addition, patients in whom duodenal biopsies were not obtained or were insufficient for histopathological evaluation were excluded. Repeat endoscopies performed in the same patients during the study period were also excluded; only the first endoscopic examination was included in the analysis.

Data Collection

Data were collected from electronic medical records and included demographic characteristics (age and sex), presenting symptoms, endoscopic findings, and histopathological results. Presenting symptoms, such as abdominal pain, vomiting, regurgitation, gastrointestinal bleeding, growth retardation, iron deficiency anemia, and changes in bowel habits (diarrhea/constipation), were documented. Endoscopic reports were reviewed for findings, including antral and corpus hyperemia, nodularity, bulbar and duodenal changes, and scalloping. Histopathological reports were evaluated for inflammatory cell infiltration, *Helicobacter pylori* (*H. pylori*) presence, intraepithelial lymphocytosis, villous atrophy, and other specific findings, such as Brunner's gland hyperplasia and lymphatic dilatation.

Endoscopic Procedure

Upper gastrointestinal endoscopies were performed using standard pediatric video endoscopes (Olympus GIF-180 and XP-18; Olympus, Tokyo, Japan) under sedation or general anesthesia according to institutional protocols. According to the institutional endoscopy protocol of our tertiary pediatric gastroenterology center, systematic biopsies were obtained from predefined sites regardless of macroscopic appearance, in line with international pediatric endoscopy guidelines. During each upper gastrointestinal endoscopy, at least two biopsies from the gastric antrum, at least two from the gastric corpus, and at least two duodenal biopsies were obtained. Duodenal sampling included at least one biopsy from the duodenal bulb and three biopsies from the second portion of the duodenum to improve diagnostic accuracy, particularly for detecting celiac disease and inflammatory changes. Biopsy specimens were fixed in formalin, embedded in paraffin, and stained with hematoxylin and eosin for routine examination. Additional stains, such as Giemsa, were used to detect *H. pylori*. Duodenal biopsies were classified according to the Modified Marsh criteria for the evaluation of celiac disease.

Histopathological Evaluation

Histopathological evaluation was performed by experienced pathologists who were blinded to the clinical data. Biopsy

specimens were assessed for acute and chronic inflammatory cell infiltration, *H. pylori* colonization, intraepithelial lymphocytosis, villous architecture, and other pathological changes in the mucosa. Duodenitis was diagnosed based on histopathological findings, including acute and chronic inflammatory cell infiltration in the lamina propria, increased intraepithelial lymphocytes, crypt hyperplasia, and various degrees of villous blunting or atrophy. Duodenal biopsies were further classified according to the Modified Marsh classification system to evaluate the presence and severity of celiac disease.

Ethics Committee Approval

Ethical approval was obtained from the University of Health Sciences Türkiye, Şişli Hamidiye Etfal Training and Research Hospital Clinical Research Ethics Committee (approval no: 1328, date: 03.09.2019). The requirement for informed consent was waived due to the retrospective nature of the study.

Statistical Analysis

All statistical analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize demographic data, clinical symptoms, endoscopic findings, and histopathological results. Categorical variables are presented as frequencies and percentages, and continuous variables are expressed as means ± standard deviations (SDs).

RESULTS

A total of 6,223 patients aged 0-18 years were evaluated. Of these, 1,494 patients (24%) with histopathologically confirmed duodenitis were included in the final analysis. Among these participants, 53.3% were female and 46.7% male, with a mean age of 9.1±3.2 years.

The most common presenting complaints were periumbilical pain (64.6%), vomiting (51.9%), epigastric pain (50.3%), and regurgitation (46.0%). Symptoms included gastrointestinal bleeding (25%), growth and developmental delay (31.9%), treatment-resistant iron-deficiency anemia (11.9%), and diarrhea or constipation (22.9%) among the patients. Endoscopic examination revealed antral hyperemia in 83.9% of patients, antral nodularity in 61.4%, corpus hyperemia in 52.4%, and esophageal hyperemia in 46% of patients. Duodenal findings in patients included bulbar hyperemia in 41%, bulbar ulceration in 28.7%, duodenal hyperplasia in 46%, and scalloping in 16.9% (Table 1).

Histopathological evaluation showed acute inflammatory cell infiltration in 45.7% and chronic inflammatory cell infiltration in 54.2% of antral biopsies. *H. pylori* infection was detected in 46% of patients. In the duodenum, intraepithelial lymphocytosis was present in 30.1%, villous atrophy in 25.7%, Brunner's gland hyperplasia in 0.14%, and lymphatic dilatation in 0.06% of cases (Table 2). Correlation between histopathological and clinical findings indicated that *H. pylori* gastritis accounted for 46% of duodenitis cases, celiac disease for 25.7%, non-specific gastritis for 23.3%, giardiasis for 4%, and Brunner's gland adenoma for 0.12% of cases (Table 2).

DISCUSSION

In this large cohort of pediatric patients undergoing upper gastrointestinal endoscopy, histopathologically confirmed duodenitis was identified in approximately one-quarter of cases, underscoring its clinical significance among children presenting with gastrointestinal symptoms. The study's findings highlight the varied etiological spectrum of duodenitis, which includes *H. pylori* infection, celiac disease, non-specific inflammatory changes, and parasitic infections such as giardiasis. Notably, nearly half of the duodenitis cases were associated with *H. pylori* gastritis, while celiac disease accounted for more than a quarter, underscoring the need for comprehensive histopathological evaluation of symptomatic pediatric patients. The frequent coexistence

Table 1. Distribution of histopathological findings of all cases with duodenitis

Histopathological finding	n	%
Acute inflammatory cell positivity (antrum)	683	45.7
Chronic inflammatory cell positivity (antrum)	810	54.2
Helicobacter pylori positivity	687	46
Intraepithelial lymphocytosis (duodenum)	450	30.1
Villous atrophy (duodenum)	384	25.7
Marsh 1	201	13.5
Marsh 2	112	7.5
Marsh 3	71	4.7
Non-specific gastritis	347	23.3
Brunner's gland hyperplasia	2	0.14
Dilated lymphatics	4	0.06
Giardia	60	4

Table 2. Etiological distribution of duodenitis cases

Etiology	n	%
Helicobacter pylori gastritis	687	46
Celiac disease	384	25.7
Non-specific gastritis	347	23.3
Giardiasis	60	4
Brunner's gland adenoma	2	0.12

of antral and duodenal inflammation, along with specific endoscopic findings such as antral nodularity and duodenal scalloping, further supports the importance of integrating clinical, endoscopic, and histological data for an accurate diagnosis and targeted management.

H. pylori is a significant factor in duodenal pathology and peptic ulcer disease, particularly among children (6). Its prevalence tends to be higher in developing countries and is associated with refractory anemia and impaired growth (7). Previous studies have indicated that infection rates among children under five years of age can reach as high as 50% in low-resource settings, whereas in developed countries they are 20% or lower (6). In our cohort, *H. pylori* was identified in 46% of biopsies, a rate that exceeds rates reported in developed nations but aligns with rates reported in developing regions. Improved sanitation, access to clean water, and widespread use of antibiotics contribute to reduced transmission and are key factors that determine the differences between developing and developed countries. Understanding these differences is crucial for adapting public health interventions and clinical strategies and underscores the importance of context-specific approaches for the diagnosis, treatment, and prevention of *H. pylori* infection in pediatric populations.

Celiac disease is another major cause. Its pathogenesis involves a combination of genetic predisposition, environmental triggers, and immune-mediated injury, leading to intraepithelial lymphocytosis, crypt hyperplasia, and varying degrees of villous atrophy (8). The global prevalence of pediatric celiac disease is estimated to be between 0.8% and 1% (8), with national studies in Turkey reporting rates ranging from 0.47% to 0.9% (9,10). In our series, 25.7% of patients diagnosed with duodenitis were ultimately found to have celiac disease, a rate significantly higher than population-based estimates. However, a notably higher proportion of celiac disease cases (25.7%) among patients with duodenitis in our series suggests a referral bias, as our center predominantly evaluates individuals with a strong clinical suspicion of celiac disease.

The prevalence of duodenitis in our cohort (24%) was higher than that reported in several previously published pediatric series (3,4,11). Alabd Alrazzak et al. (11) reported an incidence of 11% among 1,000 patients, while Alper et al. (3) found duodenitis in 12.7% of 2,772 endoscopies. Akbulut et al. (12) reported a higher rate of 30.7% in a smaller, single-center study. The higher prevalence of duodenitis observed in our cohort, compared with previously published pediatric series, may reflect several underlying factors. Referral bias is a significant consideration, as our institution likely receives a greater proportion of complex or symptomatic cases, which could inflate the observed incidence. Additionally, the volume and thoroughness of endoscopic evaluations performed at our center may contribute to increased detection rates. Variability in diagnostic criteria and histopathological interpretation across studies can also influence the reported prevalence, making direct comparisons challenging.

Parasitic infections have also been identified as causes of duodenitis, with *Giardia* intestinalis reported in 2-5% of pediatric populations in previous studies (13). In our study, 4% of the patients were diagnosed with *giardiasis*. This prevalence is consistent with previously reported rates of 2-5% in developed countries. The clinical course of parasitic infections can range from acute or chronic gastrointestinal symptoms to completely asymptomatic presentations. This highlights the importance of not overlooking parasitic etiologies during the diagnostic process, especially in pediatric patients presenting with non-specific symptoms.

Other rare etiologies include Brunner's gland hyperplasia and adenoma, which are observed in 0.14% and 0.12% of cases, respectively (14). While these lesions are exceedingly uncommon in children, studies in adults have demonstrated occasional dysplastic changes, emphasizing the importance of recognizing these lesions. Intestinal lymphangiectasia was found in four patients (0.06%), which is consistent with its rarity in the literature (15). Our series did not encounter any cases of eosinophilic duodenitis. According to a study conducted in our country, eosinophilic duodenitis is classified among the rare secondary causes of duodenitis (16). The absence of eosinophilic duodenitis cases in our study may be attributed to the small number of infant patients, a population in which this condition might be more commonly observed.

Overall, our findings support the diagnostic value of duodenal biopsy in children undergoing upper gastrointestinal endoscopy (5). Even in cases where gross endoscopic findings are non-specific or absent, histological evaluation can yield critical diagnostic information, particularly for differentiating celiac disease, *H. pylori* infection, and parasitic involvement. This highlights the role of biopsy as a valuable tool in pediatric endoscopic practice.

Study Limitations

The main limitations of this study are its retrospective and single-center design, which may limit the generalizability of the findings and preclude causal inference. As the study was conducted in a tertiary referral center, referral bias toward more severe cases cannot be excluded. The lack of

comparative statistical analyses and the absence of long-term clinical follow-up data constitute additional limitations. Nevertheless, the large sample size provides valuable epidemiological insight and supports the importance of routine duodenal histopathological evaluation in pediatric endoscopic practice.

CONCLUSION

Our findings indicate that duodenitis is a prevalent histopathological diagnosis in children undergoing upper gastrointestinal endoscopy, predominantly linked to *H. pylori* infection and celiac disease. Despite the non-specific nature of gross endoscopic findings, duodenal biopsy is crucial for diagnosis, especially for detecting celiac disease, *H. pylori* gastritis, and parasitic infection. Our findings must be interpreted cautiously because of the study's retrospective, single-center design. However, the substantial sample size underscores the need to perform routine duodenal biopsies during pediatric endoscopic procedures.

ETHICS

Ethics Committee Approval: Ethical approval was obtained from the University of Health Sciences Türkiye, Şişli Hamidiye Etfal Training and Research Hospital Clinical Research Ethics Committee (approval no: 1328, date: 03.09.2019).

Informed Consent: The requirement for informed consent was waived due to the retrospective nature of the study.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: B.Y., Concept: N.U., B.Y., Design: N.U., Data Collection or Processing: T.K., B.Y., Analysis or Interpretation: S.B.A., Literature Search: S.B.A., A.M.U., Writing: S.B.A., A.M.U.

Conflict of Interest: No conflict of interest was declared by the authors.

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Research

Clinical Outcomes of TEP and Lichtenstein Repair in Bilateral Inguinal Hernia Surgery: A Retrospective Comparative Study

Bilateral İnguinal Herni Cerrahisinde TEP ve Lichtenstein Onarımının Klinik Sonuçları: Retrospektif Karşılaştırmalı Çalışma

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ABSTRACT

Objective: The optimal surgical approach for bilateral inguinal hernia repair remains controversial. This study aimed to compare the clinical outcomes of laparoscopic total extraperitoneal repair (TEP) and open Lichtenstein repair in patients undergoing elective bilateral inguinal hernia surgery.

Methods: Patients who underwent elective surgery for bilateral inguinal hernia between January 2021 and December 2025 were retrospectively evaluated. Patients were divided into two groups according to the surgical technique: TEP and Lichtenstein repair. Demographic characteristics, perioperative findings, postoperative complications, recurrence, chronic pain, and length of hospital stay were compared between the groups.

Results: A total of 264 patients were included in the study. Of these, 145 underwent TEP repair and 119 underwent Lichtenstein repair. Operative time was significantly shorter in the TEP group compared with the Lichtenstein group (73.4±26.8 vs. 101.2±35.2 minutes, p<0.001). Overall morbidity rates were similar between the groups (22.1% vs. 30.3%, p=0.130). Chronic postoperative pain was significantly lower in the TEP group (2.8% vs. 8.4%, p=0.042). Although recurrence was numerically higher in the TEP group (6.9% vs. 3.4%), the difference was not statistically significant (p=0.202). No significant difference was observed in length of hospital stay (p=0.235).

Conclusion: Both TEP and Lichtenstein repairs are safe and effective options for bilateral inguinal hernia surgery, with comparable morbidity and recurrence rates. However, TEP repair was associated with shorter operative time and lower chronic postoperative pain. Surgical approach should be individualized according to patient characteristics, anesthetic risk, and surgeon experience.

Keywords: Bilateral inguinal hernia, total extraperitoneal repair, Lichtenstein repair, laparoscopic hernia repair, chronic postoperative pain

ÖZ

Amaç: Bilateral inguinal herni onarımında optimal cerrahi yaklaşım hala tartışmalıdır. Bu çalışmada, elektif bilateral inguinal herni cerrahisi uygulanan hastalarda laparoskopik total ekstraperitoneal onarım (TEP) ile açık Lichtenstein onarımının klinik sonuçlarının karşılaştırılması amaçlandı.

Gereç ve Yöntem: Ocak 2021 ile Aralık 2025 tarihleri arasında bilateral inguinal herni nedeniyle elektif cerrahi uygulanan hastalar retrospektif olarak değerlendirildi. Hastalar uygulanan cerrahi tekniğe göre TEP ve Lichtenstein grupları olarak ikiye ayrıldı. Demografik özellikler, perioperatif bulgular, postoperatif komplikasyonlar, nüks, kronik ağrı ve hastanede yatış süresi iki grup arasında karşılaştırıldı.

Bulgular: Toplam 264 hasta çalışmaya dahil edildi. Bunların 145'ine TEP, 119'una Lichtenstein onarımı uygulandı. Ameliyat süresi TEP grubunda Lichtenstein grubuna göre anlamlı olarak daha kısa bulundu (73,4±26,8 dk'ya karşı 101,2±35,2 dk, p<0,001). Toplam morbidite oranları iki grup arasında benzerdi (%22,1'e karşı %30,3, p=0,130). Kronik postoperatif ağrı oranı TEP grubunda anlamlı olarak daha düşük saptandı (%2,8'e karşı %8,4, p=0,042). Nüks oranı TEP grubunda sayısal olarak daha yüksek olmasına rağmen (%6,9'a karşı %3,4), anlamlı fark izlenmedi (p=0,202). Hastanede yatış süresi açısından gruplar arasında fark saptanmadı (p=0,235).

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ÖZ

Sonuç: TEP ve Lichtenstein onarımları, bilateral inguinal herni cerrahisinde benzer morbidite ve nüks oranları ile güvenli ve etkili yöntemlerdir. Bununla birlikte TEP tekniği daha kısa ameliyat süresi ve daha düşük kronik postoperatif ağrı oranı ile ilişkili bulunmuştur. Cerrahi yaklaşım hasta özellikleri, anestezi riski ve cerrah deneyimine göre bireyselleştirilmelidir.

Anahtar Kelimeler: Bilateral inguinal herni, total ekstraperitoneal onarım, Lichtenstein onarımı, laparoskopik herni onarımı, kronik postoperatif ağrı

INTRODUCTION

Inguinal hernias are among the most frequently encountered surgical conditions and account for nearly 75% of all abdominal wall hernias. An inguinal hernia is expected to occur over a lifetime in nearly 27% of men and 3% of women (1). Both open repair and laparo-endoscopic methods are widely accepted as standard surgical options for the management of inguinal hernias (2,3). With recent advances in surgical techniques, laparoscopic approaches have increasingly been preferred because of benefits including less postoperative pain, shorter recovery time, and quicker resumption of normal daily activities (3,4). International HerniaSurge guidelines recommend that laparo-endoscopic approaches be considered the preferred option for bilateral inguinal hernias in experienced centers (2,3).

Bilateral inguinal hernias represent a more complex group of patients for surgical planning than unilateral cases. The requirement for simultaneous repair of both sides increases the importance of surgical approach selection with regard to operative time, anesthesia choice, postoperative complication profile, chronic pain development, and recurrence rates (4,5). Laparoscopic total extraperitoneal repair (TEP) may offer advantages in bilateral cases, as it allows simultaneous treatment of bilateral defects through a single preperitoneal approach. In contrast, open Lichtenstein repair remains a widely preferred and reliable method because of its technical feasibility, short learning curve, and safe applicability in a broad patient population (2,5).

Although numerous studies have compared laparoscopic and open techniques, most have evaluated unilateral and bilateral cases together, leaving data specific to bilateral inguinal hernia relatively limited (5,6). In a limited number of studies evaluating bilateral hernias, laparoscopic approaches have been associated with less early postoperative pain, shorter hospital stay, and lower rates of chronic pain. However, most of these data are derived from the transabdominal preperitoneal (TAPP) approach, whereas direct comparisons between TEP and open Lichtenstein repair remain scarce (6,7).

This study evaluated the surgical outcomes of laparoscopic TEP and open Lichtenstein repair in patients undergoing surgery for bilateral inguinal hernias. The two techniques were compared with respect to operative duration, length of hospitalization, development of long-term pain, postoperative adverse events, and hernia recurrence. In addition, the study aimed to contribute to the selection of an appropriate surgical strategy for the treatment of bilateral inguinal hernia.

METHODS

The medical records of patients who underwent elective bilateral inguinal hernia surgery in the Department of General Surgery at our hospital between January 2021 and December 2025 were retrospectively analyzed. Based on the surgical approach, the cases were evaluated in two groups: patients treated with TEP and those who underwent open Lichtenstein repair.

The study included adult patients aged 18 years or older who underwent elective bilateral inguinal hernia repair, either via TEP or open Lichtenstein repair. Excluded were patients treated under emergency conditions; those undergoing surgery for unilateral inguinal hernia; cases converted from laparoscopy to open surgery; patients who underwent laparoscopic repair on one side and open repair on the contralateral side; patients treated with the TAPP technique; cases requiring additional surgical procedures; and patients with incomplete clinical data.

Age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) score, Charlson comorbidity index, accompanying comorbidities, smoking and alcohol use, history of abdominal surgery, anticoagulant use, presenting complaints, and duration of symptoms were recorded.

Groin hernia defects were assessed according to the European Hernia Society classification. Based on clinical characteristics, hernias were classified as primary or recurrent, and anatomical distribution was defined as lateral, medial, or femoral. The size of the hernia defect was determined based on the transverse width of the hernia opening and classified into three categories: Grade 1 (<1.5 cm), Grade 2 (1.5-3 cm), and Grade 3 (>3 cm). Right- and

left-sided hernias were recorded separately according to this classification (8).

Radiological findings (ultrasonography and computed tomography), defect diameters, anesthesia method, operative time, drain use, postoperative morbidity, chronic pain, recurrence rates, and length of hospital stay were also evaluated. Chronic pain was defined as groin pain persisting beyond the third postoperative month. Hernia recurrence was defined as detection during follow-up by physical examination and/or radiological imaging.

The study groups were compared with respect to operative duration, postoperative adverse events, chronic postoperative pain, recurrence, and duration of hospitalization.

Ethical Approval

The study protocol was conducted in line with the ethical standards outlined in the Declaration of Helsinki. Prior to commencing study, approval was obtained from the University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital Clinical Research Ethics Committee (approval no: 2026-07-08, date: 18.03.2026). Informed consent was obtained from all patients included in the study.

Statistical Analysis

Statistical findings were expressed using measures of central tendency and dispersion, together with frequency distributions. Data distribution was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Parametric continuous variables were compared using Student's t-test, whereas non-parametric variables were analyzed using the Mann-Whitney U test. Relationships between categorical parameters were evaluated by chi-square analysis, and Fisher's exact test was preferred in cases where chi-square assumptions were not fulfilled. All analyses were conducted with IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA).

RESULTS

A total of 308 patients who underwent elective bilateral inguinal hernia repair during the study interval were retrospectively evaluated. Among them, 9 patients who required conversion from laparoscopic to open surgery and 8 patients who were treated with a laparoscopic approach on one side and an open repair on the opposite side were excluded. Of the 291 patients who met the eligibility criteria, 167 had received laparoscopic surgery and 124 had undergone open repair. Within the laparoscopic cohort, 17 patients who were managed with the TAPP technique and 5 patients with missing data were further excluded. In the open surgery cohort, 5 additional patients were excluded because of incomplete records. As a result, the final study population consisted of 264 patients, including 145 in the TEP group and 119 in the Lichtenstein group. Figure 1 presents the patient selection process and study grouping.

The mean age of the 264 included patients was 56.7±12.3 years, and the vast majority were male (97.7%). The mean BMI was 26.6±3.3 kg/m^2. While 74.2% of the patients were classified as ASA II, the mean Charlson comorbidity index was 1.7±1.4. The most common presenting complaint was swelling (48.5%), followed by pain (40.5%). At least one comorbidity was present in 60.6% of patients; smoking was present in 41.3%, and anticoagulant use in 20.8%. Demographic and baseline clinical characteristics are summarized in Table 1.

The most common hernia type on the right side was PL2 (28.4%), followed by PL1 (24.6%) and PM1 (17.0%). On the left side, PL1 was the most common type (31.1%), followed by PL2 (22.3%) and PM1 (15.9%). Primary lateral hernias constituted the predominant subgroup on both sides. Ultrasonographic evaluation was available for 84.1% of the cohort. The average defect size measured 18.5±9.5 mm on the right side and 17.9±8.3 mm on the left side. Computed tomography was performed in 17.0% of patients, and bilateral hernia defects were detected in 66.7% of these patients. Details regarding hernia classification and radiological assessment findings are presented in Table 2.

TEP repair was performed in 54.9% of patients, and Lichtenstein repair in 45.1%. The most preferred anesthesia method was general anesthesia (72.3%), followed by spinal anesthesia (18.9%) and laryngeal mask airway anesthesia (8.7%). Average operative duration was calculated as 86.0±33.8 minutes, while the average hospitalization period was 1.1±0.6 days. Drain use was required in 12.1% of patients. The overall morbidity rate was 25.8%. The most common postoperative complications were hematoma, chronic pain, and recurrence (5.3% each), followed by seroma and scrotal edema (3.8% each). Wound infection was observed in 2.7% of patients, urinary complaints and groin numbness or burning sensation in 0.8%, and testicular ischemia in 0.4%. No mortality was observed. Postoperative outcomes were assessed using hospital records and outpatient follow-up data, with a mean follow-up duration of 16.2±8.4 months. Operative and postoperative outcomes are summarized in Table 3.

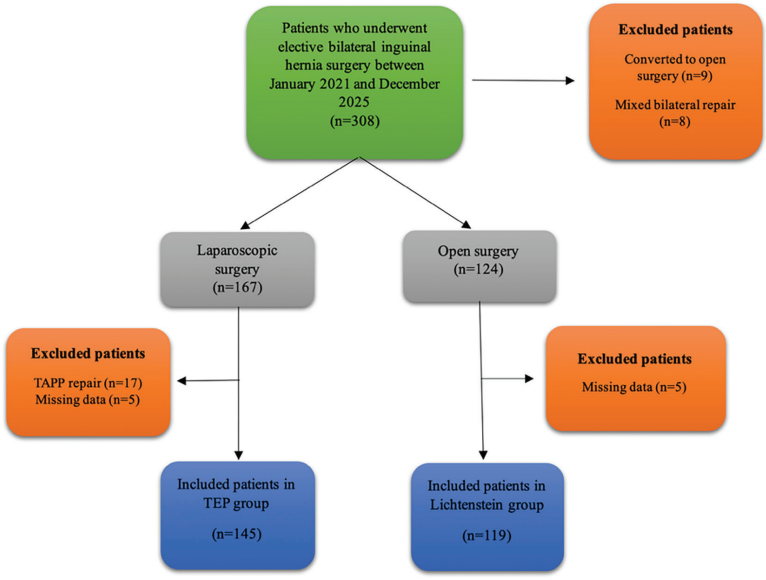

Figure 1. Flowchart of patient selection and allocation into the TEP and Lichtenstein groups
TEP: Total extraperitoneal repair, TAPP: Transabdominal preperitoneal

Baseline demographic and clinical characteristics, including age, sex, BMI, Charlson comorbidity index, and accompanying comorbid conditions, were comparable between the TEP and Lichtenstein groups (all p>0.05). The Lichtenstein group had significantly higher ASA scores (p=0.016), and anticoagulant use was more common in this group (p=0.028). Regarding presenting symptoms, pain was reported more frequently in the Lichtenstein group, whereas swelling alone and combined pain and swelling were more prevalent in the TEP group (all p<0.001). Regarding anesthesia preference, general anesthesia was used more often in the TEP group, while spinal anesthesia was used more often in the Lichtenstein group (p<0.001). The TEP group demonstrated a significantly shorter operative duration compared with the Lichtenstein group (73.4±26.8 vs. 101.2±35.2 minutes, p<0.001). Recurrence rates, overall morbidity, drain utilization, and length of hospitalization did not differ significantly across the study groups (all p>0.05). Detailed comparative results are shown in Table 4.

Postoperative morbidity rates did not differ significantly between the study groups (22.1% vs. 30.3%, p=0.130). Evaluation of individual postoperative complications demonstrated a statistically significant difference only for chronic postoperative pain, which occurred less frequently in patients treated with TEP than in those undergoing Lichtenstein repair (2.8% vs. 8.4%, p=0.042). Although recurrence was observed more often in the TEP cohort (6.9% vs. 3.4%), this difference did not reach statistical significance (p=0.202). The frequencies of hematoma, seroma, scrotal edema, wound infection, urinary symptoms, groin numbness

Table 1. Baseline demographic and clinical characteristics of the study population

		Min-max	Median	Mean±SD/n-%	
Age (years)		18.0-87.0	58.0	56.7±12.3	
Sex	Female			6	2.3%
	Male			258	97.7%
BMI (kg/m^2)		18.3-36.9	26.5	26.6±3.3	
ASA score	I			28	10.6%
	II			196	74.2%
	III			38	14.4%
	IV			2	0.8%
CCI		0.0-6.0	1.0	1.7±1.4	
COPD				10	3.8%
Prostate disease				23	8.7%
Constipation				2	0.8%
Comorbidity present				160	60.6%
Smoking				109	41.3%
Alcohol use				14	5.3%
Previous abdominal surgery				72	27.3%
Anticoagulant use				55	20.8%
Presenting complaint					
Pain				107	40.5%
Swelling				128	48.5%
Pain+swelling				29	11.0%
Constipation				1	0.4%
Symptom duration (months)		1.0-144.0	2.0	5.8±12.9	

BMI: Body mass index, ASA: American Society of Anesthesiologists, CCI: Charlson comorbidity index, COPD: Chronic obstructive pulmonary disease, SD: Standard deviation

or burning sensation, and testicular ischemia were similar in both treatment groups (all p>0.05). Detailed postoperative complication data are summarized in Table 5.

DISCUSSION

In our cohort, patients treated with TEP demonstrated a markedly reduced operative duration in comparison with those who underwent Lichtenstein repair (73.4±26.8 vs. 101.2±35.2 minutes, p<0.001). Traditionally, laparoscopic inguinal hernia repair has been considered more time-consuming than open surgery because of technical complexity and the learning curve (2,4). However, in bilateral cases, simultaneous repair of both defects through a single preperitoneal dissection plane may provide an important time advantage for the TEP approach. In a prospective randomized study by Ielpo et al. (6) comparing TAPP and Lichtenstein repair in bilateral inguinal hernias, operative times were similar. In contrast, Mahon et al. (7) reported shorter operative times in the laparoscopic group in bilateral cases. Likewise, Feliu et al. (9) demonstrated shorter operative duration in the TEP group compared with Lichtenstein repair in bilateral inguinal hernias. The difference observed in our cohort may be explained by the open technique's requirement for separate dissections on each side, whereas TEP allows bilateral repair through a single working space. In addition, the experience of our center in laparoscopic hernia surgery may have contributed to this result. These findings suggest that TEP may also be an efficient time-saving option in experienced centers with appropriate infrastructure.

Table 2. Hernia characteristics and radiological findings

		Min-max	Median	Mean±SD/n-%	
Right-sided hernia type	None			2	0.8%
	PL1			65	24.6%
	PL2			75	28.4%
	PL3			15	5.7%
	PM1			45	17.0%
	PM2			34	12.9%
	PM3			2	0.8%
	RL1			5	1.9%
	RL2			9	3.4%
	RL3			3	1.1%
	RM1			3	1.1%
	RM2			4	1.5%
	RM3			2	0.8%
Left-sided hernia type	None			2	0.8%
	PL1			82	31.1%
	PL2			59	22.3%
	PL3			21	8.0%
	PM1			42	15.9%
	PM2			27	10.2%
	PM3			5	1.9%
	RL1			11	4.2%
	RL2			7	2.7%
	RL3			1	0.4%
	RM1			5	1.9%
	RM2			1	0.4%
	RM3			1	0.4%
USG				222	84.1%
Right USG defect diameter (mm)		4.0-62.0	16.0	18.5±9.5	
Left USG defect diameter (mm)		4.0-50.0	16.0	17.9±8.3	
CT				45	17.0%
CT defect status	No hernia			6	13.3%
	Unilateral			9	20.0%
	Bilateral			30	66.7%

USG: Ultrasonography, CT: Computed tomography, SD: Standard deviation

Table 3. Operative and postoperative outcomes of the study population

		Min-max	Median	Mean±SD/n-%	
Surgical technique	TEP			145	54.9%
	Lichtenstein			119	45.1%
Type of anesthesia	Spinal			50	18.9%
	LMA			23	8.7%
	General anesthesia			191	72.3%
Operative time (minutes)		24.0-220.0	85.0	86.0±33.8	
Length of hospital stay (days)		1.0-7.0	1.0	1.1±0.6	
Drain use				32	12.1%
Morbidity				68	25.8%
Hematoma				14	5.3%
Chronic pain				14	5.3%
Recurrence				14	5.3%
Seroma				10	3.8%
Scrotal edema				10	3.8%
Wound infection				7	2.7%
Urinary complaints				2	0.8%
Groin numbness/burning sensation				2	0.8%
Testicular ischemia				1	0.4%
Follow-up duration (months)				16.2±8.4	
Mortality				0	0.0%

TEP: Total extraperitoneal repair, LMA: Laryngeal mask airway, SD: Standard deviation

A significantly lower incidence of chronic postoperative pain was observed in the TEP group compared with the Lichtenstein group (2.8% vs. 8.4%, p=0.042). Chronic pain following inguinal hernia repair is a major long-term postoperative concern and can negatively affect patients' quality of life. The risk of postoperative neuralgia may be greater in anterior open techniques because of more extensive tissue dissection and increased manipulation of the ilioinguinal, iliohypogastric, and genitofemoral nerves (10,11). Numerous studies have shown that laparo-endoscopic techniques offer an advantage with respect to chronic pain. In the prospective randomized study by Yosypenko et al. (12) involving bilateral inguinal hernia patients, lower postoperative pain scores were reported in the TEP group. Feliu et al. (9) also reported better postoperative comfort in patients undergoing TEP repair.

Table 4. Comparison of demographic, clinical, and perioperative characteristics between TEP and Lichtenstein groups

		TEP group, n=145			Lichtenstein group, n=119			p-value	
		Mean±SD/n-%		Median	Mean±SD/n-%		Median		
Age (years)		55.5±12.0		58.0	58.2±12.5		58.0	0.114	m
Sex	Female	5	3.4%		1	0.8%		0.157	x2
	Male	140	96.6%		118	99.2%			
BMI (kg/m^2)		26.6±3.3		26.6	26.5±3.3		26.2	0.784	t
ASA score	I	16	11.0%		12	10.1%		0.016	x2
	II	114	78.6%		82	68.9%			
	III	14	9.7%		24	20.2%			
	IV	1	0.7%		1	0.8%			
CCI		1.6±1.5		2.0	1.7±1.4		1.0	0.450	m
Comorbidity present		85	58.6%		75	63.0%		0.466	x2
Smoking		61	42.1%		48	40.3%		0.776	x2
Alcohol use		10	6.9%		4	3.4%		0.202	x2
Previous abdominal surgery		45	31.0%		27	22.7%		0.130	x2
Anticoagulant use		23	15.9%		32	26.9%		0.028	x2
Presenting complaint									
Pain		22	15.2%		85	71.4%		<0.001	x2
Swelling		97	66.9%		31	26.1%		<0.001	x2
Pain+swelling		26	17.9%		3	2.5%		<0.001	x2
Symptom duration (months)		5.5±13.6		2.0	6.2±12.0		3.0	0.002	m
USG performed		120	82.8%		102	85.7%		0.514	x2
Right USG defect diameter (mm)		18.2±9.1		15.0	18.8±10.0		17.0	0.600	m
Left USG defect diameter (mm)		17.3±7.5		16.0	18.6±9.2		17.0	0.564	m
CT performed		27	18.6%		18	15.1%		0.452	x2
CT hernia laterality	No hernia	4	14.8%		2	11.1%		0.912	x2
	Unilateral	5	18.5%		4	22.2%			
	Bilateral	18	66.7%		12	66.7%			
Type of anesthesia	Spinal	3	2.1%		47	39.5%		<0.001	x2
	LMA	5	3.4%		18	15.1%			
	General anesthesia	137	94.5%		54	45.4%			
Operative time (minutes)		73.4±26.8		69.0	101.2±35.2		105.0	<0.001	m
Drain use		22	15.2%		10	8.4%		0.094	x2
Morbidity		32	22.1%		36	30.3%		0.130	x2
Length of hospital stay (days)		1.1±0.5		1.0	1.2±0.7		1.0	0.235	m

t: Independent samples t-test, m:Mann-Whitney U test, x2: Chi-square test (Fisher's exact test)
TEP: Total extraperitoneal repair, BMI: Body mass index, ASA: American Society of Anesthesiologists, USG: Ultrasonography, CT: Computed tomography, CCI: Charlson comorbidity index, SD: Standard deviation, LMA: Laryngeal mask airway

Table 5. Comparison of postoperative complications between TEP and Lichtenstein groups

	TEP group, n=145			Lichtenstein group, n=119			p-value	
	Mean±SD/n-%		Median	Mean±SD/n-%		Median		
Chronic pain	4	2.8%		10	8.4%		0.042	x2
Recurrence	10	6.9%		4	3.4%		0.202	x2
Hematoma	7	4.8%		7	5.9%		0.704	x2
Seroma	4	2.8%		6	5.0%		0.334	x2
Scrotal edema	5	3.4%		5	4.2%		0.758	x2
Wound infection	3	2.1%		4	3.4%		0.515	x2
Urinary complaints	0	0.0%		2	1.7%		0.202	x2
Groin numbness	1	0.7%		1	0.8%		1.000	x2
Testicular ischemia	0	0.0%		1	0.8%		0.451	x2

x2: Chi-square test (Fisher's exact test)
SD: Standard deviation, TEP: Total extraperitoneal repair

Furthermore, the meta-analysis by Bobo et al. (13) demonstrated that TEP repair was associated with lower rates of chronic pain than the Lichtenstein technique. Our findings are consistent with these data and suggest that the TEP approach may provide an advantage in long-term pain control and in quality of life for patients with bilateral inguinal hernias. Reduced contact with neural structures in the posterior preperitoneal approach and less irritating mesh placement, compared with the anterior plane, may partly explain this difference.

Despite a numerically greater recurrence frequency in the TEP cohort (6.9% vs. 3.4%), the intergroup difference did not reach statistical significance (p=0.202). This finding suggests that both techniques provide comparable effectiveness and durability in the treatment of bilateral inguinal hernias. Previous studies have similarly reported no marked difference in recurrence rates between laparoscopic and open mesh repairs. In bilateral cases, both Yosypenko et al. (12) and Feliu et al. (9) reported similar recurrence outcomes between TEP and Lichtenstein techniques. The numerically higher recurrence rate in the TEP group may be attributable to technical factors such as the learning curve, mesh positioning, insufficient overlap area, or mesh fixation strategy. Because bilateral repair requires wider preperitoneal dissection, the surgeon's experience likely plays a decisive role in long-term recurrence rates.

The TEP group demonstrated a lower overall postoperative morbidity rate; however, the observed difference between groups was not statistically significant (22.1% vs. 30.3%, p=0.130). No significant differences were found between the groups regarding hematoma, seroma, scrotal edema, wound infection, or urinary complications. These findings indicate that both approaches have comparable safety profiles. In the randomized controlled study by Langeveld et al. (14), no significant difference in major complications was reported between TEP and Lichtenstein repair. Similarly, the meta-analysis by Bobo et al. (13) showed comparable overall complication rates. In contrast, Neumayer et al. (15) reported higher complication rates in the laparoscopic group, whereas Timişescu et al. (16) found lower complication rates in the TEP group. These heterogeneous findings may be related to differences in surgeon experience, patient selection, complication definitions, and duration of follow-up. The numerically lower morbidity observed in the TEP group in our cohort may be explained by reduced tissue trauma, smaller incisions, and avoidance of anterior inguinal canal dissection. Nevertheless, the lack of statistical significance may be due to the limited sample size and the relatively low number of complication events.

A marked difference was also observed in anesthesia preference. General anesthesia was used more frequently in the TEP group, whereas spinal anesthesia was more commonly used in the Lichtenstein group (p<0.001). This finding is expected, as TEP repair generally requires the creation of a preperitoneal working space and the use of laparo-endoscopic equipment, and is therefore most often performed under general anesthesia. In contrast, Lichtenstein repair can be safely performed with spinal or other regional anesthesia. The higher ASA scores observed in the open surgery group also suggest that the open technique may have been preferred for patients with greater anesthetic risk. Therefore, open Lichtenstein repair remains an important alternative, particularly in patients at high risk for general anesthesia.

This study has several strengths. First, focusing exclusively on patients with bilateral inguinal hernia provided a more homogeneous study population than heterogeneous series that included both unilateral and bilateral cases.

Second, the evaluation of all cases at a single center under similar surgical practice increased internal consistency. A comprehensive assessment of both techniques in terms of demographic characteristics, perioperative outcomes, and postoperative complications adds value to the study.

Study Limitations

Nevertheless, several limitations should be acknowledged. The retrospective single-center design cannot completely eliminate the risk of selection bias. Another limitation of the study is the lack of a standardized postoperative pain scoring system, such as the visual analog scale, due to the retrospective design. The non-randomized choice of surgical technique and the higher ASA scores in the open surgery group may have led to baseline differences between the groups. In addition, the sample size may have limited the statistical power, particularly for rare complications and recurrence outcomes. Additionally, the inability to perform multivariate analysis due to the limited number of outcome events, particularly for chronic pain and recurrence, represents another limitation of the study. Larger multicenter prospective randomized studies are needed to validate these findings.

CONCLUSION

Both TEP and Lichtenstein repairs can be safely performed in cases of bilateral inguinal hernia, with comparable overall morbidity and recurrence rates. However, TEP repair was associated with shorter operative time and lower rates of chronic postoperative pain. Open Lichtenstein repair remains an important alternative, particularly in patients with increased anesthetic risk. Surgical technique should be individualized according to patient characteristics, anesthetic risk, surgeon experience, and institutional resources. Larger prospective randomized studies may help determine the optimal approach for the treatment of bilateral inguinal hernia.

ETHICS

Ethics Committee Approval: The study protocol was conducted in line with the ethical standards outlined in the Declaration of Helsinki. Prior to commencing study, approval was obtained from the University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital Clinical Research Ethics Committee (approval no: 2026-07-08, date: 18.03.2026).

Informed Consent: Informed consent was obtained from all patients included in the study.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: N.Ş., M.S.D., F.T.Ö., S.B., M.Y.Ş., İ.G., B.A., A.M., D.K., M.Ç., A.S., Concept: N.Ş., M.S.D., A.S., Design: N.Ş., M.S.D., F.T.Ö., Data Collection or Processing: N.Ş., A.M., D.K., Analysis or Interpretation: N.Ş., S.B., M.Y.Ş., Literature Search: N.Ş., İ.G., B.A., Writing: N.Ş., M.Ç.

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Research

Association of Baseline Vitamin B12 and Vitamin D Levels with Clinical Response to Paraffin Therapy in Patients with Hand Symptoms

El Semptomları Olan Hastalarda Başlangıç Vitamin B12 ve D Vitamini Düzeyleri ile Parafin Tedavisine Klinik Yanıt Arasındaki İlişki

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ABSTRACT

Objective: Paraffin bath therapy is commonly used in rehabilitation for hand and wrist symptoms, but clinical response varies among patients. This study evaluated whether baseline vitamin B12 and 25-hydroxyvitamin D [25(OH)D] levels were associated with short-term clinical response after paraffin therapy in patients with hand pain and/or numbness.

Methods: This single-center, retrospective, observational study included 128 adults who completed a 10-session paraffin therapy program. Pain, numbness, and hand-related function were assessed before treatment and after the 10th session, using the visual analogue scale (VAS) scores and the patient-rated wrist/hand evaluation (PRWHE). Clinical response was defined as either a ≥30% improvement in PRWHE total score or a ≥2-point reduction in VAS numbness score. Serum vitamin B12 and 25(OH)D levels, obtained before treatment, were analyzed both as continuous and as categorical variables.

Results: Significant improvements were observed in VAS pain, VAS numbness, PRWHE total score, and appearance-related discomfort after therapy (all p<0.001). Overall, 63 patients (49.2%) were classified as responders. Responders had higher baseline vitamin B12 and 25(OH)D levels than non-responders. Patients with 25(OH)D levels ≥30 ng/mL had a higher response rate than those with lower levels (74.4% vs. 38.2%, p<0.001). Vitamin B12 ≥300 pg/mL was also associated with response in categorical analysis, but not after adjustment. In multivariable logistic regression analysis, 25(OH)D ≥30 ng/mL was independently associated with clinical response (odds ratio: 4.48, 95% confidence interval: 1.66-12.05, p=0.003).

Conclusion: Baseline vitamin D status was independently associated with the short-term clinical response to paraffin therapy in patients with hand pain and/or numbness. Further prospective, controlled studies are needed.

Keywords: Paraffin therapy, vitamin D, vitamin B12, hand pain, numbness, rehabilitation, patient-rated wrist/hand evaluation

ÖZ

Amaç: Parafin banyosu tedavisi el ve el bileği semptomlarında rehabilitasyon pratiğinde sık kullanılan bir yöntemdir; ancak klinik yanıt hastalar arasında değişkenlik gösterebilir. Bu çalışmada, el ağrısı ve/veya uyuşma yakınması olan hastalarda parafin tedavisi sonrası kısa dönem klinik yanıtın başlangıç vitamin B12 ve 25-hidroksivitamin D [25(OH)D] düzeyleri ile ilişkisi değerlendirildi.

Gereç ve Yöntem: Bu tek merkezli retrospektif gözlemsel çalışmaya, el ağrısı, uyuşma veya parestezi nedeniyle 10 seans parafin tedavisini tamamlayan 128 erişkin hasta dahil edildi. Ağrı, uyuşma ve el ile ilişkili fonksiyonel durum tedavi öncesinde ve 10. seans sonrasında görsel analog skala (VAS) ve hasta bildirimli el bileği/el değerlendirme ölçeği (PRWHE) ile değerlendirildi. Klinik yanıt, PRWHE toplam skorunda ≥%30 iyileşme veya VAS uyuşma skorunda ≥2 puan azalma olarak tanımlandı. Tedavi öncesi serum vitamin B12 ve 25(OH)D düzeyleri sürekli ve kategorik değişkenler olarak analiz edildi.

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ÖZ

Bulgular: Tedavi sonrası VAS ağrı, VAS uyuşma, PRWHE toplam skoru ve görünümle ilişkili rahatsızlık skorlarında anlamlı iyileşme saptandı (tümü p<0,001). Toplam 63 hasta (%49,2) yanıt veren olarak sınıflandırıldı. Yanıt verenlerde başlangıç vitamin B12 ve 25(OH)D düzeyleri daha yüksekti. 25(OH)D düzeyi ≥30 ng/mL olanlarda klinik yanıt oranı daha yüksekti (%74,4 vs. %38,2; p<0,001). Vitamin B12 ≥300 pg/mL kategorik analizde yanıtla ilişkiliydi; ancak düzeltme sonrası anlamlılığını korumadı. Çok değişkenli lojistik regresyonda yalnızca 25(OH)D ≥30 ng/mL klinik yanıtla bağımsız ilişkili bulundu (olasılık oranı: 4,48; %95 güven aralığı: 1,66-12,05; p=0,003).

Sonuç: Başlangıç D vitamini durumu, el ağrısı ve/veya uyuşma yakınması olan hastalarda parafin tedavisi sonrası kısa dönem klinik yanıtla bağımsız olarak ilişkili bulundu. Prospektif kontrollü çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Parafin tedavisi, D vitamini, vitamin B12, el ağrısı, uyuşma, rehabilitasyon, hasta bildirimli el bileği/el değerlendirme ölçeği

INTRODUCTION

Hand and wrist pain, stiffness, numbness, and functional limitations are common complaints in physical medicine and rehabilitation practice. These symptoms may occur in various conditions, including hand osteoarthritis, carpal tunnel syndrome (CTS), tenosynovitis, trigger finger, soft-tissue pain, and neuropathic symptoms of cervical origin. Although the underlying etiology may differ, many patients experience overlapping problems such as impairment of daily activities, reduced grip performance, nocturnal paresthesia, and pain aggravated by hand use.

Paraffin bath therapy is a superficial heat modality that has been used for many years in the management of hand and wrist disorders. It is commonly applied for hand osteoarthritis and painful soft-tissue conditions to reduce pain, to increase tissue extensibility, and to prepare the hand for therapeutic exercises. Previous studies have reported that paraffin therapy may provide short-term benefits in pain, stiffness, and functional limitation in patients with hand osteoarthritis (1,2). However, paraffin therapy is usually delivered as part of a multimodal rehabilitation program, and the degree of clinical response may vary considerably between patients. This variation makes it important to investigate patient-related factors that may influence treatment response.

Vitamin D is frequently evaluated in rehabilitation practice because of its potential relationship with muscle function, neuromuscular performance, and musculoskeletal pain. Although vitamin D deficiency has been associated with muscle weakness, diffuse musculoskeletal pain, and impaired functional capacity, this relationship is not consistent across studies (3,4). Therefore, vitamin D status may be better considered a patient-related factor that could influence rehabilitation outcomes rather than a direct cause of pain. Vitamin B12 is another important factor for peripheral nervous system function. Deficiency or borderline-low levels may be associated with paresthesia, numbness, burning sensations, and peripheral neuropathy-like symptoms (5). Because these symptoms may overlap with local compressive neuropathies or mechanical hand disorders, evaluating the association between vitamin B12 levels and post-treatment changes in symptoms represents a practical clinical question.

The existing literature has mainly focused on the short-term symptomatic effects of paraffin therapy, particularly in hand osteoarthritis and other hand disorders (1,2). However, whether baseline vitamin B12 and vitamin D levels are associated with clinical response to paraffin therapy has not been adequately investigated. In routine practice, patients who complete the same treatment protocol may show markedly different degrees of improvement. This variability may not be explained solely by diagnosis, age, or baseline symptom severity; metabolic and neuromuscular factors may also contribute.

The aim of this study was to evaluate the association of baseline serum vitamin B12 and 25-hydroxyvitamin D [25(OH)D] levels with changes in pain, numbness, and hand function after standard paraffin therapy in patients with hand pain and/or numbness. The study was designed to identify patient-related factors that may influence treatment response in routine physical medicine and rehabilitation practice, rather than to prove the efficacy of paraffin therapy itself.

METHODS

Study Design and Ethical Approval

This single-center, retrospective, observational cohort study was based on the medical records of patients who were evaluated in the physical medicine and rehabilitation outpatient clinic for hand pain and/or numbness and who subsequently received paraffin therapy. Ethical approval was obtained from the University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital Clinical Research Ethics Committee (approval no: 2026-10-02, date: 22.04.2026).

Patient Selection

Patients aged 18 years or older who presented with pain, numbness, or paresthesia involving the hand and/or wrist who were scheduled for paraffin therapy based on clinical

judgment and who completed a 10-session treatment program were included in the study. To be eligible for analysis, patients were required to have pre- and post-treatment patient-rated wrist/hand evaluation (PRWHE), and visual analogue scale (VAS) assessments available, as well as recorded serum vitamin B12 and 25(OH)D levels obtained before treatment initiation.

Patients who did not complete the paraffin therapy program, who received paraffin therapy for conditions unrelated to the hand or wrist, who had incomplete clinical assessment forms, or who had missing laboratory data were excluded. Patients with severe neurological disorders that could influence treatment response and patients who had recently received vitamin B12 or vitamin D supplementation were also excluded from the analysis.

Age, sex, height, weight, body mass index (BMI), diagnostic group, comorbidities, history of diabetes mellitus, serum vitamin B12 level, and serum 25(OH)D level were recorded. Diagnoses were classified according to the medical records, clinical examination findings, imaging results, and, when available, electrophysiological assessments. Patients were grouped as having hand osteoarthritis, CTS, tenosynovitis or trigger finger, or other causes of hand pain, paresthesia, or both. CTS was diagnosed based on clinical findings and electrophysiological assessment.

Paraffin Therapy

All patients received the standard paraffin bath protocol used in our clinic. Paraffin therapy was applied as a superficial heat modality targeting the hand and wrist region. During the procedure, the hand was dipped repeatedly into heated paraffin to create a paraffin layer and was then wrapped in a plastic covering and a towel to retain heat. Each session lasted approximately 20 minutes, and the treatment was completed in 10 sessions. No additional study-specific intervention was applied.

Clinical Assessment

Clinical assessments were performed before the start of paraffin therapy and after the 10th session. Pain and functional status were evaluated using the PRWHE, a patient-reported measure of pain and functional limitation in hand and wrist disorders. Higher scores indicate greater pain and functional impairment. The original and Turkish validity and reliability studies were reported by MacDermid et al. (6) and Öke Topcu and İkbali Afşar (7), respectively. Appearance-related discomfort was recorded using a 0-10 numeric rating scale, and the perceived importance of hand appearance was categorized as very important, somewhat important, or not important.

Pain and/or numbness severity was assessed using a 0-10 VAS, where higher scores indicated more severe symptoms (8). The primary outcome was a clinical response to paraffin therapy. Because there is no universally accepted responder definition for paraffin therapy in heterogeneous hand disorders, clinical response was defined a priori using clinically meaningful change thresholds derived from the hand/wrist and pain outcome literature. Clinical response was defined as either a ≥30% improvement in PRWHE total score or a ≥2-point reduction in VAS numbness score after treatment (9-11). Patients meeting at least one of these criteria were classified as the "clinical response" group, whereas those meeting neither criterion were classified as the "no clinical response" group. This composite definition was chosen because the cohort included patients with both pain-dominant and sensory symptom-dominant presentations. Improvement in PRWHE was used to reflect clinically meaningful recovery in hand-related pain and function, whereas improvement in VAS numbness was used to capture sensory symptom relief that may be particularly relevant to CTS and neuropathic-like hand symptoms.

Laboratory Assessment

Serum vitamin B12 and 25(OH)D levels, measured as part of routine clinical evaluation before treatment, were recorded. No additional laboratory testing was performed for the purposes of this study. Serum 25(OH)D level was analyzed both as a continuous and a categorical variable. For the primary categorical analysis, 25(OH)D <20 ng/mL was defined as vitamin D deficiency; an additional analysis was performed using the <30 ng/mL threshold. Serum vitamin B12 level was also evaluated both as a continuous and as a categorical variable. In the primary analysis, vitamin B12 levels <300 pg/mL were considered low or borderline-low, while the conventional deficiency threshold of <200 pg/mL was used for additional analysis.

Sample Size

Sample size estimation was performed using G*Power software version 3.1.9.7 (Heinrich Heine University Düsseldorf, Düsseldorf, Germany). The calculation was based on a comparison of PRWHE total score improvements between two independent groups defined by baseline vitamin status. Because previous studies on paraffin therapy did not provide directly comparable data on response groups defined by vitamin levels, a moderate effect size was assumed for the expected between-group difference in PRWHE improvement. Using a two-tailed independent-samples t-test with Cohen's d=0.50, an alpha error probability of 0.05, an allocation ratio of 1:1, and a statistical power of 80%, the minimum required total sample

size was estimated to be approximately 128 patients. Accordingly, the final study cohort of 128 patients was considered sufficient for detecting a moderate between-group difference, although subgroup analyses by diagnosis were not separately powered (7,12).

Statistical Analysis

Statistical analyses were performed using appropriate statistical software. Continuous variables were summarized as mean±standard deviation and median (minimum-maximum), while categorical variables were presented as numbers and percentages. The distributions of continuous variables were assessed using visual methods and normality tests.

Because the main clinical outcome variables were not normally distributed, pre- and post-treatment scores for VAS pain, VAS numbness, PRWHE total, and appearance-related discomfort were compared using the Wilcoxon signed-rank test. Comparisons between responders and non-responders were performed using the Mann-Whitney U test for continuous variables. Categorical variables, including sex, diagnostic categories, diabetes mellitus, night awakening, vitamin D categories, and vitamin B12 categories, were compared using Pearson's chi-square test or Fisher's exact test when expected cell counts were low.

Vitamin D and Vitamin B12 levels were analyzed as both continuous and categorical variables. For vitamin D, 25(OH) D levels were categorized using thresholds of <20 ng/mL and <30 ng/mL. For vitamin B12, values <300 pg/mL were considered low or borderline-low, and values <200 pg/mL were used as the conventional deficiency threshold. Correlations between serum vitamin levels and clinical improvement, measured by PRWHE and VAS numbness scores, were evaluated using Spearman's rank correlation analysis.

Binary logistic regression analysis was performed to identify factors independently associated with clinical response. Variables with clinical relevance and/or with $p<0.10$ in univariable analyses were entered into the multivariable model. To reduce the risk of overfitting, a parsimonious model was constructed considering the number of clinical response events. The final model included baseline VAS numbness score, night awakening due to symptoms, hand appearance importance, vitamin B12 status (≥300 pg/mL), and vitamin D status (≥30 ng/mL). Odds ratios (ORs) with 95% confidence intervals (CIs) were reported. Model performance was assessed using the Omnibus test, Nagelkerke R^2, and overall classification accuracy. A p-value <0.05 was considered statistically significant.

RESULTS

Participant Characteristics

A total of 128 patients were included in the study. The mean age was 55.94±11.90 years, and 107 participants (83.6%) were female. The mean BMI was 29.19±5.28 kg/m^2. The most common diagnosis was hand osteoarthritis (53.9%), followed by CTS (23.4%). Diabetes mellitus was present in 27.3% of the participants, and 50.0% reported night awakening due to hand symptoms. Mean serum vitamin B12 and 25(OH)D levels were 465.47±254.59 pg/mL and 27.04±16.70 ng/mL, respectively. Baseline mean VAS pain, VAS numbness, and PRWHE scores were 5.22±2.27, 4.07±3.88, and 59.16±21.44, respectively (Table 1).

Changes in Clinical Outcomes Following Paraffin Therapy

Significant improvements were observed in all clinical outcome measures following paraffin therapy. Mean VAS pain scores decreased from 5.22±2.27 to 3.77±2.11 ($p<0.001$), while VAS numbness scores decreased from 4.07±3.88 to 2.70±3.23 ($p<0.001$). Similarly, PRWHE scores improved significantly, decreasing from 59.16±21.44 to 46.73±22.57 ($p<0.001$). Appearance-related discomfort scores also showed a significant reduction from 5.14±3.44 to 4.38±3.25 ($p<0.001$) (Table 2).

Comparison of Responders and Non-Responders

According to the predefined response criteria, 63 patients (49.2%) were classified as responders and 65 patients (50.8%) as non-responders.

Responders had significantly higher baseline serum vitamin B12 levels (513.98±217.76 vs. 418.46±279.50 pg/mL, $p=0.001$) and 25(OH)D levels (30.25±15.10 vs. 23.94±17.67 ng/mL, $p=0.001$) compared with non-responders. Baseline VAS numbness scores were also significantly higher in responders (5.19±3.58 vs. 2.98±3.88, $p=0.002$). In addition, responders more frequently reported night awakening due to symptoms (60.3% vs. 40.0%, $p=0.022$) and had higher appearance discomfort scores (5.95±3.10 vs. 4.35±3.59, $p=0.009$).

No significant differences were observed between responders and non-responders with respect to age, BMI, sex distribution, smoking status, alcohol consumption, diabetes mellitus, diagnosis, baseline pain severity, or baseline PRWHE scores (all $p>0.05$) (Table 3).

When vitamin levels were analyzed categorically, patients with 25(OH)D levels ≥20 ng/mL had a higher clinical response rate than those with levels <20 ng/mL (60.8% vs. 30.6%, $p=0.001$). Similarly, the response rate was higher in patients with 25(OH)D levels ≥30 ng/mL compared with those below this threshold (74.4% vs. 38.2%, $p<0.001$). Patients with vitamin

B12 levels ≥300 pg/mL also had a higher response rate than those with levels <300 pg/mL (62.5% vs. 35.9%, p=0.003). However, the conventional deficiency threshold of 200 pg/mL was not associated with treatment response (p=0.182).

Multivariable Logistic Regression Analysis

A multivariable logistic regression model was constructed including baseline numbness severity, night awakening, hand appearance importance, vitamin B12 status (≥300 pg/mL), and vitamin D status (≥30 ng/mL). The overall model was significant (Omnibus test, p<0.001) with a Nagelkerke R^2 of 0.262 and an overall classification accuracy of 75.8%.

Table 1. Baseline demographic, clinical, and laboratory characteristics of the study population (n=128)

Variable	Value
Demographic characteristics	
Age (years)	55.94±11.90
Female sex, n (%)	107 (83.6)
Height (cm)	160.38±9.46
Weight (kg)	74.85±13.72
Body mass index (kg/m^2)	29.19±5.28
Smoking, n (%)	23 (18.0)
Alcohol use, n (%)	6 (4.7)
Clinical characteristics	
Diabetes mellitus, n (%)	35 (27.3)
Other comorbidity, n (%)	32 (25.0)
No comorbidity, n (%)	61 (47.7)
Night awakening due to symptoms, n (%)	64 (50.0)
Appearance discomfort score (0-10)	5.14±3.44
Diagnostic categories	
Hand osteoarthritis	69 (53.9)
Carpal tunnel syndrome	30 (23.4)
Tenosynovitis/trigger finger	14 (10.9)
Other diagnoses	15 (11.7)
Importance of hand appearance	
Very important	66 (51.6)
Somewhat important	47 (36.7)
Not important	15 (11.7)
Laboratory parameters	
Vitamin B12 (pg/mL)	465.47±254.59
25(OH)D (ng/mL)	27.04±16.70
Baseline symptom severity	
VAS pain score (0-10)	5.22±2.27
VAS numbness score (0-10)	4.07±3.88
PRWHE total score (0-100)	59.16±21.44

Values are presented as mean±standard deviation or n (%)
BMI: Body mass index, PRWHE: Patient-rated wrist/hand evaluation, VAS: Visual analogue scale, 25(OH)D: 25-hydroxyvitamin D

Among the variables entered into the model, serum 25(OH)D levels ≥30 ng/mL emerged as the only independent predictor of clinical response (OR: 4.48, 95% CI: 1.66-12.05, p=0.003). Baseline numbness severity showed a borderline association with treatment response (OR: 1.17, 95% CI: 0.99-1.39, p=0.061). Vitamin B12 status (OR: 1.84, 95% CI: 0.81-4.16, p=0.144), night awakening (OR: 0.98, 95% CI: 0.28-3.40, p=0.973), and importance of hand appearance were not independently associated with treatment response (Table 4).

Correlation Analyses

Serum vitamin B12 and 25(OH)D levels were moderately correlated (r_s=0.460, p<0.001). Higher serum vitamin B12 levels were associated with greater improvements in PRWHE scores (r_s=0.282, p=0.001) and VAS numbness scores (r_s=0.347, p<0.001). Similarly, higher serum 25(OH)D levels were positively correlated with improvements in PRWHE scores (r_s=0.355, p<0.001) and VAS numbness scores (r_s=0.260, p=0.003) (Table 5).

DISCUSSION

The present study evaluated whether baseline vitamin B12 and 25(OH)D status were associated with short-term clinical response to standard paraffin therapy in patients with hand pain and/or numbness. The main finding was that serum 25(OH)D ≥30 ng/mL was independently associated with clinically meaningful response after adjustment for baseline numbness, night awakening, hand appearance importance, and vitamin B12 status. Although higher vitamin B12 levels were associated with greater improvement in PRWHE and VAS numbness scores in univariable and correlation analyses, vitamin B12 status did not remain an independent predictor.

The short-term improvements observed after paraffin therapy are consistent with previous studies evaluating superficial heat modalities in hand disorders. In symptomatic hand osteoarthritis, paraffin therapy combined with exercise or compared with other physical modalities has been reported to improve pain, hand function, grip strength, and quality of life, although the magnitude of benefit varies across studies (12-15). In CTS, paraffin therapy combined with wrist orthosis has also been associated with symptom improvement, although ultrasound with orthosis may provide greater functional benefit in some patients (16). A recent systematic review and meta-analysis similarly reported that paraffin bath therapy may reduce pain and improve hand function, grip strength, and pinch strength in various hand diseases, but emphasized the limited number and heterogeneity of available trials (2). Overall, current

Table 2. Changes in clinical outcomes after paraffin therapy (n=128)

Outcome	Baseline	Post-treatment	p-value
VAS pain (0-10)	5.22±2.27, median: 6 (0-9)	3.77±2.11, median: 4 (0-9)	<0.001
VAS numbness (0-10)	4.07±3.88, median: 5 (0-10)	2.70±3.23, median: 1 (0-10)	<0.001
PRWHE total score (0-100)	59.16±21.44, median: 62.25 (7-99)	46.73±22.57, median: 45.00 (1-98)	<0.001
Appearance discomfort score (0-10)	5.14±3.44, median: 5 (0-10)	4.38±3.25, median: 5 (0-10)	<0.001

Values are presented as mean±standard deviation and median (minimum-maximum). Comparisons between baseline and post-treatment measurements were performed using the Wilcoxon signed-rank test
PRWHE: Patient-rated wrist/hand evaluation, VAS: Visual analogue scale

evidence supports paraffin as a symptomatic modality in selected hand conditions while highlighting variability in treatment response across patients and diagnoses (17).

The diagnostic heterogeneity of the cohort should also be considered when interpreting the relationship between vitamin D status and the response to paraffin therapy. Hand osteoarthritis and CTS have distinct underlying mechanisms. In hand osteoarthritis, symptoms are mainly related to joint degeneration, periarticular stiffness, pain, reduced grip strength, and functional limitation. In this setting, paraffin therapy may provide symptomatic benefit through superficial heating, reduction of stiffness, increased soft-tissue extensibility, and facilitation of hand use and exercise, as supported by previous studies in symptomatic hand osteoarthritis and by recent systematic reviews of paraffin therapy in hand disorders (1,2,12,15,17). By contrast, CTS is primarily a compression neuropathy of the median nerve, and paraffin therapy should not be expected to directly reverse the mechanical or electrophysiological basis of nerve compression. Its potential benefit in CTS is more likely related to short-term symptom modulation, local comfort, reduced soft-tissue tension, and improved tolerance to hand activity or splint-based rehabilitation (16). Therefore, vitamin D status may not interact with paraffin therapy through a single disease-specific pathway. Rather, adequate vitamin D levels may reflect a more favorable neuromuscular and musculoskeletal background, potentially influencing pain perception, muscle performance, functional recovery, and rehabilitation responsiveness in both degenerative and neuropathic-like hand conditions (3,18). In addition, previous evidence suggests that vitamin D deficiency may be associated with CTS symptom severity and that supplementation may improve pain and functional outcomes in some CTS studies, although the level of evidence remains limited (19). This interpretation remains hypothesis-generating because the present study was not designed to test diagnosis-specific mechanisms or vitamin D-by-diagnosis interactions.

The association between vitamin D status and clinical response may be clinically meaningful in rehabilitation, where pain, muscle performance, neuromuscular control, and functional hand use are closely linked. Although the relationship between vitamin D and musculoskeletal pain is inconsistent, vitamin D status may be relevant to pain perception, muscle function, and physical performance in selected patient groups (3,18). In the present study, the ≥30 ng/mL threshold was more strongly associated with clinical response than the conventional deficiency threshold of <20 ng/mL. This may suggest that in patients undergoing rehabilitation for hand symptoms, avoiding severe deficiency alone may not be sufficient to define an optimal metabolic status for functional recovery. However, this association should not be interpreted as evidence that vitamin D supplementation improves response to paraffin therapy.

From a biological perspective, vitamin D may influence the response to paraffin therapy through several complementary mechanisms. Vitamin D has recognized roles in neuromuscular function, skeletal muscle performance, pain modulation, and peripheral nerve health (3,18). Therefore, adequate vitamin D status may create a more favorable biological background for symptomatic and functional recovery after a superficial heat intervention. In hand osteoarthritis, paraffin therapy may reduce pain and stiffness by increasing tissue extensibility, improving periarticular soft-tissue flexibility, and enhancing joint compliance (1,2,12,15). In this context, sufficient vitamin D levels may support muscle function and pain regulation, thereby facilitating better hand use after thermal treatment. In CTS, the mechanism is likely different. Paraffin therapy cannot directly reverse median nerve compression, but local heat may improve comfort, enhance microcirculation, reduce soft-tissue tension, and increase the symptom threshold (16). Because vitamin D deficiency has been linked to neuromuscular dysfunction and neuropathic-like symptoms, better vitamin D status may partly modulate sensory symptoms and functional tolerance in CTS (19). Thus, the observed association between 25(OH)D levels and clinical response may reflect an interaction between the local thermal and mechanical effects of paraffin therapy and systemic neuromuscular or pain-related factors. However, this proposed mechanism remains hypothetical and should

Table 3. Comparison of baseline characteristics according to clinical response status

Variable	Non-responder (n=65)	Responder (n=63)	p-value
Demographic characteristics			
Age (years)	55.12±11.85 55 (27-73)	56.78±11.99 60 (25-75)	0.290
BMI (kg/m^2)	28.56±4.07 27.41 (18.42-38.21)	29.85±6.26 29.14 (17.36-48.48)	0.422
Female sex, n (%)	54 (83.1)	53 (84.1)	0.873
Smoking, n (%)	12 (18.5)	11 (17.5)	0.883
Alcohol use, n (%)	3 (4.6)	3 (4.8)	0.969
Clinical characteristics			
Diabetes mellitus, n (%)	20 (30.8)	15 (23.8)	0.370
Night awakening due to symptoms, n (%)	26 (40.0)	38 (60.3)	0.022
Appearance discomfort score	4.35±3.59 4 (0-10)	5.95±3.10 7 (0-10)	0.009
Diagnostic categories			
Hand osteoarthritis, n (%)	39 (60.0)	30 (47.6)	0.478
Carpal tunnel syndrome, n (%)	14 (21.5)	16 (25.4)	
Tenosynovitis / trigger finger, n (%)	5 (7.7)	9 (14.3)	
Other diagnoses, n (%)	7 (10.8)	8 (12.7)	
Laboratory parameters			
Vitamin B12 (pg/mL)	418.46±279.50 342 (132-1624)	513.98±217.76 471 (188-1025)	0.001
25(OH)D (ng/mL)	23.94±17.67 20.0 (5.52-91.0)	30.25±15.10 27.7 (7.5-75.0)	0.001
Baseline symptom severity			
VAS pain score (0-10)	5.08±2.12 6 (0-9)	5.37±2.42 6 (0-9)	0.317
VAS numbness score (0-10)	2.98±3.88 0 (0-10)	5.19±3.58 6 (0-10)	0.002
PRWHE total score (0-100)	58.52±19.91 61 (10.5-96.5)	59.81±23.06 63 (7-99)	0.625
Vitamin categories			
Vitamin D <20 ng/mL, n (%)	34 (52.3)	15 (23.8)	0.001
Vitamin D ≥20 ng/mL, n (%)	31 (47.7)	48 (76.2)	
Vitamin D <30 ng/mL, n (%)	55 (84.6)	34 (54.0)	<0.001
Vitamin D ≥30 ng/mL, n (%)	10 (15.4)	29 (46.0)	
Vitamin B12 <300 pg/mL, n (%)	41 (63.1)	23 (36.5)	0.003
Vitamin B12 ≥300 pg/mL, n (%)	24 (36.9)	40 (63.5)	
Vitamin B12 <200 pg/mL, n (%)	4 (6.2)	1 (1.6)	0.182*
Vitamin B12 ≥200 pg/mL, n (%)	61 (93.8)	62 (98.4)	

Values are presented as mean±standard deviation and median (minimum-maximum) or n (%). Percentages are column percentages. Continuous variables were compared using the Mann-Whitney U test. Categorical variables were compared using Pearson's chi-square test or Fisher's exact test when appropriate
PRWHE: Patient-rated wrist/hand evaluation, VAS: Visual analogue scale, 25(OH)D: 25-hydroxyvitamin D, *: Fisher's exact test

be confirmed in prospective studies designed separately for hand osteoarthritis and CTS.

The relationship between vitamin D status and response may also be relevant for patients presenting with numbness or neuropathic-like hand symptoms. In the present cohort, CTS was the second most common diagnostic group, and baseline VAS numbness scores were higher among responders. Previous evidence suggests that vitamin D deficiency may be associated with the severity of symptoms in CTS, although available data are limited. In a systematic review, Anusitviwat et al. reported that vitamin

Table 4. Multivariable logistic regression analysis of factors associated with clinical response

Variable	B	SE	OR (95% CI)	p-value
Night awakening due to symptoms	-0.021	0.635	0.98 (0.28-3.40)	0.973
Baseline VAS numbness score	0.160	0.085	1.17 (0.99-1.39)	0.061
Hand appearance importance (overall)	—	—	—	0.761
├ Somewhat important vs. very important	-0.334	0.458	0.72 (0.29-1.76)	0.465
└ Not important vs. very important	-0.218	0.710	0.80 (0.20-3.23)	0.758
25(OH)D ≥30 ng/mL	1.499	0.505	4.48 (1.66-12.05)	0.003
Vitamin B12 ≥300 pg/mL	0.609	0.417	1.84 (0.81-4.16)	0.144

Binary logistic regression analysis. Variables entered the model were night awakening due to symptoms, baseline VAS numbness score, hand appearance importance, vitamin B12 status (≥300 pg/mL), and vitamin D status (≥30 ng/mL)
OR: Odds ratio, CI: Confidence interval, VAS: Visual analogue scale, 25(OH)D: 25-hydroxyvitamin D

Table 5. Correlations between vitamin levels and clinical improvement outcomes

Variables	PRWHE improvement (r_s, p)	VAS numbness improvement (r_s, p)
Vitamin B12	0.282, p=0.001	0.347, p<0.001
25(OH)D	0.355, p<0.001	0.260, p=0.003

Spearman correlation coefficients (r_s). Positive coefficients indicate greater clinical improvement with increasing vitamin levels
PRWHE: Patient-rated wrist/hand evaluation, VAS: Visual analogue scale, 25(OH)D: 25-hydroxyvitamin D

D supplementation was associated with improvements in pain, functional status, and sensory conduction velocity in some studies of patients with CTS; however, the authors also emphasized the low level of evidence and the lack of a standardized supplementation dose or duration (19). These findings are compatible with the present results and suggest a possible link between vitamin D status and improvement in hand symptoms, particularly numbness. However, because our study did not evaluate vitamin D supplementation and included a heterogeneous group of hand disorders, this association should be considered hypothesis-generating, rather than confirmatory.

Vitamin B12 showed a different pattern. Patients with vitamin B12 levels ≥300 pg/mL had a higher clinical response rate, and higher serum vitamin B12 levels correlated with greater improvements in PRWHE and VAS numbness scores. This is biologically plausible because vitamin B12 is required for normal peripheral nerve function, and low or borderline-low levels may contribute to paresthesia and neuropathic-like symptoms. However, vitamin B12 status did not remain an independent predictor after adjustment, suggesting that its association with improvement may partly reflect baseline numbness severity or its correlation with vitamin D status. Limited previous evidence has examined B vitamins in hand disorders, but available studies are small and not directly comparable with the present rehabilitation cohort (20). Therefore, the B12 findings in our study should be interpreted as supportive but not definitive. Clinically, these findings may help explain variable responses to commonly used rehabilitation modalities. Patients receiving the same paraffin protocol may exhibit varying degrees of improvement, which are unlikely to be explained solely by diagnosis or baseline symptom severity. Vitamin D status and, to a lesser extent, vitamin B12 status, may therefore be considered part of a comprehensive rehabilitation assessment, particularly in patients with hand pain accompanied by numbness, paresthesia, or non-specific musculoskeletal complaints.

Study Limitations

This study has several limitations. First, its retrospective, single-center design limits the ability to control for all potential confounding factors. Second, the absence of a control group precludes causal conclusions regarding the efficacy of paraffin therapy, and the observed improvements cannot be clearly distinguished from the natural course of symptoms, placebo effects, regression to the mean, or other routine care factors. Third, the study population was diagnostically heterogeneous, including patients with hand osteoarthritis, CTS, tenosynovitis (trigger finger), and other causes of hand pain or paresthesia. Although this reflects routine rehabilitation practice, it limits diagnosis-specific interpretation. In addition, the sample size was not sufficient to perform robust subgroup analyses or interaction models separately for hand osteoarthritis and CTS. Therefore, the observed association between vitamin D status and clinical response should be interpreted as a general patient-related rehabilitation factor rather than a diagnosis-specific effect. Fourth, although CTS was diagnosed by electrophysiological assessment, the study was not designed to perform diagnosis-specific analyses of severity or to evaluate whether electrophysiological

severity modified the treatment response. Fifth, serum vitamin B12 and 25(OH)D levels were obtained from routine clinical records, and the study did not evaluate the effect of vitamin supplementation. Therefore, the findings should be interpreted as associations between baseline vitamin status and clinical response rather than evidence of a therapeutic effect of vitamin replacement. Finally, only short-term outcomes after a 10-session treatment program were assessed, and longer follow-up is needed to determine whether these associations persist over time.

CONCLUSION

Baseline vitamin D status was independently associated with short-term clinical response to paraffin therapy in patients with hand pain and/or numbness. Serum 25(OH) D ≥30 ng/mL was associated with a higher likelihood of clinically meaningful improvement. Vitamin D status may, therefore, be considered part of the broader rehabilitation assessment in patients with hand-related symptoms. Prospective controlled studies are needed to determine whether correction of vitamin D deficiency can improve rehabilitation outcomes.

ETHICS

Ethics Committee Approval: Ethical approval was obtained from the University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital Clinical Research Ethics Committee (approval no: 2026-10-02, date: 22.04.2026).

Informed Consent: Because of the retrospective design, the requirement for individual informed consent was waived.

FOOTNOTES

Authorship Contributions

Concept: D.F., Y.A., S.Ç., Design: D.F., B.G.A., T.S., T.Ş., Data Collection or Processing: D.F., B.G.A., M.Ç., T.S., Y.A., Analysis or Interpretation: D.F., M.Ç., T.Ş., Literature Search: D.F., B.G.A., M.Ç., Y.A., S.Ç., Writing: D.F., T.S., T.Ş., S.Ç.

Conflict of Interest: No conflict of interest was declared by the authors.

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Research

Determinants of Food Choice in Professional Basketball Players: An Age-, Gender-, and Position-Based Assessment Using the Athlete Food Choice Questionnaire

Profesyonel Basketbolcularda Besin Seçimini Belirleyen Faktörler: Sporcu Besin Seçimi Anketi Kullanılarak Yaş, Cinsiyet ve Pozisyona Dayalı Bir Değerlendirme

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ABSTRACT

Objective: The aim of this study is to evaluate the characteristics affecting food choices in professional basketball players using the Athlete Food Choice Questionnaire (AFCQ) and to investigate the effect of age, gender, and player position variables on food choice.

Methods: The study included 197 professional basketball players (102 men and 95 women). Data for the study were collected using the Turkish or English versions of the AFCQ, along with participants' demographic information. Data were analyzed using SPSS 26.0; kurtosis and skewness were used to assess normality. Independent-groups t-tests and analysis of variance were used for variables that met the assumption of normality, while Spearman's correlation and appropriate non-parametric tests were used for variables that did not.

Results: Age and gender significantly affected some AFCQ subscale scores, and the overall consistency of the positions performed was also significant. Female athletes scored significantly higher than male athletes in the "emotional effects" (p=0.011) and "emotional appeal" (p=0.001). Athletes under the age of 18 scored significantly lower than athletes in other age groups on "nutritional properties of food," "emotional effects," "food and health awareness," "weight control," "food values and beliefs," and "performance" (p<0.05).

Conclusion: Age and gender are important variables that determine the food choices of professional basketball players. Therefore, age- and gender-focused individualized education programs can contribute to improving nutrition in athletes, thereby enhancing performance and reducing the risk of sports injuries.

Keywords: Athlete Food Choice Questionnaire, basketball, food, choice

ÖZ

Amaç: Bu çalışmanın amacı, profesyonel basketbolcularda yiyecek seçimlerini etkileyen özellikleri Sporcu Besin Seçimi Anketi (SBSA) kullanılarak değerlendirmek ve yiyecek seçimi üzerinde yaş , cinsiyet ve oyuncu pozisyonu değişkenlerinin etkisini araştırmaktır.

Gereç ve Yöntem: Çalışmaya 199 profesyonel basketbolcu (102 erkek, 95 kadın) dahil edildi. Katılımcıların demografik bilgileri ile birlikte SBSA'nın Türkçe veya İngilizce versiyonu kullanılarak çalışma için veri toplandı. Veriler SPSS 26.0 programı ile analiz edilmiş; normallik değerlendirmesinde basıklık ve çarpıklık değerleri kullanılmıştır. Normallik sağlayan değişkenlerde bağımsız gruplar t-testi ve varyans analizi, sağlanamayanlarda ise Spearman bakımı ve uygun parametrik olmayan testler kullanılmıştır.

Bulgular: Yaş ve cinsiyet değişkenlerinin bazı SBSA alt ölçek puanları üzerinde anlamlı sonuçlar olduğu, ancak gerçekleştirilen pozisyonların genel olarak anlamlı kalıcılığı tespit edilmiştir. Kadın sporcular "duygusal etkiler" (p=0,011) ve "duygusal çekicilik" (p=0,001) erkek sporculardan puanlarında anlamlı olarak yüksek skorlar elde etti. On sekiz yaşın altındaki sporcuların "gıdanın besinsel özellikleri", "duygusal etkiler", "gıda

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ÖZ

ve sağlık bilinci", "kilo kontrolü", "gıda değerleri ve inançlar" ve "performans" puanları diğer yaşlarına göre anlamlı olarak daha düşük olarak saptanmıştır ($p<0,05$).

Sonuç: Profesyonel basketbolcularda yaş ve cinsiyet, yiyecek seçimlerini belirleyen önemli değişkenlerdir. Bu nedenle yaş ve cinsiyet odaklı bireyselleştirilmiş eğitim eğitim programları, sporcularda beslenmeyi iyileştirerek performansın artırılmasına ve spor yaralanması riskinin azaltılmasına katkı sağlayabilir.

Anahtar Kelimeler: Sporcu Besin Seçimi Anketi, basketbol, besin, seçim

INTRODUCTION

Athletes are a unique group distinct from the rest of society because factors related to sports and performance influence their food choices (1,2).

Nutrition is considered one of the fundamental elements of athletic performance (3). This is because nutrition is considered a critical component for enhancing performance, facilitating physiological adaptations, and preventing injuries in athletes (4).

Basketball is one of the most popular sports in the world, played by men and women of all levels and ages (5). Basketball is classified as a sport that combines aerobic and anaerobic activities (6).This sport involves short periods of high-intensity activities such as sprinting, quick changes of direction, acceleration, deceleration, and running backwards, as well as short periods of low-intensity activities such as walking, jogging, and recovery periods, which place high demands on anaerobic/aerobic capacity (7). This, in turn, places high physical and physiological demands on basketball players, particularly with respect to nutrition.

In the general population, factors such as age, gender, education level, and income can influence food choices (8,9). In addition, many factors such as cost, taste, and availability affect food choices (10). Unlike those of the general population, athletes' food choices may be influenced by numerous factors, such as impacts on athletic performance, food preparation, coaches' and teammates' influence, and sports culture (10).

Although studies on determinants of food choice are widespread, it is noted that these studies have not been conducted in specific populations (11). For this reason, the authors aimed to evaluate the factors affecting food choice in basketball players, who have unique characteristics and physiological needs. They hypothesized that variables such as gender, age group, and playing position may influence food selection among basketball players.

METHODS

The study was designed as a survey. Data collection for the study began after obtaining approval from the University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Research and Training Hospital Non-Interventional Scientific Research Ethics Committee (approval no: 2025-17-05, date: 17.09.2025). Written informed consent was obtained from all adult participants. For participants younger than 18 years, written informed consent was obtained from their parents or legal guardians, and assent was obtained from the participants themselves. Those with known food allergies, food intolerances, previous surgical treatment related to the digestive system, diagnosed chronic diseases, or who did not sign the informed consent form were not included in the study.

No personal information was used for any basketball player who agreed to participate in the study. The following information for all participants was recorded on questionnaire forms and subsequently transferred to a computer database.

- Gender,
- Age (grouped as under 18, 18-25, and over 25),
- Position played,
- Height,
- Weight,
- Body mass index (BMI).

All basketball players who agreed to participate in the study completed the Athlete Food Choice Questionnaire (AFCQ). This questionnaire uses a 1 (never) to 5 (always) rating scale and was originally developed to identify food choice determinants in English-speaking populations (12). This questionnaire consists of 32 items representing nine factors: nutritional characteristics of food, emotional effects, food and health awareness, influence of others, eating habits, weight control, food values and beliefs, emotional appeal, and performance. For basketball players whose native language is Turkish, the previously adapted Turkish version of this questionnaire was used (13). For basketball players whose native language is not Turkish, the original English version of the questionnaire, designed for English-speaking populations, was used. All players' responses were recorded separately for statistical analysis.

Statistical Analysis

Data analysis was performed using SPSS 26.0 and was conducted at a 95% confidence level. In this study, skewness and kurtosis coefficients were examined to determine the suitability of the variables for a normal distribution. Skewness and kurtosis values obtained from the variables ranging between +3 and -3 were considered sufficient for normal distribution (14-16). Normality was achieved for skewness and kurtosis values between -3 and +3, but not for variables outside this range. Accordingly, the relationships between height and scale scores and between weight and scale scores were tested using Pearson correlation analysis, while the relationship between BMI and scale scores was tested using Spearman correlation analysis. Differences in scale scores by gender were analyzed using the t-test, whereas differences by age and playing position were analyzed using analysis of variance (ANOVA). If a difference was found in the ANOVA test, the post-hoc analysis was performed using the lysergic acid diethylamide test.

RESULTS

A total of 197 basketball players were included in the study. Among the participants, 60.9% (n=120) were under 18 years old, 26.4% (n=52) were between 18 and 25 years old, and 12.7% (n=25) were over 25 years old. Regarding gender distribution, 51.8% (n=102) of participants were male and 48.2% (n=95) were female. When evaluating positions played, participants were distributed as follows: 20.8% (n=41) guards, 13.7% (n=27) point guards, 21.8% (n=43) shooting guards, 25.4% (n=50) power forwards, and 18.3% (n=36) centers. The participants' height ranged from 150 cm to 219 cm, with an average of 185.9±12.69 cm. Body weight ranged from 48 kg to 118 kg, with an average of 77.18±14.18 kg. BMI ranged from 17.09 to 42.22, with an average of 22.2±2.58.

Table 1 presents the average responses of all study participants to the 9 questionnaire headings.

Data on the relationship between determinants of food choice and age show that the "nutritional properties of food" score is 3.49±0.77 in the under-18 group, 3.78±0.75 in the 18-25 age group, and 3.89±0.81 in the over-25 age group. The ANOVA test revealed a significant difference between the groups (F=4.290, p=0.015). Post-hoc analyses show that this difference is due to lower scores in the under-18 group compared with those in the 18-25 and over-25 age groups. The "emotional effects" score was 2.51±1.06 in the under-18 group, 2.62±0.98 in the 18-25 age group, and 3.11±1.27 in the over-25 age group. A significant difference was observed between the groups (F=3.207, p=0.043); post-hoc analyses indicate that the under-18 group scored lower than the over-25 group. The "food and health awareness" score is 3.51±0.70 in the under-18 group, 3.85±0.79 in the 18-25 age group, and 3.94±0.76 in the over-25 age group. A significant difference was observed between the groups (F=6.063, p=0.003); post-hoc analysis showed that the under-18 group scored lower than the other two age groups. The "influence of others" score is 2.91±0.88 in the under-18 group, 2.67±0.91 in the 18-25 age group, and 2.80±1.06 in the over-25 age group. There is no significant difference between the groups (F=1.287, p=0.278). The "normal eating practices" score was 3.26±0.84 in the under-18 group, 3.40±0.86 in the 18-25 age group, and 3.72±0.89 in the over-25 age group. There is a significant difference between groups (F=3.092, p=0.048), with the under-18 group scoring lower than the over-25 group. The "weight control" score is 3.48±0.84 in the under-18 age group, 4.05±0.70 in the 18-25 age group, and 4.11±0.77 in the over-25 age group. There was a significant difference between the groups (F=13.033, p<0.001); the under-18 group had a lower score than the other two age groups.The "food values and beliefs" score is 2.21±1.00 in the under-18 group, 2.69±1.13 in the 18-

Table 1. Average responses of participants in the study to the 9 headings in the questionnaire and the skewness and kurtosis values for these data

	Mean±SD	Skewness	Kurtosis
Nutritional properties of food	3.62±0.79	-0.267	-0.034
Emotional effects	2.62±1.08	0.230	-0.660
Food and health awareness	3.66±0.75	-0.300	-0.052
Influence of others	2.84±0.91	0.026	-0.162
Normal eating practices	3.36±0.86	0.037	-0.551
Weight control	3.71±0.84	-0.496	0.271
Food values and beliefs	2.38±1.09	0.610	-0.302
Emotional appeal	3.98±0.81	-0.712	0.652
Performance	4.4±0.76	-1.401	1.897

SD: Standard deviation

25 age group, and 2.55±1.30 in the over-25 age group. A significant difference between the groups was observed (F=3.811, p=0.024); the under-18 group scored lower than the 18-25 age group. The "emotional attractiveness" score is 3.96±0.80 in the under-18 group, 3.92±0.88 in the 18-25 age group, and 4.15±0.73 in the over-25 age group. There is no significant difference between the groups (F=0.678, p=0.509). The "performance" score is 4.28±0.78 in the under-18 group, 4.54±0.80 in the 18-25 age group, and 4.69±0.43 in the over-25 age group. There is a significant difference between the groups (F=4.371, p=0.014), and the under-18 group has a lower score than the other two age groups.

Data on the relationship between participants' responses and gender are presented in Table 2.

According to the data in Table 2, the "nutritional properties of food" score is 3.63±0.83 for men and 3.61±0.74 for women. The independent- groups t-test found no significant difference (t=0.096, p=0.924). The "emotional effects" score is 2.43±1.08 for men and 2.82±1.05 for women. There is a significant difference between the groups (t=-2.580, p=0.011); women's scores are higher than men's. The "food and health awareness" score is 3.58±0.75 for men and 3.74±0.74 for women. No significant difference was observed between the groups (t=-1.465, p=0.145). The "influence of others" score is 2.91±1.01 for men and 2.76±0.79 for women. No significant difference was observed between the groups (t=1.158, p=0.248). The "usual eating practices" score is 3.32±0.93 in men and 3.40±0.77 in women**.** There is no significant difference between the groups (t=-0.712, p=0.478). The "weight control" score is 3.63±0.84 in men and 3.79±0.85 in women. No significant difference was observed between the groups (t=-1.285, p=0.200). The "food values and beliefs" score is 2.24±1.04 for men and 2.54±1.13 for women. There is no significant difference between the groups (t=-1.946, p=0.053). The "emotional attractiveness" score is 3.80±0.85 for men and 4.16±0.72 for women. A significant difference between the groups (t=-3.232, p=0.001); women's scores were higher than men's. The "performance" score is 4.34±0.80 in men and 4.46±0.73 in women. There is no significant difference between the groups (t=-1.069, p=0.286).

The relationship between participants' answers and the positions they played is shown in Figure 1.

According to the data in Figure 1, the "nutritional properties of food" score is 3.60±0.89 for the guard position, 3.52±0.94 for the point guard position, 3.73±0.72 for the shooting guard position, 3.70±0.73 for the power forward position, and 3.48±0.69 for the center position. The ANOVA test found no significant difference (F=0.695, p=0.596). Emotional effects scores are 2.54±1.07 for the guard position, 2.48±1.19 for the point guard position, 2.55±1.06 for the shooting guard position, 2.66±1.08 for the power forward position, and 2.85±1.04 for the center position. There is no significant

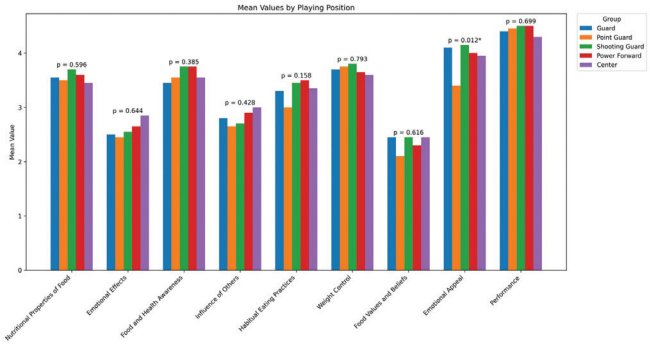

Figure 1. Distribution of participants' responses according to their playing positions

Table 2. Data showing the relationship between determinants of food choice and gender

	Gender			
	Male	Female	**t**	**p-value**
	Average	Average		
Nutritional properties of food	3.63±0.83	3.61±0.74	0.096	0.924
Emotional effects	2.43±1.08	2.82±1.05	-2.580	0.011
Food and health awareness	3.58±0.75	3.74±0.74	-1.465	0.145
Influence of others	2.91±1.01	2.76±0.79	1.158	0.248
Normal eating practices	3.32±0.93	3.4±0.77	-0.712	0.478
Weight control	3.63±0.84	3.79±0.85	-1.285	0.200
Food values and beliefs	2.24±1.04	2.54±1.13	-1.946	0.053
Emotional appeal	3.8±0.85	4.16±0.72	-3.232	0.001
Performance	4.34±0.8	4.46±0.73	-1.069	0.286

difference between the groups (F=0.627, p=0.644). The "food and health awareness" score is 3.52±0.80 for the guard position, 3.59±0.77 for the point guard position, 3.77±0.61 for the shooting guard position, 3.77±0.75 for the power forward position, and 3.57±0.81 for the center position. There is no significant difference between the groups (F=1.045, p=0.385).The "influence of others" score is 2.83±1.01 for the guard position, 2.63±1.01 for the point guard position, 2.73±0.98 for the shooting guard position, 2.91±0.74 for the power forward position, and 3.03±0.84 for the center position. There is no significant difference between the groups (F=0.965, p=0.428). The "normal eating practices" score is 3.29±0.88 for the guard position, 3.02±0.98 for the point guard position, 3.45±0.79 for the shooting guard position, 3.52±0.80 for the power forward position, and 3.35±0.85 for the center position. There is no significant difference between the groups (F=1.673, p=0.158).The "weight control" score is 3.73±0.93 for the guard position, 3.76±1.00 for the point guard position, 3.81±0.75 for the shooting guard position, 3.65±0.83 for the power forward position, and 3.60±0.78 for the center position. There is no significant difference between the groups (F=0.421, p=0.793). The "food values and beliefs" score is 2.50±0.98 for the guard position, 2.15±1.01 for the point guard position, 2.46±1.21 for the shooting guard position, 2.27±1.19 for the power forward position, and 2.47±1.01 for the center position. No significant difference was observed between the groups (F=0.667, p=0.616). The "emotional attractiveness" score is 4.11±0.75 for the guard position, 3.49±0.91 for the point guard position, 4.14±0.72 for the shooting guard position, 3.99±0.69 for the power forward position, and 3.96±0.95 for the center position. The ANOVA test revealed a significant difference (F=3.288, p=0.012). According to the post-hoc analysis results, the Emotional Attractiveness score is higher in the guard, shooting guard, power forward, and center positions than in the point guard position. The performance score is 4.38±0.78 for the guard position, 4.42±0.79 for the point guard position, 4.46±0.91 for the shooting guard position, 4.47±0.59 for the power forward position, and 4.24±0.76 for the center position. No significant difference was observed between the groups (F=0.551, p=0.699).

DISCUSSION

The most important finding of this study is that age and gender affect food choices in professional basketball players, whereas playing position does not.

Previous studies in the literature have shown that gender is an important factor in dietary differences (17,18). Food choices are significantly influenced by health beliefs, and since men and women have different health beliefs, differences in food choices are expected (19). In their study evaluating the food choices of athletes competing in international competitions, Pelly and colleagues used a questionnaire different from the AFCQ and found that there were differences between men and women in the factors influencing food choice (2). Thurecht and colleagues also investigated the variables affecting food choices of athletes in international competitions and used the AFCQ in this study (20). This study found that the food selection criteria of "performance" and "emotional effects" affected female athletes' food choices more than males (20). Carey et al. (21) evaluated food selection in athletes in the Irish population using the AFCQ and found differences between women and men in terms of "food and health awareness," "nutritional values," "emotional appeal," and "emotional effects". They emphasized that "emotional effects" are more important in women's food choices. Sevim et al. (13), in their work on the Turkish validation of the AFCQ, showed that "influence of others," "emotional effects," and "emotional appeal" were more effective in female athletes' food choices, while "weight control" was a more effective variable in male athletes' food choices. In our study, we separately examined the effects of AFCQ parameters on food selection among female and male athletes. Consistent with other studies, we found differences in food selection between female and male athletes. In the present study, significant gender differences were observed only in the emotional effects and emotional appeal, with female athletes scoring higher than male athletes. No statistically significant gender differences were found for nutritional properties of food, food and health awareness, influence of others, usual eating practices, weight control, food values and beliefs, or performance.

Few studies have evaluated the relationship between athlete age and food choice. Carey et al. (21) evaluated food choice in athletes in the Irish population using the AFCQ. In this study, they found that for every 10-year increase in age among athletes, the effect of "nutritional values" on food selection increased, the effect of "emotional influences" on food selection decreased with age, and the effect of "influence of others" also decreased with age. In our study, we evaluated the relationship between age and food selection factors identified using the AFCQ. We examined the average scores of athletes under 18 years of age, athletes between 18 and 25 years of age, and athletes over 25 years of age in the areas of "nutritional properties of food," "emotional effects," "food and health awareness," "weight control," "food values and beliefs," and "performance".

We found that athletes under 18 years of age had lower average scores than athletes aged 18-25 and athletes over 25 years of age.

Nutrition is one of the fundamental factors that determines not only the physical and psychological health of athletes, but also their athletic performance, risk of injury, and recovery time after injury (22). However, the current literature reveals that athletes experience various difficulties in adhering to recommended nutrition protocols and often make food choices that do not meet their performance requirements (13,23). This situation can increase the incidence of injuries and lead to prolonged rehabilitation periods, especially in sports such as basketball, which involve high energy requirements and injury risks. A study conducted in Türkiye found that athletes who had previously received nutrition education demonstrated a significant increase in awareness of factors such as "nutrition and health awareness," "nutritional properties of foods," "weight control," and "established eating habits. This finding demonstrates that nutrition education has a direct effect on eating behaviors. Therefore, implementing individualized nutrition education programs for elite athletes may contribute to reducing the risk and frequency of injuries both directly and indirectly.

Study Limitations

As with any study, this one has certain limitations. First, because the study had a cross-sectional design, the relationship between variables cannot be interpreted as causal. The collection of data using self-report methods may lead to recall bias and social desirability bias. Since the study was conducted only on professional basketball players, the generalizability of the findings to different sports or amateur athletes is limited. Furthermore, the interaction between cultural and environmental factors and food choices was not directly assessed. Although the factors influencing food choices have been identified, the lack of examination of athletes' actual food consumption levels and their relationship with performance or injury outcomes constitutes a limitation.

CONCLUSION

The present findings suggest that age and gender are important determinants of food choice among professional basketball players, while playing position generally has no significant effect. The findings show that young and male athletes, in particular, pay less attention to health and nutritional values in their food choices. Considering the effects of nutrition on injury, performance, and physiology, individualized nutrition education tailored to athletes' age and gender characteristics can contribute both to the development of nutritional habits and to sports performance and recovery processes, with the aim of eliminating negative effects.

ETHICS

Ethics Committee Approval: Data collection for the study began after obtaining approval from the University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Research and Training Hospital Non-Interventional Scientific Research Ethics Committee (approval no: 2025-17-05, date: 17.09.2025).

Informed Consent: Written informed consent was obtained from all adult participants. For participants younger than 18 years, written informed consent was obtained from their parents or legal guardians, and assent was obtained from the participants themselves.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: B.B., S.A., Concept: B.B., S.A., S.E., A.D., Design: B.B., S.A., A.D., Data Collection or Processing: B.B., S.A., M.E., Analysis or Interpretation: B.B., S.A., M.E., Literature Search: B.B., S.A., M.E., S.E., Writing: B.B., S.A., A.D.

Conflict of Interest: Altuğ Duramaz Prof. MD is a Editorial Member in Medical Journal of Bakırköy. He had no involvement in the peer-review of this article and had no access to information regarding its peer-review. The other authors declared no conflict of interest.

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Research

The Effect of Surgical Fear Level Before Abdominal Surgery on Postoperative Recovery

Abdominal Cerrahi Öncesi Cerrahi Korku Düzeyinin Ameliyat Sonrası İyileşme Üzerine Etkisi

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ABSTRACT

Objective: Surgical fear, which is common before abdominal surgery, adversely affects postoperative recovery and prolongs hospital stay. This study was conducted to determine the effect of preoperative fear level on recovery after abdominal surgery. This study employed a prospective, correlational design.

Methods: The researcher conducted the study involving 200 patients undergoing abdominal surgery. Data were collected using the patient information form, Surgical Fear Questionnaire, and postoperative recovery index.

Results: The mean preoperative total surgical score among patients was 27.22±22.73. Analyses of univariate linear regression models found that fear of surgery complicates patients' postoperative recovery [(T_1, β=0.234; p=0.001; R^2=0.055); (T_2, β=0.195; p=0.006; R^2=0.038)].

Conclusion: The study showed that preoperative fear of abdominal surgery increased patients' difficulty during postoperative recovery.

Keywords: Abdominal surgery, postoperative recovery, surgical

ÖZ

Amaç: Abdominal cerrahi öncesinde yaygın olan cerrahi korku, hastaların ameliyat sonrası iyileşmesini olumsuz yönde etkiler ve hastanede kalış sürelerinin uzamasına neden olmaktadır. Bu çalışma, abdominal cerrahi sonrası iyileşme üzerine ameliyat öncesi korku düzeyinin etkisini belirlemek amacıyla yürütüldü. Bu çalışma prospektif ve ilişkisel tipte bir tasarım kullanılarak uygulandı.

Gereç ve Yöntem: Araştırmacı, abdominal cerrahi geçiren 200 hasta ile çalışmayı uyguladı. Veriler hasta bilgi formu, Cerrahi Korku Anketi ve ameliyat sonrası iyileşme indeksi kullanılarak toplandı.

Bulgular: Hastaların ameliyat öncesi toplam cerrahi korku düzeyi ortalaması 27,22±22,73 olarak bulunmuştur. Tek değişkenli doğrusal regresyon modeli analiz sonuçlarına göre, ameliyat korkusunun hastaların postoperatif iyileşme sürecini zorlaştırdığı bulunmuştur [(T_1, β=0,234; p=0,001; R^2=0,055); (T_2, β=0,195; p=0,006; R^2=0,038)].

Sonuç: Çalışmada, karın ameliyatı öncesi ameliyat korkusunun hastaların ameliyat sonrası iyileşme sürecindeki zorluk düzeyini artırdığı görüldü.

Anahtar Kelimeler: Abdominal cerrahi, ameliyat sonrası iyileşme, cerrahi korku

INTRODUCTION

Emergency or elective abdominal surgery constitutes a controlled trauma that affects patients both physiologically and psychologically. Despite advances in technology and surgical techniques, patients undergoing surgery today may experience problems such as fear of pain and anesthesia, separation from family, and interventions that alter body image, which can lead to fear of surgery (1-4). In patients undergoing abdominal surgery, Factors that may cause fear

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of surgery—unlike in other types of surgery—include the possibility of impairing the functions of vital organs, such as digestion and excretion, and concern that abdominal pain will restrict movement. Surgical fear is defined as the excessive fear experienced by a person anticipating surgical interventions (5). This condition, which varies from patient to patient, may negatively affect patient outcomes during and after surgery (6). Studies have reported that preoperative fear negatively affects the patient's recovery, increases the use of anesthetic drugs during surgery, and causes surgical complications (5,7). In addition, surgical fear may lead to increased postoperative pain, delayed wound healing, and increased need for analgesics. It may prolong hospital stays and adversely affect recovery (8,9). In the preoperative period, each patient should be carefully evaluated for surgical anxiety, and postoperative recovery should be supported by nursing care tailored to the patient's needs (10). Delayed recovery is associated with problems such as delayed return to home and work activities, difficulty moving, fatigue, the belief that more time is needed for recovery, loss of appetite, nausea, and pain (10,11). The majority of studies on anesthesia and postoperative recovery have focused on physiological parameters, recovery time, and rates of adverse outcomes, including serious complications and mortality. It has been emphasized in the literature that fear of surgery negatively affects postoperative recovery (1,8,11,12). Unlike other studies, it aimed to answer how fear-induced stress before abdominal surgery would affect the patient and their recovery. We aimed to evaluate the effect of preoperative fear on postoperative recovery.

METHODS

Study Design, Population, and Sample Size

The study was conducted the general surgery departments of a training and research hospital in Türkiye from March to August 2024. This study employed a descriptive, relational design. The population comprised patients undergoing abdominal surgery in the general surgery department of a training and research hospital in Türkiye from March to August 2024. The sample size was determined to be 196 patients using G*Power 3.1, with a margin of error of 0.05, an 80% confidence level, and a power of 80%. A total of 205 patients who met the inclusion criteria were enrolled to account for potential withdrawals or exclusions during the study. During data collection, two patients had previously used antipsychotic and antidepressant drugs, two had speech problems and one refused to participate; therefore, the study was completed with 200 patients. This study addressed the following questions.

Study Inclusion Criteria

Participants aged 18-70 years who underwent elective abdominal surgery (appendectomy, cholecystectomy, total gastrectomy, hemicolectomy) and had no hearing or speech problems impairing communication or psychiatric illness were included.

Exclusion Criteria

Patients with psychiatric disorders who underwent emergency surgery were excluded from the study.

Instruments

Research data were collected using the patient identification form, the Surgical Fear Questionnaire (SFQ), and the postoperative recovery index (PoRI).

Patient Identification Form

The researcher developed the patient information form based on data from the literature (1,2,13). It consists of 11 questions assessing age, gender, education, profession, marital status, type of surgery, previous hospitalizations, previous surgeries, chronic diseases, preoperative pain, and current medications.

Surgical Fear Questionnaire

Theunissen and colleagues designed this scale to examine levels of surgical fear in patients undergoing surgery. The original scale's Cronbach's alpha was 0.87 (14). Construct validity and internal consistency for Turkish were assessed by Bağdigen and Karaman Özlü (15). It is a Likert-type scale consisting of eight items. The questionnaire is scored on a scale from 0 to 10 (0=not at all; 10=very afraid). Scores range from 0 to 80, depending on the patient's level of fear. A higher score indicates a higher level of fear. The Cronbach's alpha coefficient for the adapted scale is 0.93 (15). In this study, Cronbach's alpha was determined to be 0.98.

Postoperative Recovery Index

The PoRI, whose validity and reliability were tested by Butler et al. (16) in 2012, consists of five subdimensions: psychological symptoms, physical activities, general symptoms, bowel symptoms, and appetite symptoms. Scores for items included in each subdimension are summed, averaged, and used to determine their subdimension scores. The statistical validity and reliability of the Turkish adaptation of PoRI were assessed by Cengiz and Aygin (17). The scale consists of 25 items. Items 1-4 of the scale include psychological symptoms; items 5-12 include physical symptoms; and items 13-25 include general symptoms, bowel symptoms, and desire symptom (17). High scores on the scale indicate difficult postoperative recovery, whereas low scores indicate easier postoperative recovery. Cronbach's alpha reliability coefficient was calculated as α=0.967.

In this study, Cronbach's alpha (α) values for the total PoRI score at the first and second postoperative evaluations were 0.932 and 0.935, respectively.

Ethical Considerations

Ethics committee approval was obtained prior to data collection from İstanbul Atlas University Non-Interventional Scientific Research Ethics Committee (approval no: 02/08, date: 08.02.2024). Before surgery, patients were provided with necessary explanations about the study. Both verbal and written consent were obtained. This scientific study was completed in accordance with the Declaration of Helsinki.

Data Collection

Before surgery, the researcher administered the patient identification form (SFQ) to the patients. Postoperatively, PoRI was administered to evaluate both early and late recovery outcomes. The scale was administered face-to-face by the researcher on postoperative day 2 to evaluate early recovery, and once by phone between postoperative days 15 and 30 to evaluate late recovery. All patients were given research information and informed that they could withdraw from the study at any time. Data entry was performed by a researcher not involved in data collection.

Statistical Analysis

SPSS 27.0 was used to analyze the data. Normality was assessed using the skewness and kurtosis coefficients, which ranged from -1.5 to +1.5. Categorical data are presented as frequencies and percentages, and continuous data are presented as means and standard deviations. Independent-samples t-tests were used for two-group comparisons, one-way analysis of variance was used for more than two groups, paired t-tests were used for repeated measures, and Pearson correlation analysis was used for inter-variable relationships. The effect of fear of surgery on postoperative recovery was examined using linear regression analysis.

RESULTS

The mean age of patients in the study was 53.75±12.35 years. Of the participants, 55.5% were female, 81% were married, 60% were high school graduates, and 44.5% had chronic diseases. 62% of participants had prior surgical experience, and 137 (68.5%) had been hospitalized for at least one day. No statistically significant differences were found in mean PoRI scores among patients according to their descriptive characteristics ($p>0.05$). Female patients ($t=2.225$; $p=0.027$) and patients with no previous hospitalization experience ($t=2.653$; $p=0.009$) had significantly higher levels of surgical fear (Table 1).

A statistically significant positive correlation was found between the patients' PoRI level and their total [(T_1, $r=0.234$; $p=0.001$); (T_2, $r=0.195$; $p=0.006$)], short-term [(T_1, $r=0.222$; $p=0.002$); (T_2, $r=0.186$; $p=0.008$)], and long-term [(T_1, $r=0.242$; $p=0.001$); (T_2, $r=0.202$; $p=0.004$)] surgical fear levels. A statistically significant positive correlation was found between the patients' PoRI levels and their long-term surgical fear levels. A statistically significant but weak positive correlation was observed between patients' level of surgical fear and the PoRI (Table 2).

The patients' PoRI scores had a mean of 2.88±0.55 (range, 1.3-4.2) at the first measurement and 1.74±0.43 (range, 1-3) at the second measurement. A statistically significant improvement of approximately 39.6% in patients' postoperative recovery difficulty was observed at the second measurement compared with the first ($t=39.468$; $p<0.001$). Findings for the PORI subscales paralleled those obtained from the total scale score (Table 3). According to the results of the univariate linear regression analysis, preoperative surgical fear increased the level of difficulty experienced by patients during postoperative recovery (T_1: $\beta=0.234$; $p=0.001$; $R^2=0.055$; T_2: $\beta=0.195$; $p=0.006$; $R^2=0.038$). When subgroup analyses were examined, surgical fear was identified as causing the greatest difficulty experienced by patients in recovery with respect to psychological symptoms [(T_1, $\beta=0.273$; $p<0.001$; $R^2=0.074$); (T_2, $\beta=0.307$; $p<0.001$; $R^2=0.094$)] (Table 4).

DISCUSSION

Multiple reasons underlie patients' fear of surgery, which often begins when they decide to undergo the procedure. These reasons include anticipation of surgery, risks of surgery, fear of disability, fear of pain, distorted body image, and previous surgical experiences. Fear of surgery leads to postoperative morbidity and prolonged hospital stay, which negatively impact postoperative recovery (18). Postoperative recovery is defined as patient-centered care aimed at improving an individual's quality of life. Therefore, surgical fear and its impact on postoperative recovery should be considered fundamental factors in the care of patients undergoing surgery (19).

The findings of this study indicate that pre-surgery fear levels were not elevated. Based on the average scores obtained from the scale, patients exhibited low levels of fear. This may be attributed to differences in levels of surgical fear according to the extent of the surgical procedure. When the literature was reviewed, no studies were found investigating the level of surgical fear among patients undergoing abdominal surgery. Kapıkıran et al. (20) reported

Table 1. Patient descriptive characteristics PoRI and SFQ score mean

Descriptive characteristics		n	PoRI-T_1	PoRI -T_2	SFQ
Age	20-49	52	2.84±0.55	1.64±0.34	30.58±22.22
	50-54	28	2.87±0.54	1.74±0.43	30.04±25.27
	55-60	45	2.86±0.45	1.75±0.40	26.33±22.22
	61-70	75	2.93±0.60	1.80±0.48	24.37±22.41
	Test value[b]		0.341[b]	1.444[b]	0.936[b]
	p-value		0.795	0.231	0.424
Gender	Female	111	2.91±0.51	1.75±0.42	30.34±23.87
	Male	89	2.86±0.59	1.72±0.44	23.33±20.68
	Test value[a]		0.664[a]	0.464[a]	**2.225[a]**
	p-value		0.507	0.643	**0.027****
Marital status	Married	162	2.86±0.54	1.74±0.43	27.22±22.34
	Single	38	2.97±0.57	1.74±0.39	27.24±24.61
	Test value[a]		1.074[a]	0.030[a]	0.005[a]
	p-value		0.284	0.976	0.996
Educational level	Literate	11	2.89±0.68	1.59±0.32	31.55±26.48
	Primary education	69	2.98±0.51	1.79±0.44	29.42±22.21
	High school and above	120	2.83±0.55	1.72±0.43	25.56±22.70
	Test value[b]		1.659[b]	1.294[b]	0.842[b]
	p-value		0.193	0.277	0.432
Working status	Yes	90	2.85±0.53	1.74±0.44	24.76±19.64
	No	110	2.91±0.56	1.74±0.41	29.24±24.87
	Test value[a]		0.810[a]	0.037[a]	1.423[a]
	p-value		0.419	0.970	0.156
Chronic illness	Yes	89	2.88±0.57	1.74±0.44	27.09±22.48
	No	111	2.89±0.53	1.74±0.41	27.32±23.02
	Test value[a]		0.073[a]	0.076[a]	0.072[a]
	p-value		0.942	0.939	0.942
Use of medicines	Yes	91	2.87±0.58	1.74±0.45	26.43±22.27
	No	109	2.90±0.52	1.74±0.40	27.88±23.18
	Test value[a]		0.437[a]	0.137[a]	0.449[a]
	p-value		0.663	0.891	0.654
Previous surgery	Yes	124	2.88±0.51	1.72±0.44	25.51±22.22
	No	76	2.90±0.60	1.78±0.41	30.01±23.41
	Test value[a]		0.288[a]	0.925[a]	1.364[a]
	p-value		0.773	0.356	0.174
Previous hospitalization	Yes	137	2.89±0.54	1.70±0.43	24.37±21.39
	No	63	2.87±0.57	1.83±0.42	33.41±24.43
	Test value[a]		0.185[a]	1.957[a]	**2.653[a]**
	p-value		0.854	0.052	**0.009***

*: p<0.01, **: p<0.05, [a](t): Independent sample t-test, [b](F): One-way analysis of variance test, SD: Standard deviation, T_1: Postoperative 2nd day, T_2: Postoperative 15th-30th day, PoRI: Postoperative recovery index, SFQ: Surgical Fear Questionnaire

moderate levels of surgical fear among patients undergoing gastrectomy, cholecystectomy, hepatectomy, and excision of liver cysts. The results differ from those reported in this study. The sociodemographic characteristics of the patients in the sample group differed. Scientific studies conducted with various sample groups using the same scale have also found surgical fear scores similar to those in this study (19,21-24). Taylan and Çelik (5) highlighted surgical fear

Table 2. The relationship between patients level of surgical fear and PoRI

		SFQ short term		SFQ long term		SFQ-total score	
Scales and subscales	**Time**	**r**	**p**	**r**	**p**	**r**	**p**
PoRI-psychological symptoms	T_1	0.247	**<0.001***	0.295	**<0.001***	0.273	**<0.001***
	T_2	0.281	**<0.001***	0.329	**<0.001***	0.307	**<0.001***
PoRI-physical activities	T_1	0.107	0.131	0.115	0.104	0.112	0.114
	T_2	0.065	0.361	0.080	0.261	0.073	0.304
PoRI-general symptoms	T_1	0.199	**0.005****	0.220	**0.002****	0.211	**0.003****
	T_2	0.039	0.580	0.054	0.447	0.047	0.508
PoRI-bowel symptoms	T_1	0.062	0.380	0.056	0.427	0.060	0.397
	T_2	0.168	**0.017*****	0.155	**0.029*****	0.162	**0.022*****
PoRI-appetite symptoms	T_1	0.220	**0.002****	0.231	**0.001****	0.227	**0.001****
	T_2	0.224	**0.001****	0.238	**0.001****	0.233	**0.001****
PoRI-total score	T_1	0.222	**0.002****	0.242	**0.001****	0.234	**0.001****
	T_2	0.186	**0.008****	0.202	**0.004****	0.195	**0.006****

*: p<0.001, **: p<0.01, ***: p<0.05, r: Pearson correlation test, T_1: Postoperative 2nd day, T_2: Postoperative 15th-30th day, PoRI: Postoperative recovery index, SFQ: Surgical Fear Questionnaire

Table 3. PoRI and surgical fear score

Scales and subscale scores	**Time**	**Mean±SD**	**Median (min-max)**	α	**T_1 vs. T_2**
PoRI-psychological symptoms	T_1	1.78±0.72	1.5 (1-4)	0.906	t=10.353
	T_2	1.36±0.43	1.2 5 (1-3.5)	0.855	p<0.001*
PoRI-physical activities	T_1	3.61±0.74	3.75 (1.3-5)	0.952	t=30.376
	T_2	2.14±0.66	2 (1-3.8)	0.962	p<0.001*
PoRI-general symptoms	T_1	2.87±0.85	3 (1-5)	0.955	t=19.760
	T_2	1.74±0.68	2 (1-4)	0.964	p<0.001*
PoRI-bowel symptoms	T_1	3.12±0.96	3 (1-5)	0.979	t=25.674
	T_2	1.80±0.75	2 (1-4)	0.977	p<0.001*
PoRI-appetite symptoms	T_1	2.26±0.83	2 (1-5)	0.963	t=19.868
	T_2	1.25±0.46	1 (1-3)	0.959	p<0.001*
PoRI-total score	T_1	2.88±0.55	2.92 (1.3-4.2)	0.932	t=39.468
	T_2	1.74±0.43	1.68 (1-3)	0.935	p<0.001*
Short-term surgical fear score	T_0	13.55±11.51	10 (0-44)		N/A
Long-term surgical fear score	T_0	13.67±11.38	10 (0-40)		N/A
Surgical fear scale total score	T_0	27.22±22.73	20 (0-80)	0.985	N/A

*: p<0.001, t: Paired sample t-test, T_0: Preoperative period, T_1: Postoperative 2nd day, T_2: Postoperative 15th-30th day, SD: Standard deviation, N/A: Not available, PoRI: Postoperative recovery index

scores among patients undergoing cataract surgery. A study of patients undergoing urological surgery found that their levels of surgical fear were low (7).

Despite advancements in technology, surgical fear remains a significant problem. Surgical fear varies according to the patient's personality, age, gender, type of anesthesia, previous surgical experience, extent of surgery, and sociocultural factors (1,23,25-28). In this study, levels of surgical fear in women were found to be significantly higher than those in men (p<0.05). In previous studies, preoperative surgical fear was found to be higher in women, similar to this study (1,3,7,19,24,25,27). This result is consistent with the literature. Biochemical changes in estrogen and progesterone hormones in women can cause women to become more sensitive and have difficulty coping with stress (29). Because they are more sensitive and emotional, they experience surgical fear when away from their loved ones and families and when anxious about not being able to return to their roles in the family. Patients' experiences in the preoperative period are also among the factors affecting surgical fear. In the relevant study, higher levels of surgical fear were found among patients without prior

Table 4. The effect of preoperative surgical fear on postoperative recovery level (linear regression analysis results)

Variables	Time	B	SE	β	t	p-value	R^2	Model
Psychological symptoms	T_1	0.009	0.002	0.273	3.990	**<0.001***	0.074	$F_{(1-198)}$=15.921*
	T_2	0.006	0.001	0.307	4.545	**<0.001***	0.094	$F_{(1-198)}$=20.660*
Physical activities	T_1	0.004	0.002	0.112	1.589	0.114	0.013	$F_{(1-198)}$=2.526
	T_2	0.002	0.002	0.073	1.031	0.304	0.005	$F_{(1-198)}$=1.062
General symptoms	T_1	0.008	0.003	0.211	3.040	**0.003****	0.045	$F_{(1-198)}$=9.242**
	T_2	0.001	0.002	0.047	0.663	0.508	0.002	$F_{(1-198)}$=0.439
Bowel symptoms	T_1	0.003	0.003	0.060	0.849	0.397	0.004	$F_{(1-198)}$=0.720
	T_2	0.005	0.002	0.162	2.317	**0.022*****	0.026	$F_{(1-198)}$=5.367***
Appetite symptoms	T_1	0.008	0.003	0.227	3.280	**0.001****	0.052	$F_{(1-198)}$=10.761**
	T_2	0.005	0.001	0.233	3.368	**0.001****	0.054	$F_{(1-198)}$=11.342*
PoRI-total score	T_1	0.006	0.002	0.234	3.385	**0.001****	0.055	$F_{(1-198)}$=11.456*
	T_2	0.004	0.001	0.195	2.804	**0.006****	0.038	$F_{(1-198)}$=7.863*

*: p<0.001, **: p<0.01, ***: p<0.05, B: Unstandardised regression estimate, β: Standardised regression estimation, SE: Standard error, PoRI: Postoperative recovery index

hospitalization. No study in the literature has investigated the surgical fear scores of patients who underwent abdominal surgery and were hospitalized. However, studies of patients undergoing elective surgery found high levels of surgical fear among those with no prior hospital experience, as observed in this study (27,29).

The postoperative recovery process begins when the patient decides to undergo surgery. Postoperative recovery is a process involving physical, psychological, and social dimensions. Fear of surgery heightens the body's stress response, leading to elevated levels of hormones such as cortisol and adrenaline and rendering the individual more psychologically vulnerable. The results of this study showed that the higher the patients' preoperative surgical fear levels, the more difficult it was for them to recover after surgery. Similarly, Gümüs (11) investigated fear of surgery in 80 patients who underwent abdominal surgery and emphasized that recovery quality was lower in patients with high anxiety levels than in patients with lower anxiety levels.

Surgical fear, which affects psychological well-being, may impair postoperative recovery and delay the healing process. A scientific study has shown that fear of surgery causes delayed recovery due to psychological symptoms. A study evaluating the effect of anxiety levels on the quality of recovery in patients undergoing abdominal surgery emphasized that anxiety and recovery quality should be investigated (11). The postoperative recovery status of patients who underwent elective major surgery in the general surgery, orthopedics, and traumatology clinics was evaluated, and these patients experienced substantial difficulty in their postoperative recovery (30). A study using a different sample group showed that preoperative patient anxiety negatively affected the emotional-state dimension of the quality of recovery three days after surgery (12). A patient-centered approach for patients undergoing surgical intervention may accelerate postoperative recovery and reduce the fear and anxiety they experience.

Study Limitations

Given these limitations, this study was conducted among patients undergoing abdominal surgery in the general surgery department at a single hospital. Therefore, future multicenter studies including patients undergoing major abdominal surgery may be important to increase the generalizability of the findings.

CONCLUSION

The results indicate that preoperative fear of abdominal surgery increases the difficulty experienced by patients during postoperative recovery.

Future research should focus on developing effective nursing care to reduce patients' fear prior to abdominal surgery. Possible causes of preoperative fear should be identified and addressed, and measures should be taken to improve patients' psychological state.

ETHICS

Ethics Committee Approval: Ethics committee approval was obtained prior to data collection from İstanbul Atlas University Non-Interventional Scientific Research Ethics Committee (approval no: 02/08, date: 08.02.2024).

Informed Consent: Both verbal and written consent were obtained.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: Ç.T., A.Y.G., Concept: Ç.T., İ.Ç., A.Y.G., Design: Ç.T., İ.Ç., A.Y.G., Data Collection or Processing: Ç.T., İ.Ç., E.H., A.Y.G., Analysis or Interpretation: Ç.T., İ.Ç., E.H., A.Y.G., Literature Search: Ç.T., A.Y.G., Writing: Ç.T., İ.Ç., A.Y.G.

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