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Türk Osteoporoz Dergisi
TURKISH JOURNAL OF OSTEOPOROSIS

Editörden / Editorial

Sevgili Meslektaşlarımız,

Değerli meslektaşlarımıza akademik çalışmalarını yayınlanmak üzere Emerging Sources Citation Index (ESCI) tarafından indekslenen dergimize düzenli olarak ilettikleri için çok teşekkür ederiz. Dergimiz kapsamında bu akademik çalışmaları yayınlamaktan büyük mutluluk duyuyoruz.

WCO-IOF-ESCEO Kongresi (Osteoporoz, Osteoartrit ve Kas-İskelet Sistemi Hastalıkları Dünya Kongresi) 10-13 Nisan, 2025 tarihlerinde Roma, İtalya'da yer almıştır. Tüm dünyadan 8500 kişi katılmış olup, kemik, eklem ve kas sağlığı alanında en güncel gelişmeler ve bilimsel çalışmalar paylaşılmıştır. Türkiye Osteoporoz Derneği bu kongre kapsamında Ulusal Dernekler bölümünde yer almış olup, kurulan stant alanıyla yapılan aktiviteler tanıtılmıştır. Ayrıca bu kongrede ülkemizden de birçok araştırıcının sunumları gerçekleşmiştir.

Gelecek yıl yapılacak olan WCO-IOF-ESCEO Kongresi 16-19 Nisan, 2026 tarihlerinde Prag'ta gerçekleştirilecektir.

Türkiye Osteoporoz Derneği tarafından düzenlenen;

OSTEOAKADEMİ 2025 Sempozyumu 23-26 Ekim 2025 tarihlerinde, KKTC'de yapılacaktır.

Siz değerli meslektaşlarımıza mutluluğun ve başarının yaşamınızdan eksik olmamasını dileyerek sevgi ve saygılarımı sunarım.

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Opportunistic Prediction of Osteoporosis with Machine Learning Models Based on Clivus-radiomic Features Obtained from CT Images

Klivusa Ait BT Tabanlı Radiomics Özelliklerinden Makine Öğrenme Algoritmaları Kullanılarak Elde Edilen Modellerin Osteoporoz Tanısındaki Yeri

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Abstract

Objective: Osteoporosis (OP) is a major public health problem that causes significant mortality and morbidity. Therefore, early diagnosis is essential. We aimed to predict OP by combining computed tomography (CT)-based radiomic data of the clivus with machine learning (ML) algorithms.

Materials and Methods: In this retrospective study, 140 cases that underwent dual energy X-ray absorptiometry (DEXA) and craniofacial CT within one year of each other between 2015 and 2021, were examined at our institution. According to DEXA T-scores, cases were divided into three groups: 30 OP, 33 osteopenia, and 77 normal. Trabecular components of the clivus were segmented, and 1023 radiomic features were extracted using 3D Slicer. Radiomic outputs consist of features from original, Laplacian of Gaussian, and wavelet transform filtered images. Voxel resampling was standardized as 1x1x1 mm^3. Orange Data Mining program was used for ML. Relief and fast correlation-based filter were used for feature reduction. K-nearest neighborhood, decision tree, random forest, logistic regression, support vector machine (SVM), Naive Bayes, and neural network were used as classifiers. Area under the curve (AUC), sensitivity, specificity, receiver operating characteristic curve, and confusion matrix were used for performance evaluation.

Results: In binary classification as OP and non-OP, neural network achieved the highest success in predicting OP (AUC 0.87). In the binary classification of BMD as low BMD and normal BMD, SVM was the best in predicting low BMD cases (AUC: 0.82). In the ternary classification of BMD as OP, osteopenia, and normal, Naive Bayes achieved the highest performance in distinguishing OP (AUC: 0.9) and osteopenia (AUC: 0.69). The Hounsfield Units values of the clivus were significantly different between low BMD and normal BMD cases ($p<0.001$).

Conclusion: ML algorithms using CT-based radiomic features of the clivus can predict OP and provide BMD information.

Keywords: Osteoporosis, clivus, machine learning, radiomics

Öz

Amaç: Bilgisayarlı tomografi (BT) görüntüleri üzerinden klivusun radiomics verilerini, makine öğrenme algoritmaları ile kombine ederek osteoporozu (OP) tahmin etmeyi amaçladık.

Gereç ve Yöntem: Retrospektif çalışmamızda, kurumumuzda çift enerjili X-ışını absorpsiyometrisi (DEXA) ve bir yıl içerisinde kraniofasial bölgeye BT tetkiki yapılmış olan 140 olgu incelemeye alındı. Hastalar DEXA T-skorlarına göre, 30'u OP, 33'ü osteopeni ve 77'si normal üç gruba ayrıldı. Segmentasyon işlemi ve radiomics özelliklerin çıkarımı "3D slicer" programı ile tek hekim tarafından yapıldı. Klivusun manuel çizilerek segmente edildi. Radiomics çıktıları, orijinal, ince-kaba Laplacian of Gaussian ve wavelet transform filtreli görüntülerden oluşmaktadır. Toplam 1023 adet radiomics özellik elde edildi. Voksel yeniden örnekleme 1x1x1 mm^3 olarak standardize edildi. Makine öğrenmesi (MÖ) için Orange Data Mining programı kullanıldı. Özellik azaltma için relieff ve fast correlation based filter metodları uygulandı. MÖ algoritmaları olarak k-nearest neighborhood, decision tree, random forest, logistic regression, support vector machine (SVM), Naive Bayes ve neural network sınıflandırmaları kullanıldı. Sınıflandırmaları karşılaştırmak için eğri altında kalan alan (EAA), duyarlılık (sensitivity, recall), özgüllük (spesifite), alıcı çalışma karakteristik eğri analizi, hata matriksi gibi parametreler kullanıldı. Tüm istatistiksel sonuçlar için $p<0,05$ değeri anlamlı kabul edildi.

Bulgular: OP ve OP olmayan (osteopeni + normal) ikili sınıflandırmada OP tahminin en yüksek başarıyı nöral network algoritması elde etti (EAA: 0,87). Düşük kemik mineral yoğunluğu (KMY) ile normal KMY'li olgulardan oluşan ikili sınıflandırmada, düşük KMY'yi en iyi tahmin eden

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Öz

SVM algoritması oldu (EAA: 0,82). Son olarak OP, osteopeni ve normal olmak üzere üçlü gruplandırma yapıldı. OP'yi ayırt etmede en yüksek performansı Naive Bayes algoritması elde etti (EAA: 0,9). Osteopeni grubunu tahmin etmede de Naive Bayes algoritması ön plana çıktı (EAA: 0,69). Düşük KMY ile normal KMY'li olgular arasında HU değerleri anlamlı olarak farklıydı (p<0,001).

Sonuç: Çalışmamızda klivusun BT tabanlı radiomics çıktılarını kullanarak elde edilen MÖ algoritmalarının OP tahmininde kullanılabileceğini ve KMY hakkında fikir verdiği gösterdi.

Anahtar kelimeler: Osteoporoz, klivus, makine öğrenmesi, radiomics

Introduction

Osteoporosis (OP) is a serious public health problem with the increasing elderly population worldwide. In developed countries, 30% of all postmenopausal women have OP, and 50% of these patients experience one or more osteoporotic fractures in their lifetime (1). Vertebral and femoral fractures are more common than other bone fractures and are a significant cause of morbidity and mortality. Therefore, early diagnosis and fracture risk prediction are important in OP diagnosis (2,3).

Dual energy X-ray absorptiometry (DEXA) is the gold standard diagnostic method for OP diagnosis. However, erroneous results may be obtained with this two-dimensional examination in cases with osteodegenerative bony changes, vertebral instrumentations, and aortic calcifications. In recent years, quantitative computed tomography (CT) has emerged as a new diagnostic method in OP diagnosis, successfully calculating bone density and mass (4). However, since it is a relatively expensive technique, researchers have searched for alternative methods to predict OP, such as detecting morphological changes in bone structures through conventional imaging techniques and analyzing histogram features of bone structures through software, without the need for new hardware. There are many studies in periodontology and implant dentistry with these purposes (5-9). Lespessailles et al. (10) reported that the combined evaluation of bone tissue analysis and bone mineral density (BMD) is superior to the evaluation of BMD alone in the diagnosis of OP. Kawashima et al. (11) retrospectively extracted the histogram features of the sphenoid triangle, mandibular condyle, and clivus from cranial CT images and reported significant results in the diagnosis of OP.

Radiomics, a new image-processing approach, has been developed in recent years. Hundreds of features from medical images that the human eye cannot distinguish are obtained quantitatively (12). Radiomics achieves successful results in the differential diagnosis of tumors, determining the prognosis, and evaluating the response to treatment (13-15). In recent years, the number of studies related to radiomics and artificial intelligence in OP has been steadily increasing (16-25). Machine learning (ML) is a subset of artificial intelligence. It is used in the medical field to calculate large and complex data sets and assist in medical decision-making.

He et al. (26) showed that magnetic resonance imaging (MRI) of the lumbar spine and radiomics models could be used in the diagnosis of OP. Rastegar et al. (27) obtained radiomics data from DEXA images and created ML models that can be used in the classification of bone mineral loss.

We aim to investigate the usability of radiomics and ML algorithms in OP prediction. The reason why we chose clivus is that studies focusing on clivus for OP prediction are very rare. The only study we encountered was published by Kawashima et al. (11). Unlike this histogram analysis-based study, we used radiomic outputs and ML algorithms, which consist of a much larger number of high-level tissue features.

Materials and Methods

Cases with DEXA and craniofacial region CT (brain, neck, maxillofacial, and paranasal sinus CT) imaging within a maximum interval of one year between 2015 and 2021 were scanned retrospectively. Age and gender were not considered as exclusion criteria. CT images with motion artifacts, IV contrast, and slice thickness of more than 1 mm were excluded from the study. Finally, a study group with 140 cases was obtained.

DEXA scan was performed with Lunar Prodigy (model 8743, GE Lunar, Madison, WI, USA). The patient height and weight were recorded. Anterior-posterior lumbar vertebrae and femur BMD are routinely measured. Body regions with implants were excluded during imaging.

The DEXA scan used L1-4 and the femur as the basis for T-scores. The lowest T-score was used to group cases. The cases were classified as "osteoporosis" if the T-score was <-2.5, "osteopenia" if it was between -2.5 and -1, and normal if it was >-1.23 Binary classification was made as OP and non-OP (osteopenia + normal), low BMD (OP + osteopenia), and normal BMDs, and ternary classification was made as OP, osteopenia, and normal.

CT scans were performed with a 64-slice multidetector CT (Aquillon 64, Toshiba, Otawara, Japan). The parameters used in imaging are Pitch factor 0.6-0.9, rotation time 0.5-0.75 seconds, tube voltage 120 kV, tube current 150-250 mAs, and slice thickness 0.5-1 mm.

3D Slicer 4.11.2 (www.slicer.org) program was utilized for the segmentation process. After anonymization, CT images were obtained in DICOM format and imported into 3D Slicer. An experienced radiologist manually segmented trabecular bone components of the clivus. The petrooccipital fissure laterally and the hypoglossal canal inferiorly limited the segmentation borders. Dorsum sella and cortical bone were excluded from the segmentation (Figure 1).

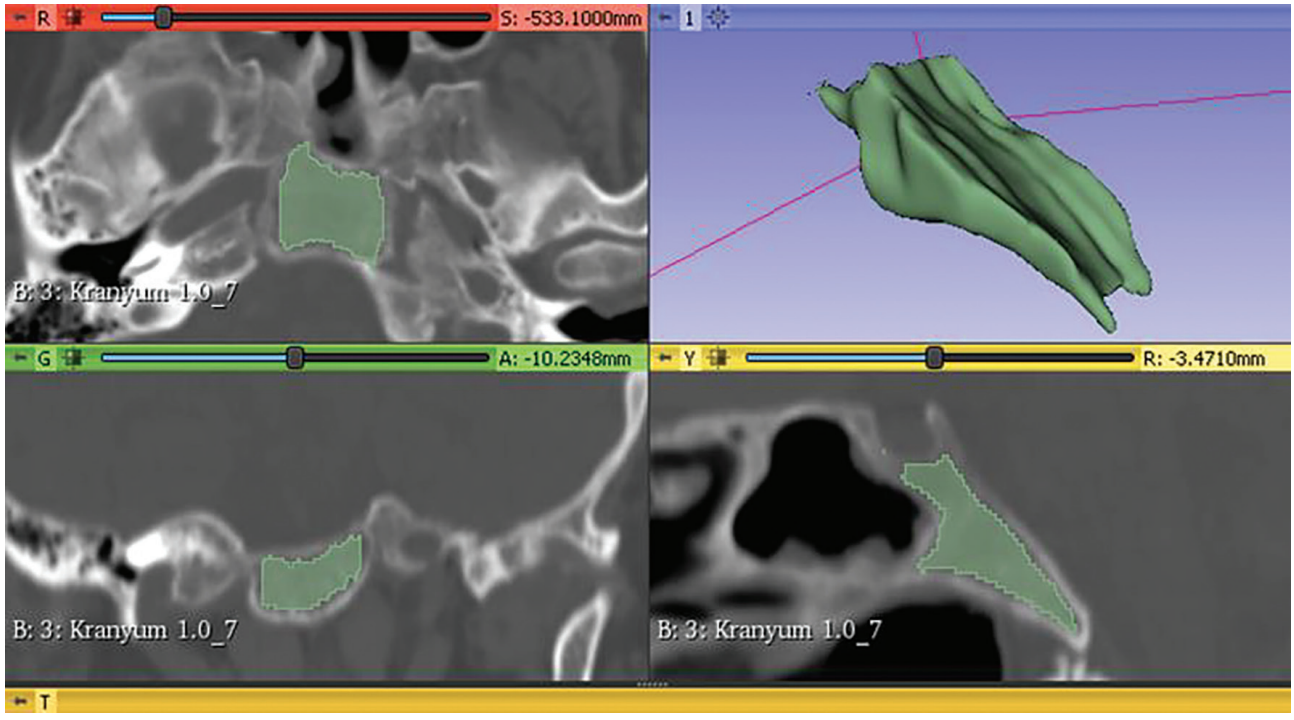

Figure 1. Clivus segmentation process

Laplacian of Gaussian image filters with two sigma values (0.5 mm and 2.5 mm) and wavelet transform filters were used for image filtering before radiomic feature extraction to create a high-throughput dataset. Voxel size for resampling was defined as 1x1x1 mm^3 for standardization.

A total of 1023 features were obtained, including 18 first-order features, 24 GLCM (Gray Level Co-Occurrence Matrix), 14 GLDM (Gray Level Dependence Matrix), 16 GLRLM (Gray Level Run Length Matrix), 16 GLSZM (Gray Level Size Zone Matrix), 5 NGTDM (Neighbouring Gray Tone Difference Matrix) based features, 93 features from Laplacian of Gaussian filtered images with sigma value of 0.5 mm, 93 features from Laplacian of Gaussian filtered images with sigma value of 2.5 mm, and 744 features from wavelet transformed images. Detailed mathematical descriptions of radiomic features are available in the pyRadiomics library (https://pyradiomics.readthedocs.io/en/latest/features.html).

Orange Data Mining Tool Version 3.27 (https://orange.biolab.si) was used for feature reduction and classification models. One scoring method among information gain, information gain ratio, Gini decrease, ANOVA, chi² (x^2), ReliefF, and fast correlation-based filter (FCBF) was used for feature selection. The best combination of the feature selection method and the number of features to be used was determined by the best-performing ML algorithm: The one with the highest area under the curve (AUC) after numerous tests. Stratified 10-fold cross-validation technique was used for validation.

K-nearest neighborhood, decision tree, random forest, logistic regression, support vector machine (SVM), Naive Bayes, and neural network were used as ML algorithms. AUC, classification accuracy (CA), sensitivity (recall), specificity, F1 score, precision, receiver operating characteristic (ROC) curve, and confusion matrix were used to evaluate ML model performances.

The Local Clinical Research Ethics Committee of Balıkesir University approved this study on 03.11.2021 with the decision number 2021/249.

Statistical Analysis

Statistical analysis was performed in the IBM SPSS 22.0 (SPSS Inc., Chicago, IL, USA) program. The Kolmogorov-Smirnov test was used to determine whether the data was normally distributed. Independent variables were shown as mean and standard deviation. The Tukey's HSD posthoc test was used to determine the relationship between BMD groups. Pearson and Spearman correlation tests evaluated the relationship between continuous independent variables. Dependent variables were evaluated with the chi-square test.

The Hounsfield Units (HU) values of the clivus were measured by drawing the largest region of interests (ROI) covering the trabecular bone from three consecutive axial CT slices, and their arithmetic mean was calculated for each case. Whether the mean HU values were discriminative in detecting the BMD group was evaluated with AUC, cut-off, sensitivity, and specificity parameters by performing ROC analysis. $P<0.05$ was considered significant in all statistical results.

The flow diagram is summarized in Figure 2.

Results

In our study, a total of 140 cases consisting of 124 women and 16 men aged between 33-91 years were included. Cases were

divided into three groups consisting of 30 OP, 33 osteopenia, and 77 normal cases according to T-scores. No statistically significant relationship was found between gender, age, and OP due to the low number of cases and the inhomogeneous age distribution. However, when compared according to T-scores, the mean T-scores of men (0.11) were significantly higher than the mean T-scores of women [(-1) (t(133)=-2.2, p=0.024]. BMI values were significantly lower in the OP group compared to the normal group (p=0.002) (Table 1). No statistically significant difference was found when the osteopenia vs. normal group and OP vs. osteopenia group comparisons were made.

First, cases were divided into two groups: OP and non-OP (osteopenia + normal). The feature selection method was chosen as ReliefF. 10 out of 1023 features were selected. In the classification process, the best-performing classifier predicting OP was neural network (AUC=0.87, CA=0.86) (Table 2). 102 of 110 non-OP cases were correctly identified, resulting in a very high specificity value (specificity 0.93). Some classifiers showed higher specificity values, such as SVM and logistic regression. However, these classifiers have lower reliability due to their lower sensitivity and F1 scores. The ROC curves of the ML algorithms are given in Figure 3.

The other binary classification was performed between cases with low BMD (osteopenia + OP) and normal BMD. We aimed to predict the decrease in BMD with ML algorithms. Sixteen features were selected from the database with ReliefF. In the classification process, SVM showed the most successful performance (AUC: 0.82, CA: 0.79) (Table 3), correctly predicting 46 of 63 patients with abnormal BMD and 65 of 77 patients with normal BMD. Other performance metrics of SVM were calculated as sensitivity 0.73, specificity 0.84, F1 score 0.76, and precision 0.79. All performance metrics of SVM to predict low BMD were higher

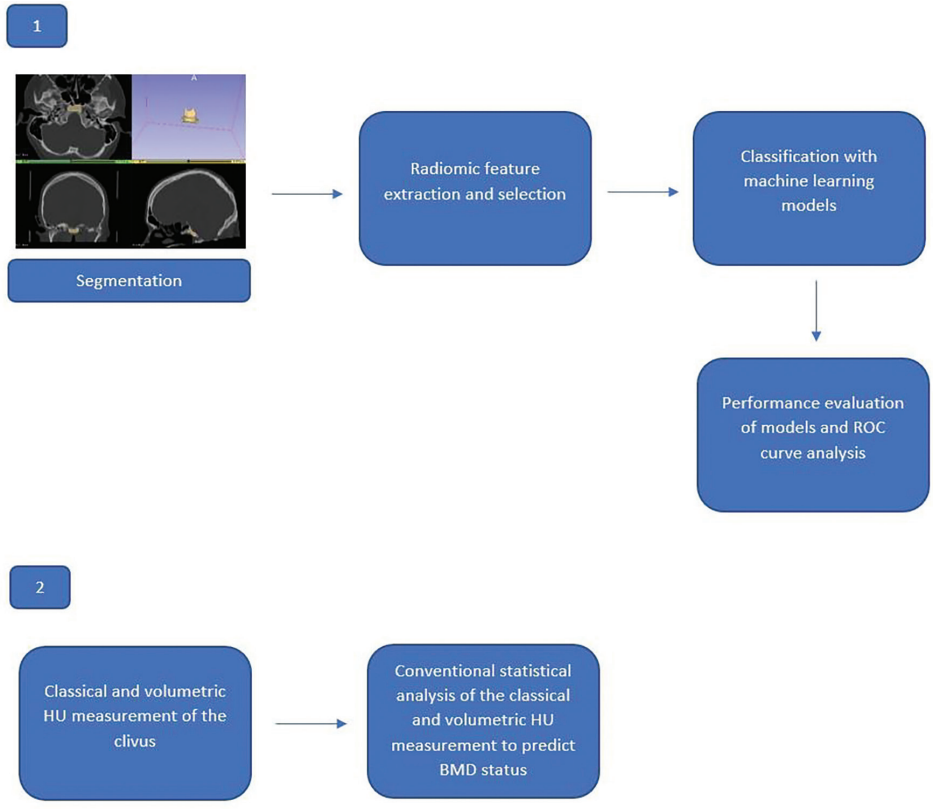

Figure 2. Flow diagram

BMD: Bone mineral density, HU: Hounsfield Units, ROC: Receiver operating characteristic

Table 1. Demographic data of BMD groups

	Osteoporosis n=30	Osteopenia n=33	Normal n=77	p-value
Gender (female/male)	27/3	32/1	65/12	0.149
Age (mean ± SD)	73±10	69±11	68±12	0.076
BMI	27±5	28±5	31±6	0.002

BMD: Bone mineral density, BMI: Body mass index, SD: Standard deviation

than the other algorithms. The ROC curves of the ML algorithms are given in Figure 4.

As a final ML classification step, cases were divided into three groups: Osteopenia, OP, and normal. FCBF method was applied, and the most optimal seven features were selected. In this ternary classification, the Naive Bayes algorithm was the best-performing classifier in distinguishing OP (AUC: 0.9, CA: 0.86) (Table 4), correctly predicting 22 of 30 cases with OP and 66 of 77 normal cases. Sensitivity was 0.73, and specificity was 0.89. Some classification methods, such as SVM, logistic regression, and random forest, reach higher specificity. However, these algorithms' sensitivities and F1 scores lag behind the Naive Bayes algorithm. The ROC curves of the algorithms for estimating OP in the ternary classification consisting of OP, osteopenia, and normal cases are given in Figure 5.

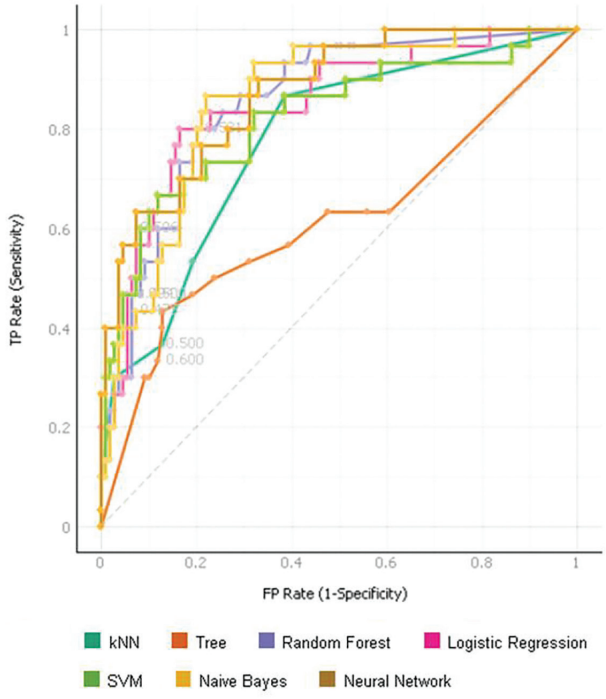

Figure 3. ROC curves of the ML algorithms to predict OP in the binary classification (OP and non-OP)

ML: Machine learning, OP: Osteoporosis, ROC: Receiver operating characteristic, SVM: Support vector machine, kNN: K-nearest neighborhood

In the ternary classification, the performance of ML algorithms in detecting cases with osteopenia is low (Table 5). The highest performance was obtained with the Naive Bayes algorithm (AUC: 0.69, CA: 0.76), predicting 11 of 33 osteopenic patients. 15 were misclassified as normal, and seven as OP.

When the mean HU values of clivus from three axial slices were calculated by the ROI method, a moderate positive correlation was found between HU values and T-scores (r^2=0.45 p<0.001). The cases were divided into three groups: OP, osteopenia, and normal. The mean HU value was 103 (74.9-131.1 with a 95% confidence interval) in the OP group, 113.8 (88.9-138.7 with a 95% confidence interval) in the osteopenia group, and 192 (168-215,9 with a 95% confidence interval) in the normal group (Table 6). Significant differences were found in the values measured between the low BMD (OP + osteopenia) and the normal group (p<0.001). No significant relationship was found between the mean HU values in the OP and osteopenia groups. ROC analysis was performed to determine the success of the classical HU measurement method in predicting the low BMD group (Figure 6). The AUC value was 0.75 (0.67-0.83 with a 95% confidence interval), the cut-off value was 137 HU, and the sensitivity and specificity values were 0.6 and 0.72, respectively. Finally, the volumetric mean HU values obtained from the segmentation of the clivus were examined. The original first-order mean values among the radiomic features, which express the volumetric mean HU value, were used without extra processing. There was no significant correlation between volumetric mean HU values and OP, osteopenia, and normal groups.

Discussion

High AUC values, such as 0.9 and 0.87, were obtained in the OP estimation using radiomics and ML algorithms. Osteopenia prediction performance was lower than OP prediction performance but at an acceptable level, at 0.82 (AUC). The combined use of radiomics and ML algorithms was significantly superior to HU values measured using the traditional ROI method in detecting OP and low BMD.

Table 2. Performance metrics of ML algorithms to predict OP in the binary classification (OP vs. non-OP)

Model	AUC	CA	F1	Precision	Sensitivity	Specificity
Neural network	0.87	0.9	0.7	0.7	0.63	0.93
Random forest	0.86	0.8	0.6	0.63	0.5	0.92
SVM	0.86	0.8	0.5	0.71	0.4	0.95
Naive Bayes	0.85	0.8	0.6	0.51	0.83	0.78
Logistic regression	0.84	0.8	0.6	0.67	0.47	0.94
kNN	0.78	0.8	0.4	0.44	0.37	0.87
Tree	0.6	0.8	0.4	0.43	0.33	0.88

ML: Machine learning, OP: Osteoporosis, AUC: Area under the curve, CA: Classification accuracy, SVM: Support vector machine, kNN: K-nearest neighborhood

Apart from being two-dimensional imaging and using ionizing radiation, the most significant disadvantage of DEXA is the possibility of superimposition of dense structures such as soft tissues, metallic instruments, osteodegenerative changes, and atherosclerotic calcifications, which may cause BMD to be miscalculated. It is mentioned in the literature that the use of CT imaging in such cases can help diagnose missed OP (28,29). We chose the clivus for this study because it is less prone to degeneration and is included in the field of view of common CT scans such as brain CT.

In the literature, there are efforts to develop an alternative diagnostic tool due to the limitations of DEXA. Many studies report a positive correlation between T-scores and HU values obtained from bone CT scans, such as lumbar and wrist CT scans (30-36). Alawi et al. (37) reported a positive correlation between DEXA T-scores and HU values of lumbar vertebrae from abdominal CT images. Their study measured mean attenuation values as 115 HU in osteoporotic cases, 120 HU in osteopenic cases, and 174 HU in normal cases. While the difference between the abnormal BMD and normal groups was statistically significant, there was no statistically significant difference between the OP and osteopenia groups (37). Similar mean attenuation values were measured in our study: 103 HU in the OP group, 113 HU in the osteopenia group, and 192 HU in the normal group. Decreases in mean HU values in the low BMD group were also statistically significant in our study. Our

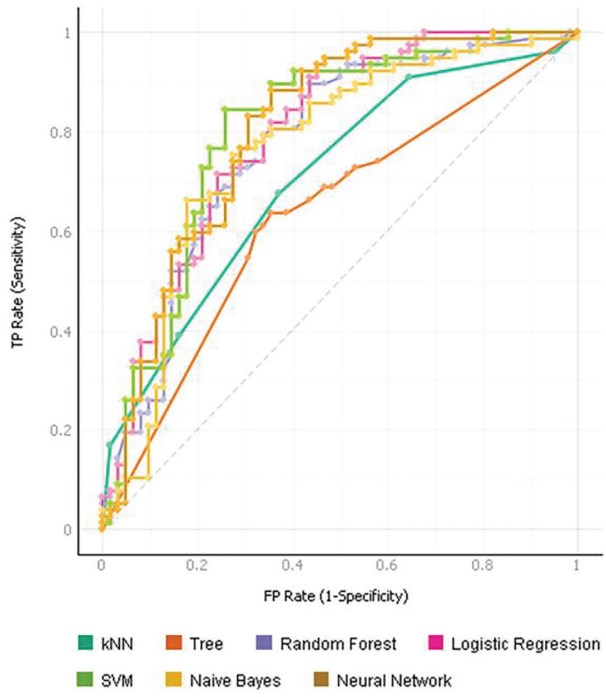

Figure 4. ROC curves of the ML algorithms to predict low BMD in the binary classification (low and normal BMD)

ML: Machine learning, BMD: Bone mineral density, SVM: Support vector machine, kNN: K-nearest neighborhood, ROC: Receiver operating characteristic

Table 3. Performance metrics of ML algorithms to predict low BMD in the binary classification (low and normal BMD)

Model	AUC	CA	F1	Precision	Sensitivity	Specificity
SVM	0.82	0.79	0.76	0.79	0.73	0.84
Neural network	0.80	0.76	0.72	0.77	0.68	0.83
Naive Bayes	0.79	0.74	0.71	0.71	0.71	0.77
Logistic regression	0.78	0.71	0.68	0.69	0.67	0.75
Random forest	0.77	0.74	0.69	0.73	0.65	0.81
kNN	0.72	0.66	0.63	0.62	0.63	0.68
Tree	0.63	0.62	0.56	0.59	0.54	0.69

ML: Machine learning, BMD: Bone mineral density, AUC: Area under the curve, CA: Classification accuracy, SVM: Support vector machine, kNN: K-nearest neighborhood

Table 4. Performance metrics of ML algorithms to predict OP in the ternary classification (OP, osteopenia, and normal)

Model	AUC	CA	F1	Precision	Sensitivity	Specificity
Naive Bayes	0.90	0.86	0.69	0.65	0.73	0.89
Logistic regression	0.87	0.79	0.00	0.00	0.00	1.00
SVM	0.84	0.85	0.62	0.68	0.57	0.93
Neural network	0.84	0.82	0.59	0.58	0.60	0.88
Random forest	0.82	0.84	0.58	0.64	0.53	0.92
kNN	0.78	0.77	0.41	0.46	0.37	0.88
Tree	0.75	0.81	0.57	0.57	0.57	0.88

ML: Machine learning, OP: Osteoporosis, AUC: Area under the curve, CA: Classification accuracy, SVM: Support vector machine, kNN: K-nearest neighborhood

Table 5. Performance metrics of ML algorithms to predict osteopenia in the ternary classification (OP, osteopenia, and normal)

Model	AUC	CA	F1	Precision	Sensitivity	Specificity
Naive Bayes	0.69	0.76	0.39	0.48	0.33	0.89
Tree	0.65	0.79	0.46	0.57	0.39	0.91
Neural network	0.61	0.76	0.33	0.50	0.24	0.93
SVM	0.59	0.78	0.34	0.57	0.24	0.94
Random forest	0.58	0.74	0.30	0.40	0.24	0.89
Logistic regression	0.54	0.76	0.00	0.00	0.00	1.00
kNN	0.39	0.71	0.20	0.28	0.15	0.88

ML: Machine learning, OP: Osteoporosis, AUC: Area under the curve, CA: Classification accuracy, SVM: Support vector machine, kNN: K-nearest neighborhood

Table 6. The means, standard deviations and 95% confidence intervals of HU values measured with the ROI method are shown

	Hounsfield Units (HU)	
	Mean ± SD	%95 confidence interval
Osteoporosis	103±13.7	74.9-131.1
Osteopenia	113.8±13.2	88.9-138.7
Normal	192±12	168-215.9

ROI: Region of interest, SD: Standard deviation

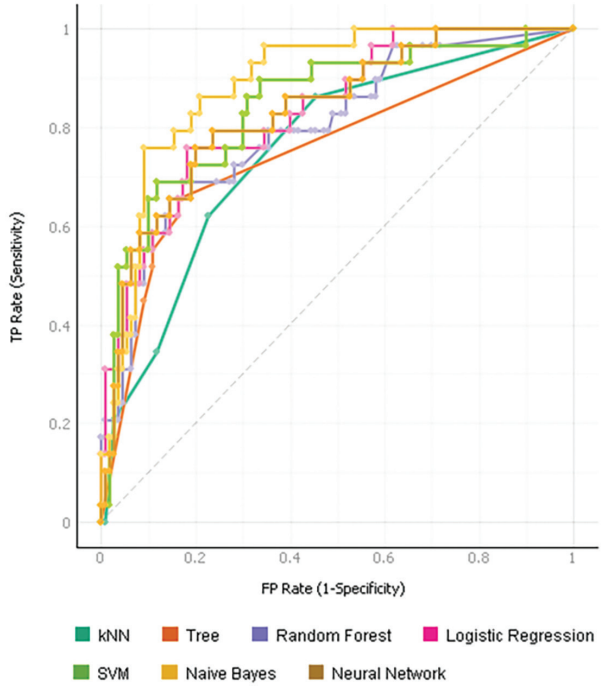

Figure 5. ROC curves of the ML algorithms to predict OP in the ternary classification (OP, osteopenia, and normal)

ML: Machine learning, OP: Osteoporosis, ROC: Receiver operating characteristic, SVM: Support vector machine, kNN: K-nearest neighborhood

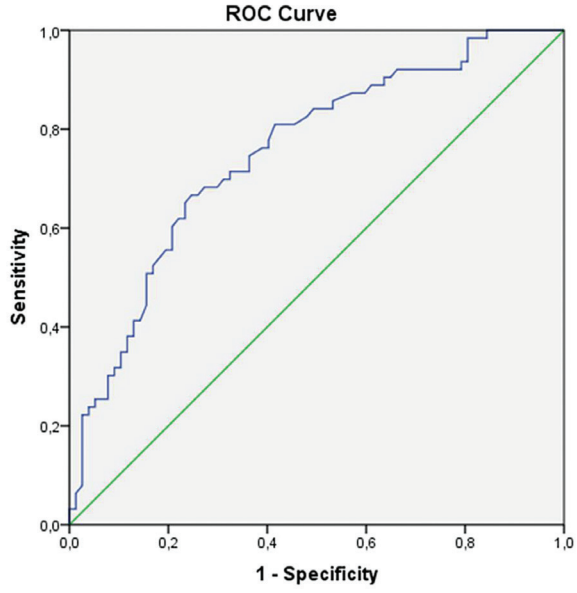

Figure 6. ROC curve of the classical HU measurement to predict low BMD

BMD: Bone mineral density HU: Hounsfield units, ROC: Receiver operating characteristic

study also had no significant difference between the OP and osteopenia groups. According to the ROC analysis, the group with low BMD was correctly diagnosed with a cut-off value of 137 HU with 72% specificity and 68% sensitivity. Considering that half of the insufficiency fractures in the population occur in osteopenic women (38), identifying patients with low BMD may be more important than distinguishing osteopenia and OP. In a study conducted with a small number of patients (29 normal, 29 OP), Kawashima et al. (11) extracted two-dimensional radiomic features from CT images of bilateral greater wings of sphenoid, bilateral mandibular condyles, and clivus using the ROI method. The various types of texture features extracted from craniofacial trabecular bones, such as histogram features, GLCM features, and GLRL features, were found to be associated with OP. It is also mentioned that the clivus, one of the three skull base structures examined in the study, stands out as being less affected by degenerative findings (11).

Rastegar et al. (27) extracted radiomic features from lumbar and femoral DEXA images with the ROI method and analyzed them with ML algorithms. Moderate diagnostic performance (AUC) values ranged from 0.5 to 0.78 in distinguishing OP, osteopenia, and normal groups (27).

In their retrospective study, Lim et al. (39) showed that the ML models using radiomic features obtained from abdominopelvic CT images can predict femoral OP. The proximal femur was automatically segmented, including the cortex. The number of radiomic features was limited to 41, consisting of semantic features, first-level tissue features, GLCM, and wavelet transform features. They used the Gini decrease for feature reduction and the random forest algorithm for classification. The cases were divided into two: 70% were used for the training dataset and 30% for the validation dataset. The random forest algorithm successfully predicted OP with 95% specificity and 80% sensitivity in the validation group. In addition, this study used 5-fold cross-validation. It is recommended to use 5 or 10 folds in the literature. We used 10-fold cross-validation technique in our study. Unlike this study, we did not divide the cases into training and validation datasets due to the limited number of cases.

In a recent article by Fang et al. (20), they mention that 2D transfer learning and 3D deep learning techniques have shown excellent performance in screening for OP in chest CT scans. In another recent article, it was found that in opportunistic OP screening using chest CT scans, the three-dimensional segmentation of the thoracic vertebral body and the subsequent radiomics outputs showed similar performance to ML models. The AUC values are similar to those in our article (AUC: 0.8-0.9) (21).

In another study regarding osteoporotic fracture estimation, using microstructural femoral MRI data and fracture risk assessment tool (FRAX) data together with ML algorithms was superior to using MRI data and FRAX data alone (40). A study conducted in India proposed that an automated diagnostic technique for low bone mass is possible using radiogrammetric measurements and texture features from radiography images together with a three-layer supervised artificial neural network (41).

Study Limitations

The main limitation of our study, apart from its retrospective nature, is the low number of patients. A larger patient group is needed for the use of training and external validation groups. In addition, the patient population was obtained from a specific region, and the findings may not be generalized worldwide. In our study, BMD was classified according to DEXA T-scores. Therefore, due to the nature of DEXA, erroneous BMD and T-scores may have been obtained, which may have misled the statistical results. In future studies, it will be possible to compare the performances of radiomics scores and ML algorithms with DEXA by grouping them as those with and without osteoporotic fractures. Using automatic segmentation can be beneficial in terms of standardization and saving time. Although the variety and number of algorithms we use are higher than most studies, it is a fact that there are more ML algorithms available to use. The DEXA and CT imaging time interval has been accepted as a maximum of one year, and this period can be kept shorter. In addition, the systemic diseases and the drugs used were not considered.

Conclusion

Our study showed that OP and osteopenia can be accurately detected using CT-based radiomic features of clivus and ML. We also found that clivus CT HU values correlated positively with DEXA T-scores.

Ethics

Ethics Committee Approval: The Local Clinical Research Ethics Committee of Balıkesir University approved this study on 03.11.2021 with the decision number 2021/249.

Informed Consent: Retrospective study.

Acknowledgments

Our study was uploaded to the 2022 thesis database with the reference number 10500307. It was also accepted and published as a poster at the Turkish Radiology Congress in 2022 and the European Radiology (ECR) Congress in 2024.

Footnotes

Authorship Contributions

Concept: C.G., E.A., G.D., Design: C.G., E.A., E.B., B.Y., Data Collection or Processing: C.G., Analysis or Interpretation: C.G., E.A., F.E., Literature Search: C.G., Writing: C.G., F.E.

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

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Is YouTube a Reliable Resource for Osteoporosis Exercise Guidance? A Descriptive Cross-sectional Study

YouTube Osteoporoz Egzersizi Rehberliği için Güvenilir Bir Kaynak mıdır? Tanımlayıcı Kesitsel Çalışma

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Abstract

Objective: The study aimed to evaluate the reliability, quality, and content analysis of English-language osteoporosis exercises videos on YouTube.
Materials and Methods: On December 12, 2023, a search for "osteoporosis exercise" was conducted on YouTube. The 200 best-match English videos were included. The content, source, and characteristics were recorded. Reliability and quality were analyzed using the modified DISCERN (mDISCERN) score, Journal of the American Medical Association benchmark criteria, and global quality scale (GQS) score.
Results: Of the 200 videos screened, 133 met the inclusion criteria. Of these, 8.2% (n=11) were presented by medical doctors, 51.8% (n=69) by physiotherapists or physical therapists, and 39.8% (n=53) by exercise specialists. GQS indicated that 15.0% (n=20) of the videos were high, 45.1% (n=60) medium, and 39.8% (n=53) poor quality. Videos featuring strengthening exercises and impact exercises had significantly higher GQS and mDISCERN scores compared to videos without these type of exercises.
Conclusion: The majority of YouTube videos on "osteoporosis exercises" are of low quality and lack reliability. Medical doctors should prioritize sharing and demonstrating exercises to improve content quality and trustworthiness.
Keywords: Osteoporosis, exercise, YouTube, video, quality, reliability

Öz

Amaç: Bu çalışma, YouTube'daki İngilizce "osteoporoz egzersizleri" videolarının güvenilirlik, kalite ve içerik analizini değerlendirmeyi amaçlamaktadır.
Gereç ve Yöntem: Aralık 2023'te YouTube'da "osteoporoz egzersizleri" araması yapıldı. En iyi eşleşen 200 İngilizce video dahil edildi. Videoların içerikleri, kaynakları ve özellikleri kaydedildi. Güvenilirlik ve kalite, modifiye DISCERN (mDISCERN) skoru, Journal of the American Medical Association kriterleri ve küresel kalite ölçeği (GQS) skoruyla analiz edildi.
Bulgular: İncelenen 200 videodan 133'ü dahil edilme kriterlerini karşıladı. Bu videoların %82'si (n=11) hekimler, %51,8'i (n=69) fizyoterapistler ve %39,8'i (n=53) egzersiz profesyonelleri tarafından sunulmuştu. GQS'ye göre videoların %15,0'i (n=20) yüksek, %45,1'i (n=60) orta ve %39,8'i (n=53) düşük kalite olarak değerlendirildi. Kuvvetlendirme ve darbe egzersizleri içeren videoların GQS ve mDISCERN skorları, bu tür egzersizler içermeyen videolara göre anlamlı derecede daha yüksekti.
Sonuç: YouTube'daki "osteoporoz egzersizleri" videolarının çoğunluğu düşük kalite ve güvenilirliktedir. İçerik kalitesini ve güvenilirliğini artırmak için hekimlerin egzersizleri paylaşması ve demonstrasyon yapması öncelikli olmalıdır.
Anahtar kelimeler: Osteoporoz, egzersiz, YouTube, video, kalite, güvenilirlik

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Introduction

An estimated 200 million women globally are thought to be affected by osteoporosis, or around a tenth of women in their 60s and one-fifth of those in their 70s. An osteoporotic fracture occurs every three seconds due to osteoporosis, which causes more than 8.9 million fractures each year (1). Osteoporosis-related fractures have a substantial financial cost, estimated at $17.9 and £4 billion annually in the United States of America and the United Kingdom, respectively (2). Clinical practice recommendations suggest calcium and vitamin D supplements as well as exercise training as preventive measures against osteoporosis, in addition to pharmaceutical therapy as a treatment for osteoporosis (3,4). Exercise programs, particularly those incorporating resistance training, weight-bearing or impact exercises, and balance training, are recognized for their beneficial effects on bone health and the enhancement of muscle mass and strength. These improvements contribute to better posture, balance, and stability, consequently reducing the likelihood of falls among older individuals over time (5,6). Exercise and mobility may be limited by a fear of falling. The lack of physical activity results in decreased flexibility, strength, and balance, ultimately raising the risk of falls and the occurrence of fractures. Lack of time and transportation are primary barriers to exercise, with 50% dropping out within 6 months (7). Especially in the elderly, weak muscles and bad posture can lead to imbalance and falls. Improved balance and a reduction in the risk of falls can be achieved by core strengthening exercises and resistance training targeting the spinal extensor muscles. It's possible that those who have osteoporosis don't have access to appropriate resources when they try to incorporate exercise into their everyday routine (8). Hence, further research is warranted to comprehend the quality of physical activity information accessible to individuals diagnosed with osteoporosis.

Research has revealed that 75% of individuals at risk for osteoporosis conduct health-related research on the internet (9). One of YouTube's biggest advantages over other social media platforms is its effective utilization of audio and visual communication features, making it accessible to everyone. With 122 million daily active users, 1 billion hours watched daily, and approximately 54% of all internet users, it is a popular choice (10). Several studies have recently assessed YouTube as a resource for medical information (11,12). Some studies have specifically evaluated YouTube videos about osteoporosis in English (13), as well as the quality and reliability of exercise videos intended for certain clinical conditions (14).

To our knowledge, while a study has evaluated online resources on physical activity for individuals with osteoporosis (8), no research has analyzed the content, reliability, and quality of YouTube videos on osteoporosis exercises in English. This study aims to assess the quality and reliability of these videos. A secondary goal is to offer recommendations for healthcare providers and associations to better utilize YouTube and promote reliable, high-quality information.

Materials and Methods

Video and Data Extraction from YouTube

This research was a descriptive cross-sectional study**.** The hypothesis was that YouTube videos on "osteoporosis exercise" would vary significantly in quality and reliability, with many lacking professional oversight. On March 15, 2024, a search for the keyword "osteoporosis exercise" was conducted on YouTube. The top 200 videos were retrieved based on relevancy. Videos addressing unrelated topics (n=34), non-English videos (n=6), videos shorter than one minute (n=18) and dublicates (n=9) were excluded. A total of 133 videos were included for evaluation.

Video Parameters, Sources, and Content

Video metrics, including views, likes, dislikes, and comments, were recorded on the same day to ensure consistency. Additional information, such as speaker type, video duration (minutes and seconds), and days online, was also documented.

Popularity was assessed using the video power index (VPI), a metric developed to account for changes over time. VPI is calculated by multiplying the like ratio [likes*100/(likes+dislikes)] and view ratio (view count/days online) and dividing by 100, providing a consistent popularity measure (15) despite variable upload dateswere categorized based on the speaker: Medical doctors, physiotherapists or physical therapists, and exercise specialists (e.g., trainers, fitness or yoga instructors). Exercise types were classified according to osteoporosis guidelines into strengthening, impact (walking, running, jumping), balance/coordination, flexibility/stretching, and core strengthening exercises. The presence or absence of each exercise type and whether demonstrations were included were noted.

Scoring Protocol

Video content was evaluated for quality, reliability, and educational value. The global quality scale (GQS) is a commonly used tool for assessing the quality of health-related online content. It rates quality on a 1-5 scale, with 1-2 indicating low quality, 3 intermediate quality, and 4-5 high quality (13,15).

The modified DISCERN (mDISCERN) is a five-point scale designed to evaluate the reliability and accuracy, assigning one point for each of the following met criteria: conciseness, reliability, balance, source referencing, and addressing uncertainty, with higher scores indicating better reliability (14).

The videos were evaluated using the Journal of the American Medical Association (JAMA) benchmark criteria, which assess accuracy and reliability using four criteria. Higher scores indicate greater reliability, with points added for authorship, attribution, disclosure, and currency (16). The educational quality and reliability of the videos were assessed by two independent physiatrists that blinded to the characteristics of the videos.

Ethical Considerations

This study involved publicly accessible videos only, without human or animal subjects, so ethics committee approval was unnecessary, aligning with similar studies (11,13,14).

Statistical Analysis

All analyses were conducted using SPSS (IBM SPSS Statistics, Version 26.0), with significance set at p<0.05. Descriptive statistics for Internet content characteristics were reported as number, percentage, and median (interquartile range, 25th-75th). The Kruskal-Wallis H test was applied to compare numerical characteristics of the videos based on video source, while video content characteristics and GQS scores were compared by video source using the chi-square test.

To compare GQS, mDISCERN, and JAMA scores based on video content characteristics, the Kruskal-Wallis H test was used, followed by pairwise comparisons in post-hoc analysis. For comparisons between two groups, the Mann-Whitney U test was used. Spearman Correlation Analysis assessed correlations among video content features, GQS, mDISCERN, and JAMA scores. Data normality was checked using the Shapiro-Wilk and Kolmogorov-Smirnov tests.

Results

Of the 133 videos analyzed, 8.2% (n=11) were presented by medical doctors, 51.8% (n=69) by physiotherapists or physical therapists, and 39.8% (n=53) by exercise specialists. No videos from independent users or patients were included. Medical doctors shared "impact exercise" videos at statistically higher rates than exercise specialists (p=0.001) and physiotherapists/physical therapists (p<0.001). Flexibility-stretching exercises were shared more frequently by physiotherapists/physical therapists (p=0.037) and exercise specialists (p<0.001) compared to medical doctors. The "no exercise demonstration" category was statistically higher in videos from medical doctors than in those from physiotherapists/physical therapists (p<0.001) and exercise specialists (p<0.001) (Table 1).

According to the GQS, 15.0% (n=20) of videos were high quality, 45.1% (n=60) were medium quality, and 39.8% (n=53) were low quality (Table 2). Comparing strengthening exercise videos and impact exercise videos to those without these elements, GQS and mDISCERN scores were significantly higher. GQS scores for balance and coordination exercise videos were also significantly higher. Videos lacking exercise demonstration had significantly higher scores for GQS (p=0.022), mDISCERN (p=0.001), and JAMA (p=0.009). GQS scores did not differ significantly between medical doctors and physiotherapists/physical therapists. However, both groups scored higher than exercise specialists (p=0.001) (Table 3). Medical doctors had significantly higher mDISCERN scores than exercise specialists (p<0.001) and physiotherapists/physical therapists (p=0.031), and physiotherapists/physical therapists had higher mDISCERN scores than exercise specialists (p=0.001). JAMA scores were also higher in medical doctors than in exercise specialists (p=0.002). Median scores were mDISCERN =3 (range, 3-4), GQS =3 (range, 2-3), and JAMA =3 (Table 3).

A significant positive correlation was found between GQS scores and both mDISCERN (r=0.734, p<0.001) and JAMA scores (r=0.403, p<0.001). Medical doctors (p=0.036) and exercise specialists (p=0.001) had longer video durations than physiotherapists/physical therapists, who also uploaded videos earlier. Video length and GQS scores had a positive correlation (r=0.318, p<0.001). Median values for video metrics were as follows: Video length =10.77 minutes (range, 5.73-17.98), views =28,802 (range, 12,056-111,501), views per day =5.24 (range, 1.14-35.18), likes =860 (range, 216-2.276), dislikes =8 (range, 1-26), comments =42.5 (range, 0-152), and VPI score =45.19 (range, 11.85-120.78). No significant differences were found between groups in views, views per day, likes, dislikes, comments, or VPI (p>0.05). Additionally, no significant associations were

Table 1. Features of video exercise content

Exercise type		Total		Medical doctors (n=11)		Physiotherapists/ physical therapists (n=69)		Exercise experts (n=53)		
		n	%	n	%	n	%	n	%	p[a]
Strengthening	No	39	29.3	1	9.1	21	30.4	17	32.1	0.300
	Yes	94	70.7	10	90.9	48	69.6	36	67.9	
Impact	No	84	63.2	1	9.1	48	69.6	35	66.0	**<0.001**
	Yes	49	36.8	10	90.9	21	30.4	18	34.0	
Balance-coordination	No	105	78.9	8	72.7	57	82.6	40	75.5	0.549
	Yes	28	21.1	3	27.3	12	17.4	13	24.5	
Flexibility-stretching	No	81	60.9	10	90.9	44	63.8	27	50.9	**0.037**
	Yes	52	39.1	1	9.1	25	36.2	26	49.1	
Core-abdominal	No	85	63.9	8	72.7	46	66.7	31	58.5	0.529
	Yes	48	36.1	3	27.3	23	33.3	22	41.5	
Exercise is demonstrated	Yes	114	85.7	4	36.4	62	89.9	48	90.6	**<0.001**
	No	19	14.3	7	63.6	7	10.1	5	9:4	

[a]: chi-square test

observed between GQS, mDISCERN, and JAMA scores with views, likes, dislikes, comments, or VPI (p>0.05) (Table 4).

Discussion

To the best of our knowledge, no prior study has specifically investigated the content and quality of YouTube videos on "osteoporosis exercise" in the English language. In this study, physical therapists or physiotherapists represented over half of the speakers, while medical doctors accounted for only 8.3%, a distribution that aligns with previous research. Esen et al. (17) reported minimal physician representation, with only 10% of videos produced by doctors. Similarly, Abed et al. (18) found that physicians produced only 10% of the videos in their study, while Özbek et al. (19) reported that 46% of the videos were uploaded by healthcare professionals other than physicians, such as physiotherapists and occupational therapists, and only 28% by physicians.

The GQS revealed that only 15.0% of the videos were classified as high quality, 45.1% as medium quality, and 39.8% as low

Table 2. Comparison of speaker distribution based on GQS-educational quality tool

Educational quality (GQS)	Total		Medical doctors (n=11)		Physiotherapists/ physical therapists (n=69)		Exercise experts (n=53)		
	n	%	n	%	n	%	n	%	p[a]
Poor	53	39.8	2	18.2	29	42.0	22	41.5	**<0.001**
Moderate	60	45.1	1	9.1	31	44.9	28	52.8	
High	20	15.0	8	72.7	9	13.0	3	5.7	

GQS: Global quality scale, [a]: chi-square test

Table 3. Comparison of GQS, mDISCERN, and JAMA values according to video content

		GQS			mDISCERN			JAMA		
		Med.	Q1	Q3	Med.	Q1	Q3	Med.	Q1	Q3
Speaker of the video	Medical doctor	4.00	3.00	4.00	4.00	4.00	5.00	3.00	2.00	3.00
	Physical therapist/ physiotherapist	4.00	4.00	5.00	3.00	3.00	4.00	3.00	2.00	3.00
	Exercise specialist	3.00	3.00	4.00	3.00	2.00	3.00	2.00	2.00	3.00
	p[a]	**0.001**			**<0.001**			**<0.001**		
Strengthening	No	2.00	2.00	3.00	3.00	2.00	3.00	3.00	2.00	3.00
	Yes	3.00	2.00	3.00	3.00	3.00	4.00	3.00	2.00	3.00
	p[b]	**0.001**			**0.019**			**0.550**		
Impact	No	3.00	2.00	3.00	3.00	2.00	3.00	3.00	2.00	3.00
	Yes	3.00	3.00	4.00	4.00	3.00	4.00	3.00	2.00	3.00
	p[b]	**<0.001**			**0.003**			**0.351**		
Balance-coordination	No	3.00	2.00	3.00	3.00	2.00	4.00	3.00	2.00	3.00
	Yes	3.00	2.50	4.00	3.00	3.00	4.00	3.00	2.00	3.00
	p[b]	0.010			0.159			0.717		
Flexibility-stretching	No	3.00	2,00	3.00	3.00	3.00	4.00	3.00	2.00	3.00
	Yes	3.00	2.00	3.00	3.00	2.00	4.00	3.00	2.00	3.00
	p[b]	0.352			0.988			0.732		
Core-abdominal	No	3.00	2.00	3.00	3.00	2.00	4.00	3.00	2.00	3.00
	Yes	3.00	2.00	3.00	3.00	3.00	4.00	3.00	2.00	3.00
	p[b]	0.753			0.484			0.203		
Exercise is demonstrated	Yes	3.00	2.00	3.00	3.00	2.00	4.00	3.00	2.00	3.00
	No	3.00	2.00	4.00	4.00	3.00	4.00	3.00	3.00	4.00
	p[b]	**0.022**			**0.001**			**0.009**		

GQS: Global quality scale, mDISCERN: modified DISCERN, JAMA: Journal of the American Medical Association, Med.: Median, [a]: Kruskal-Wallis H test, [b]: Mann-Whitney U test

Table 4. Video content characteristics and relationships between GQS, mDISCERN, and JAMA

		GQS	mDISCERN	JAMA
GQS	rho	-	-	-
	p	-	-	-
mDISCERN	rho	**0.734**	-	-
	p	**<0.001**	-	-
JAMA	rho	**0.403**	**0.658**	-
	p	**<0.001**	**<0.001**	-
Number of views	rho	0.058	0.040	-0.071
	p	0.509	0.651	0.416
Number of likes	rho	0.115	0.069	-0.051
	p	0.195	0.437	0.567
Number of dislikes	rho	0.146	0.158	0.005
	p	0.098	0.074	0.956
Number of comments	rho	0.065	0.003	-0.118
	p	0.460	0.977	0.180
Length	rho	**0.318**	0.078	-0.061
	p	**<0.001**	0.374	0.489
Days online (n)	rho	-0.075	0.032	-0.005
	p	0.393	0.710	0.959
VPI (%)	rho	0.132	0.057	-0.040
	p	0.136	0.523	0.650

GQS: Global quality scale, mDISCERN: modified DISCERN, JAMA: Journal of the American Medical Association, VPI: Video power index, Rho: Spearman's rank correlation

quality. These findings are consistent with those of Abed et al. (18) and Ertem et al. (20), who reported high-quality video rates of 19.5% to 20%. In contrast, studies by Kocyigit et al. (14) and Tolu et al. (21) on various disorders demonstrated a higher proportion of beneficial videos, with approximately 50% rated as helpful. The variability in previous findings may be attributed to factors such as the diversity of conditions analyzed or the subjective nature of video evaluations, as well as differences in the number of videos reviewed.

In this study, medical doctors were significantly more likely to share videos focused on "impact exercise", while fewer videos on stretching and flexibility exercises were shared. This suggests that doctors may adhere more closely to guidelines when sharing osteoporosis exercise videos. Conversely, videos from yoga instructors, classified under exercise specialists, primarily emphasized stretching and flexibility exercises, often diverging from guideline recommendations. Videos featuring strengthening and impact exercises were associated with higher GQS and mDISCERN scores. Additionally, videos demonstrating balance and coordination exercises exhibited significantly higher quality. According to guidelines, multi-component exercises, particularly those involving resistance and impact training, are more effective in mitigating osteoporosis and osteopenia risk factors (22,23). Adherence to guideline-recommended exercises by speakers likely contributed to the higher GQS and DISCERN values observed for these videos. This result aligns with Vancini et al. (12), who found that videos with two or more recommended exercises scored higher on both DISCERN and GQS scales compared to those with fewer exercises.

Notably, medical doctors were more likely to present videos without exercise demonstrations, and these videos received significantly higher GQS, mDISCERN, and JAMA scores. These "exercise not demonstrated" videos often consisted of long academic webinars shared primarily by doctors and physiotherapists, offering more comprehensive and accurate information on osteoporosis exercises. Despite their high quality and reliability scores, these videos may not be as useful for patients due to their academic language and lack of practical exercise demonstrations.

Physicians and physiotherapists in this study achieved higher GQS scores than exercise specialists, corroborating findings from Onder et al. (13) and Esen et al. (17), which showed that health professionals produced higher-quality videos compared to non-health professionals. This may be because physicians and physical therapists are more likely to share evidence-based information, while non-professionals tend to rely on anecdotal evidence drawn from personal experience.

mDISCERN scores were higher in videos produced by medical doctors than in those by exercise specialists or physiotherapists, with physiotherapists scoring higher than exercise specialists. JAMA scores were also significantly higher in videos by medical doctors compared to those by exercise specialists. These findings align with earlier studies suggesting that the source of a video

influences its quality, with physician-produced content providing higher-quality information (11,19). Moreover, a positive correlation was observed between GQS and mDISCERN values, as well as between mDISCERN and JAMA values, indicating a strong relationship between video reliability and quality (24). As suggested in prior research, higher-quality videos tend to be more reliable (20).

This study found a significant positive relationship between video length and quality. Yaradılmış et al. (25) attributed the poor quality of short videos to insufficient information, while Rodriguez Rodriguez et al. (24) found no statistically significant relationship between video length and quality. In general, longer videos may better address exercise types and explanations, leading to higher quality. However, other studies suggest that while longer videos can provide clearer explanations, patients may lose interest, implying that video creators should aim to deliver high-quality, relevant content within reasonable time frames (11).

Compared to physiotherapists, both medical doctors and exercise specialists tended to produce longer videos. This is consistent with the higher scores observed in the medical doctor group, as longer videos allow for more detailed and accurate content. However, despite their longer videos, exercise specialists scored lower, likely due to limited access to academic resources and guidelines, resulting in less reliable content.

Finally, no significant correlation was found between GQS, mDISCERN, JAMA scores, and viewer engagement metrics such as views, likes, dislikes, comments, and VPI. This is consistent with findings by Onder et al. (13), who also reported no significant correlation between viewer interactions and video quality. It appears that viewers may not reliably differentiate between high- and low-quality videos based solely on engagement metrics.

Study Limitations

This study has several limitations. First, only English-language YouTube videos were included, which may limit the generalizability of the results. Second, as a cross-sectional online study, it may not fully capture YouTube's evolving content, as new videos are constantly added and interacted with. Additionally, the GQS, designed for websites, may not be ideal for evaluating video quality. Finally, the search was restricted to YouTube, excluding videos from other platforms.

Conclusion

In conclusion, our study revealed that YouTube videos on "osteoporosis exercises" are generally of poor quality and reliability. To improve patient access to trustworthy content, professional review processes should be implemented before videos are published. Collaboration with leading medical associations could help generate higher-quality osteoporosis-related content. Medical professionals, whose videos ranked highest in quality, must further contribute to patient education by regularly sharing accurate and informative videos on YouTube to ensure the platform becomes a more reliable resource.

Ethics

Ethics Committee Approval: This study involved publicly accessible videos only, without human or animal subjects, so ethics committee approval was unnecessary, aligning with similar studies.

Informed Consent: N/A.

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Footnotes

Authorship Contributions

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

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Muscle Quality and Structural Changes in Stroke Patients: An Ultrasonographic Evaluation

İnme Hastalarında Kas Kalitesi ve Yapısal Değişiklikler: Ultrasonografik Değerlendirme

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Abstract

Objective: The aim of this study is to evaluate muscle changes in stroke patients by assessing muscle diameter and muscle quality using ultrasonography.

Materials and Methods: Forty male stroke patients and forty healthy male volunteers who fulfilled the predefined criteria were enrolled in the study. The patient group was evaluated with the Brunnstrom Lower Extremity Motor Evaluation, the Modified Ashworth Scale, the Functional Independence Measure, and the Functional Ambulation Scale. Diameter measurements of the quadriceps femoris muscle, were taken with B-mode ultrasonography, and shear wave elastography (SWE) values were recorded for both groups.

Results: Stroke patients' quadriceps femoris muscle diameter was significantly lower than that of controls ($p<0.001$), while SWE measurements exhibited no significant difference ($p>0.05$). Subgroup analysis based on stroke duration revealed lower diameter measurements in acute-subacute and chronic stroke patients compared to controls (both $p<0.001$), with no difference between stroke groups ($p>0.05$). Similarly, regardless of ambulation status, stroke patients had significantly lower quadriceps femoris muscle diameter than controls ($p<0.001$), with no disparity between ambulation groups ($p>0.05$). There was no significant difference in the groups' SWE measurements ($p>0.05$).

Conclusion: These results suggest a decrease in muscle thickness without deterioration in muscle quality. At this point, we believe that simultaneous evaluation with B-mode ultrasonography and elastography during ultrasonographic assessment of muscle changes will provide more objective results. This approach may help us more accurately understand the relationship between the quality and quantity of muscle tissue.

Keywords: Stroke, muscle quality, ultrasonography, elasticity imaging techniques

Öz

Amaç: Bu çalışmanın amacı, inme hastalarında kas çapı ve kalitesini ultrasonografi eşliğinde değerlendirerek kaslardaki değişiklikleri incelemektir.

Gereç ve Yöntem: Çalışmaya, belirlenmiş kriterleri karşılayan kırk erkek inme hastası ve kırk sağlıklı erkek gönüllü dahil edilmiştir. Hasta grubu Brunnstrom Alt Ekstremite Motor Değerlendirmesi, Modifiye Ashworth Skalası, Fonksiyonel Bağımsızlık Ölçütü ve Fonksiyonel Ambulasyon Skalası ile değerlendirilmiştir. Kuadriseps femoris kasının çap ölçümleri B-mod ultrasonografi ile yapılmış ve her iki grup için shear wave elastografi (SWE) değerleri kaydedilmiştir.

Bulgular: İnme hastalarının kuadriseps femoris kas çapı, sağlıklı kontrol grubuna kıyasla anlamlı derecede daha düşük bulunmuştur ($p<0,001$). Ancak, SWE ölçümleri açısından gruplar arasında anlamlı bir fark gözlenmemiştir ($p>0,05$). İnme süresine dayalı alt grup analizi, hem akut-subakut hem de kronik inme hastalarında, kontrol grubuna kıyasla daha düşük kas çapı ölçümleri ortaya koymuştur (her iki durumda da $p<0,001$); bu iki inme grubu arasında ise anlamlı bir fark bulunmamıştır ($p>0,05$). Aynı şekilde, ambulasyon durumundan bağımsız olarak, inme hastalarının kuadriseps femoris kas çapı kontrol grubuna göre anlamlı derecede düşüktür ($p<0,001$) ve ambulasyon grupları arasında fark bulunmamıştır ($p>0,05$). SWE ölçümlerinde ise gruplar arasında anlamlı bir fark tespit edilmemiştir ($p>0,05$).

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Sonuç: Bu bulgular, kas kalitesinde bozulma olmaksızın kas kalınlığında bir azalma olduğunu göstermektedir. Kas değişikliklerinin ultrasonografik değerlendirilmesinde, B-mod ultrasonografi ve elastografinin eşzamanlı kullanımının daha objektif sonuçlar sağlayabileceğini düşünüyoruz. Bu yaklaşım, kas dokusunun kalitesi ve miktarı arasındaki ilişkiyi daha doğru bir şekilde anlamamıza yardımcı olabilir.
Anahtar kelimeler: İnme, kas kalitesi, ultrasonografi, elastisite görüntüleme teknikleri

Introduction

Stroke is a sudden and often life-threatening condition. It occurs as a result of blockage or rupture in cerebral blood vessels and is characterized by a range of symptoms including loss of motor skills, sensory abilities, balance control, and cognitive functions, and in severe cases, can lead to coma (1,2). A major health issue, stroke is one of the world's leading causes of death and disability (3,4).

In patients diagnosed with stroke, muscle atrophy and weakness develop from the onset of the disease (5,6). Sarcopenia can start or worsen because of muscle weakness and skeletal muscle loss brought on by stroke-related inactivity, which limits physical activity (7).

Sarcopenia is associated with losses in muscle mass and function and represents a significant problem both economically and clinically. Methods for assessing sarcopenia include physical performance tests and evaluation of muscle strength (8,9).

Due to changes in natural functions following a stroke, it can be difficult to evaluate muscular strength and physical performance following a stroke. For example, reduced walking speed has been utilized as a sarcopenia diagnostic criterion (10). Although assessment instruments such as the 6-minute walk test have been utilized for this objective, their suitability for stroke patients is restricted because of their limited mobility. Additionally, even in stroke patients capable of movement, paralysis can affect walking, therefore reducing the walking speed test's validity and reliability as a sarcopenia monitoring tool (11).

Recent studies have highlighted that the reduction in muscle size assessed via ultrasonography may be indicative of sarcopenia, with the quadriceps muscle, in particular, holding significance among muscles evaluated for sarcopenia. Literature supports the use of ultrasonographic evaluation as a useful and objective tool in diagnosing sarcopenia (12,13). Additionally, in recent years, elastography in various patient groups has been utilized for the assessment of sarcopenia (14,15). These studies aimed not only to evaluate muscle diameter but also muscle quality.

However, in the literature, there is no study assessing both muscle diameter and muscle quality in terms of sarcopenia in stroke patients. Therefore, the aim of this study is to evaluate muscle diameter and muscle quality in stroke patients using ultrasonography.

Materials and Methods

Study Design

The design of our study is cross-sectional. Permission was obtained from Manisa Celal Bayar University Faculty of Medicine Ethics Committee for our study (decision no: 203, date: 03.11.2021). Between May 24, 2022, and September 1, 2023, 40 male patients diagnosed with stroke who applied to the department of physical medicine and rehabilitation of our hospital, and 40 healthy male volunteers were included. Participants were provided with detailed information about the study, and after obtaining their consent, they agreed to the terms of an informed consent form that our university's faculty of medicine's Ethics Committee had authorized.

Inclusion and Exclusion Criteria

Inclusion criteria for the patient group included being male, having no cognitive impairment, being between the ages of 45 and 80, and having experienced a first-time stroke.

Exclusion criteria included having undergone botulinum toxin, phenol, or alcohol injections for spasticity in the last six months, a history of spine, hip, or lower extremity surgery, presence of skin lesions in the imaging area, history of progressive neurological conditions (such as amyotrophic lateral sclerosis and multiple sclerosis), history of malignancy, systemic infection, or active localized infection.

The control group consisted of 40 healthy male volunteers of the same age range.

The number of patients to be evaluated was determined based on similar studies in the literature (16-20). Assessments of ultrasound elastography can be influenced by elements like body mass index, gender, and age (21). Therefore, to minimize the potential impact of gender differences on the study, only male patients and healthy volunteers were selected.

Assessment Methods

The evaluation of participants in the study, including sick and healthy individuals was conducted using a case form specifically designed for the study. This form was used to record demographic information during the examination and to apply relevant assessment scales. Measurements using B-mode ultrasonography and shear wave elastography (SWE) were recorded for both groups. All measurements were performed by two physiatrists (Z.Ü., C.T.) has over ten years of US musculoskeletal experience.

The patient group included in the study was evaluated using the Brunnstrom Lower Extremity Motor Staging (BSLE), Modified Ashworth Scale (MAS), Functional Independence Measure (FIM), and Functional Ambulation Scale (FAS).

Ultrasonographic Measurement Evaluation of Quadriceps Femoris Muscle Diameter

Measurements of the thickness of the quadriceps femoris muscle, including the rectus femoris and vastus intermedius, were made on the non-dominant side of healthy volunteers and the plegic side of patients during an ultrasonographic examination. The ESAOTE S.p.A Via Enrico Malen 77, 16152

Genova, ITALY-MyLabX8 Exp ultrasonography device and a linear high-frequency probe (4-15 MHz) were utilized.

The thickness of the quadriceps femoris muscle was measured halfway between the greater trochanter and the lateral condyle of the femur (13). During measurements, participants were positioned supine with their legs outstretched, and ultrasonography measurements were conducted when the muscles were fully relaxed. A substantial quantity of contact gel was used in order to reduce the pressure that the ultrasound probe applied to the skin. At the measurement sites, the ultrasonic probe was positioned perpendicular to the tissue surface, and care was taken to avoid excessive pressure that could adversely affect the muscle mass during measurements. It was measured how far the muscle-bone interface and the fat-muscle interface were apart.

Evaluation of Quadriceps Femoris Muscle with Ultrason Shear Wave Elastography

In the study, measurements of the stiffness of the plegic side of patients and the non-dominant side of healthy volunteers' quadriceps femoris muscle were performed using shear wave ultrason elastography. The ESAOTE S.p.A Via Enrico Malen 77, 16152 Genova, ITALY-MyLabX8 Exp ultrasonography device and a linear high-frequency probe (4-15 MHz) were used.

During measurements, participants were laid in a comfortable neutral position on their backs with hip and knee in full extension for elastography measurements. To standardize the position of the measurements, the probe was measured midway between the lateral condyle of the femur and the greater trochanter and placed at this point. A region of interest was determined on this region corresponding to the center of the belly of the quadriceps femoris muscle.

The probe was oriented parallel to the muscle fibers in the longitudinal axis to obtain SWE measurements and then, it was rotated 90 degrees. When taking measurements, the skin was covered with a thin coating of acoustic gel, and the probe was held steady throughout the SWE acquisition process (22).

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) 24.0 software program was used to analyze the study data. The descriptive statistics were displayed as percentages, minimum-maximum values, and mean ± standard deviation. To assess categorical variables, the Pearson chi-square test/Fisher's exact test was utilized. Both analytical techniques (Kolmogorov-Smirnov test) and visual techniques (histograms and probability plots) were used to analyze the normal distribution of the continous data.

Comparisons of normally distributed continuous variables between groups were performed using Student's t-test and One-Way Analysis of Variance (ANOVA). For non-normally distributed continuous variables, differences between groups were tested using Mann-Whitney U test and Kruskal-Wallis test. Associations between continuous variables were determined by Pearson/Spearman Correlation Coefficient. A two-sided p-value <0.05 was considered as statistically significant.

Results

Socio-demographic data of a total of 80 subjects (patient group: 40, control group: 40) is provided in Table 1 as part of the study. In the analysis of sociodemographic data, there was no discernible statistically significant difference between the two groups (p>0.05) (Table 1).

Table 2 displays plegic side, stroke etiology, mean stroke length, and mean, standard deviation, minimum and maximum values of MAS, FIM, FAS, and BSLE scores for each of the 40 patients who were part of the research.

Upon comparing the quadriceps femoris muscle diameter measures between the patient and control groups, the patient group exhibited statistically significant lower values (p<0.001) (Table 3). Nevertheless, there was no statistically significant difference between the patient and control groups when the quadriceps femoris SWE measures were examined (p>0.05) (Table 3).

Based on the amount of time since diagnosis, Table 4 separated the 40 patients into two groups: those with less than 12 months (acute-subacute) and those with more than 12 months (chronic). The values of the minimum, maximum, standard deviation, and mean of quadriceps femoris muscle diameter measurement for each group are presented. Similarly, the quadriceps femoris SWE measurement values for each group are provided.

In multiple comparison analyses, when quadriceps femoris muscle diameter measurements were compared between the acute-subacute stroke patient group statistically significantly lower values were seen in the patient group compared to the control group (p<0.001) (Table 4). In a similar vein, when contrasting the cohort of patients with chronic stroke with the control group, statistically significantly lower values were observed in the patient group (p<0.001) (Table 4). Nevertheless, there was no statistically significant difference between the acute-subacute stroke patient group and the chronic stroke patient group when compared (p>0.005).

When the quadriceps femoris SWE measurements were compared between the acute-subacute stroke patient group, the chronic stroke patient group, and the control group, there was no discernible statistical difference between the groups (p>0.05) (Table 4).

The 40 patients who were a part of the study are split into two groups in Table 5 according to whether they can walk on their own or not. The values of the minimum, maximum, standard deviation, and mean of quadriceps femoris muscle diameter measurement for each group are presented. Similarly, the quadriceps femoris SWE measurement values for each group are provided.

In multiple comparison analyses, when quadriceps femoris muscle diameter measurements were compared between the dependent ambulatory patient group and the control group, statistically significantly lower values were found in the patient group (p<0.001) (Table 5). Similarly, in the comparison between

Table 1. Socio-demographic characteristics; education level, occupation, medical history, age, body mass index, dominant side

		Patient group (n=40)	Control group (n=40)	Total (n=80)	p-value
Education level (n, %)	Non-literate-primary school	18 (45%)	14 (35%)	32 (40%)	0.588
	High school	15 (37.50%)	16 (40%)	31 (39%)	
	Undergraduate-graduate	7 (17.50%)	10 (25%)	17 (21%)	
Occupation (n, %)	Worker	3 (7.50%)	6 (15%)	9 (11%)	0.071
	Civil servant	2 (5%)	8 (20%)	10 (12.50%)	
	Retired	31 (77.50%)	25 (62.50%)	56 (70%)	
	Other	4 (10%)	1 (2.50%)	5 (6.50%)	
Medical history (n, %)	Hypertension	7 (17.50%)	14 (35%)	21 (26.25%)	0.065
	Diabetes	6 (15%)	6 (15%)	12 (15%)	
	Hyperlipidemia	1 (2.50%)	0	1 (1.25%)	
	Cardiac reasons	2 (5%)	0	2 (2.50%)	
	Hypertension + diabetes	14 (35%)	6 (15%)	20 (25%)	
	Hypertension + cardiac reasons	2 (5%)	1 (2.50%)	3 (3.75%)	
	Diabetes + cardiac reasons	1 (2.50%)		1 (1.25%)	
	Hypertension + diabetes + hyperlipidemia	2 (5%)	1 (2.50%)	3 (3.75%)	
	Hypertension + diabetes + cardiac reasons	1 (2.50%)	0	1 (1.25%)	
	None	4 (10%)	11 (27.50%)	15 (18.75%)	
Age (mean ± SD) (min.-max.)		62.62±8.97 45-76	60.87±8.64 45-77	61.74±8.80 45-77	0.377
Body mass index (mean ± SD) (min.-max.)		25.78±3.80 17.75-32.85	25.16±3.21 18.22-31.42	25.47±3.42 17.75-32.85	0.858
Dominant side	Right	37 (92.50%)	35 (87.50%)	72 (90%)	>0.999
	Left	3 (7.50%)	5 (12.50%)	8 (10%)	

Min.-max.: Minimum-maximum, SD: Standard deviation

Table 2. Stroke group's paretic side, stroke etiology, stroke duration, and evaluation scores

Patient group		
Paretic side (n, %)	Right	26 (65%)
	Left	14 (35%)
Stroke etiology (n, %)	Ischemic	30 (75%)
	Hemorrhagic	10 (25%)
Stroke duration (mounth) (mean ± SD) (min.-max.)	32.45±44.46 4-240	
BSLE score (mean ± SD) (min.-max.)	3.70±1.28 1-6	
MAS score (mean ± SD) (min.-max.)	0.03±0.19 0-1	
FIM score (mean ± SD) (min.-max.)	77.42±20.93 28-119	
FAS score (mean ± SD) (min.-max.)	2.17±1.87 0-4	

BSLE: Brunnstrom lower extremity motor staging, MAS: Modified ashworth scale, FIM: Functional independence measure, FAS: Functional ambulation scale, Min.-max.: Minimum-maximum

the independent ambulatory patient group and the control group, statistically significantly lower values were observed in the patient group (p<0.001) (Table 5). Nevertheless, there was no statistically significant difference between the independent and dependent ambulatory patient groups in the comparison (p>0.05).

There was no statistically significant difference between the dependent ambulatory patient group, the independent ambulatory patient group, and the control group when the quadriceps femoris SWE measurement data were examined (p>0.05) (Table 5).

Among the forty stroke patients, correlation analysis was used to investigate the link between ultrasonographic data and stroke assessment scores. Age and MAS score were shown to have a negative moderate and statistically significant connection with diameter measurements. Additionally, a statistically significant positive moderate correlation was observed between diameter measurements and stroke duration, FIM score, and FAS score. However there was no statistically significant association discovered between the measurements of shear waves (Table 6).

Discussion

This study demonstrated that the patient group had statistically significantly lower muscle thickness compared to the control group. However, no significant difference was observed in SWE values between the two groups. Upon review of the literature, no prior study evaluating post-stroke sarcopenia with ultrasound elastography was found. This highlights the novelty of our research in exploring both muscle quantity and quality using ultrasonographic methods.

Prior a limited number ofstudies have primarily focused on ultrasonographic measurements of muscle thickness to assess sarcopenia in stroke patients. A 2018 study by Monjo et al. (16),

Table 3. Quadriceps femoris muscle diameter measurements and shear wave elastography measurements of study groups

	Patient group (n=40) mean ± SD min.-max.	Control group (n=40) mean ± SD min.-max.	The difference between groups (p)
Measurement of diameter (cm)	23.45±2.89 10.50-38.80	34.89±8.01 18.30-53.60	**<0.001**
Shear wave measurement (m/sn)	2.89±1.29 1.38-6.94	2.43±0.62 1.28-3.81	0.237

SD: Standard deviation, Min.-max.: Minimum-maximum, Cm: Centimeter

Table 4. Distribution of quadriceps femoris muscle diameter and shear wave elastography measurements according to subgrouping based on stroke duration

	Acute-subacute stroke patient group (n=16) mean ± SD min.-max.	Chronic stroke patient group (n=24) mean ± SD min.-max.	Control group (n=40) mean ± SD min.-max.	p-value
Measurement of diameter (cm)	20.30±5.60[a] 10.50-32.20	25.50±6.60[a] 12.40-38.80	34.80±8.010[b] 18.30-53.6	**<0.001**
Shear wave measurement (m/sn)	2.96±1.71 1.38-6.94	2.84±0.95 1.76-6.05	2.43±0.62 1.28-3.81	0.129

The symbols a and b indicate the difference between groups. There is no difference between groups with the same letter
SD: Standard deviation, Min.-max.: Minimum-maximum, Cm: Centimeter

Table 5. Distribution of quadriceps femoris muscle diameter and shear wave elastography measurements according to ambulation independence subgroups of the patient group

	Dependent ambulatory patient group (n=19) mean ± SD min.-max.	Independent ambulatory patient group (n=21) mean ± SD min.-max.	Control group (n=40) mean ± SD min.-max.	p-value
Measurement of diameter (cm)	20.44±5.60[a] 10.50-35.40	26.18±6.48[a] 12.40-38.80	34.80±8.01[b] 18.30-53.6	**<0.001**
Shear wave measurement (m/sn)	3.23±1.52 1.38-6.94	2.58±0.98 1.41-5.29	2.43±0.62 1.28-3.81	0.130

The symbols [a] and [b] indicate the difference between groups. There is no difference between groups with the same letter
SD: Standard deviation, Min.-max.: Minimum-maximum, Cm: Centimeter

Table 6. Correlation analysis data of the patient group

(n=40)	Age	Stroke duration	BSLE score	MAS score	FIM score	FAS score	Measurement of diameter	Shear wave measurement
Measurement of diameter	**-0.428 0.006**	**0.345 0.029**	0.219 0.175	**-0.440 0.005**	**0.319 0.045**	**0.520 0.001**	1	-0.280 0.080
Shear wave measurement	-0.037 0.818	0.210 0.194	-0.194 0.231	0.95 0.562	-0.171 0.292	-0.265 0.98	-0.280 0.080	1

r: 0.01-0.29 indicates a low level of correlation, r: 0.30-0.70 indicates a moderate level of correlation, r: 0.71-0.99 indicates a high level of correlation, p<0.05. Spearman correlation test
BSLE: Brunnstrom Lower Extremity Motor Staging, MAS: Modified Ashworth Scale, FIM: Functional independence measure, FAS: Functional ambulation scale

involving 32 stroke patients, used ultrasonography to measure the muscle diameter of the paretic and non-paretic side muscle groups. Statistically significant differences were observed in the quadriceps muscles and tibialis anterior muscle on the paretic side, which led the authors to suggest that the quadriceps femoris muscle is the strongest predictor of both qualitative and quantitative changes on the paretic side in stroke patients. In another study, the diameter of the rectus femoris and biceps brachii muscles was measured in 29 post-polio syndrome patients and 27 healthy controls. While no significant changes were observed in the biceps brachii, the rectus femoris muscle diameter was significantly lower in the patient group compared to healthy controls (17).

The results from these studies suggest that, similar to our study, the quadriceps femoris muscle is the most appropriate muscle for assessing sarcopenia ultrasonographically. Similar findings were observed in other studies that used ultrasound to evaluate the quadriceps femoris muscle for sarcopenia assessment in stroke patients, where lower muscle diameters were observed in the paretic extremity (18-20,22-24). These findings highlight the importance of ultrasonographic measurements in evaluating sarcopenia post-stroke and suggest that ultrasound may become a valuable clinical tool for this purpose.

While studies using SWE in sarcopenia are limited, evidence from other populations provides valuable insights. In a study by Alfuraih et al. (25), muscle evaluation by SWE in healthy volunteers grouped by age revealed a gradual decrease in SWE values with aging. In a different study, SWE was used to assess the rectus femoris muscles in healthy volunteers and patients with chronic obstructive pulmonary disease (COPD), with significantly lower SWE values observed in the COPD group compared to healthy volunteers (26). Similarly, Wang et al. (14) found that SWE values were significantly lower in the sarcopenia group compared to the healthy control group. Additionally, Maeda et al. (27) examined the vastus lateralis muscles of volunteers of different ages using SWE and found an increase in SWE values with aging. In a study by Chen et al. (28), SWE values of the rectus femoris muscles were compared between kidney transplant patients and healthy volunteers, revealing significantly higher SWE values in the patient group despite lower muscle diameters. These findings reveal the potential of SWE to capture biomechanical changes in muscle tissue.

Sarcopenia is characterized by a decrease in muscle mass and a deterioration in muscle quality. Muscle quality is not only linked to muscle mass but also to the structural and functional properties of the muscle. Muscle stiffness, a key indicator of muscle biomechanics, indirectly reflects changes in muscle composition, and muscle strength is influenced by changes in muscle elasticity (28). Therefore, assessing muscle quality is crucial for a more accurate understanding of sarcopenia.

SWE is a method used to assess muscle quality and functional capacity by measuring muscle stiffness. In healthy populations, SWE has been shown to correlate with muscle strength and functional tests. A study by Tang et al. (29) found a significant correlation between muscle stiffness measured by SWE and muscle strength, suggesting that SWE is a valuable tool for assessing muscle biomechanics and can be relied upon for evaluating muscle strength and elasticity.

Changes in muscle stiffness, as measured by SWE, reflect biomechanical and structural deteriorations of the muscle, indicating a decline in the functional capacity of the muscle (30). In our study, although a significant difference in muscle diameter was observed between stroke patients and healthy controls, no significant difference was found in SWE values. These findings suggest that while muscle atrophy is evident in stroke patients, there may be no major changes in muscle biomechanics, and the structural and functional properties of the muscle tissue may be preserved.

It is believed that the concurrent use of elastography with B-mode ultrasonography for the ultrasonographic evaluation of sarcopenia could provide more objective results. This approach would allow a better understanding of the relationship between the quantity and quality of muscle tissue. By evaluating both structural changes and biomechanical properties of the muscle, this method could enable a more accurate determination of muscle quality.

Subgroup analyses based on stroke duration and ambulation ability revealed significant differences in muscle thickness, while SWE values remained consistent. These findings suggest that muscle stiffness does not vary between groups, indicating no evidence of fibrosis accompanying muscle atrophy. The decrease in muscle thickness appears to begin in the early stages of stroke and persists over time. However, increased activity levels and greater independence may help reverse this condition.

These results highlight the importance of emphasizing regular exercise, particularly muscle-strengthening activities, for stroke patients starting from the acute phase. Encouraging such rehabilitation efforts could potentially prevent or mitigate muscle loss, supporting improved functional outcomes for these individuals.

Study Limitations

This study has some limitations. First off, the study's single-center design and small sample size limit the generalizability of the findings. In addition, considering the heterogeneous nature of stroke patients and different stroke types, the lack of homogeneity of the patients in the study can also be considered a limitation. At this point, although the study was analyzed by dividing the patient group into subgroups according to stroke duration and ability to ambulate independently, there is still a risk that the study may be affected by external factors.

A person's age, gender, and body mass index are among the variables that can impact their ultrasonographic elastography assessments. Therefore, only male patients and healthy volunteers were selected to reduce the potential impact of gender differences on the study results. However, this selection can be considered a limitation of the study, as it is desirable for the results to be generalized to both genders. Despite this, the findings from the male-only sample still provide valuable insights.

Conclusion

In conclusion, our study demonstrated that muscle thickness in the stroke group was significantly lower than in healthy controls, but SWE evaluations showed no significant differences between the groups. These findings suggest that muscle atrophy occurs without corresponding deterioration in muscle quality, as assessed by SWE. Combining B-mode ultrasonography with SWE may provide a more comprehensive evaluation of muscle quantity and quality, facilitating better understanding and management of sarcopenia in stroke patients.

Future studies should explore different muscle groups and patient populations to establish standardized protocols for ultrasonographic assessments. This study lays the groundwork for integrating advanced ultrasound techniques into the clinical evaluation of sarcopenia.

Ethics

Ethics Committee Approval: Permission was obtained from Manisa Celal Bayar University Faculty of Medicine Ethics Committee for our study (date: 03.11.2021, decision no: 203).

Informed Consent: Participants were provided with detailed information about the study, and after obtaining their consent, they agreed to the terms of an informed consent form that our university's faculty of medicine's Ethics Committee had authorized.

Footnotes

Authorship Contributions

Concept: İ.C.Ö., Ö.A., C.T., Z.Ü., L.C., Design: İ.C.Ö., Ö.A., C.T., Z.Ü., L.C., Data Collection or Processing: İ.C.Ö., Ö.A., C.T., Z.Ü., L.C., Analysis or Interpretation: İ.C.Ö., Literature Search: İ.C.Ö., Writing: İ.C.Ö.

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

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Evaluation of Selection Criteria of Clinicians in the Treatment of Osteoporosis, OSTREQ Research in Türkiye

Klinisyenlerin Osteoporoz Tedavisindeki Tercih Kriterlerinin Anket ile (OSTREQ) Değerlendirilmesi Türkiye Uyarlaması Çalışması

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Abstract

Objective: This study aims to adapt the OSTREQ questionnaire, developed by Makras et al., into Turkish to assess the factors that clinicians take into consideration when planning osteoporosis treatment, as clinicians take many factors into consideration when making their decisions due to various treatment options.
Materials and Methods: The Turkish version of the OSTREQ questionnaire, comprising 17 questions and an 8-section format, used a 5-point Likert scale. From April 2018 to November 2019, the survey was conducted with 188 clinicians in rheumatology, physical therapy, rehabilitation, endocrinology, and metabolic diseases. After excluding 18 duplicate responses, data from 170 clinicians were analyzed.
Results: Participants included 21.8% endocrinologists, 28.8% rheumatologists, and 49.4% physical therapy and rehabilitation specialists. Factor analysis showed item loadings between 0.33 and 0.92, exceeding the 0.32 threshold. The overall Cronbach's alpha was 0.855, indicating high internal consistency. There were no significant differences among specialties in subscales like "disease severity and treatment efficacy". However, rheumatologists scored significantly higher than endocrinologists on "health system and cost" (p=0.034).
Conclusion: The Turkish OSTREQ questionnaire is a valid, reliable tool for evaluating factors in osteoporosis treatment decisions. With minimal modification, it can assess clinicians' views on specific anti-osteoporotic agents, aiding healthcare and pharmaceutical stakeholders.
Keywords: Osteoporosis, surveys and questionnaires, therapeutics

Öz

Amaç: Bu çalışma, çeşitli tedavi seçenekleri nedeniyle klinisyenler kararlarını verirken birçok faktörü göz önünde bulundurduğu osteoporoz tedavisini planlarken dikkate aldıkları faktörleri değerlendirmek amacıyla Makras ve ark. tarafından geliştirilen OSTREQ anketinin Türkçeye uyarlanmasını amaçlamaktadır.
Gereç ve Yöntem: OSTREQ anketinin 17 soruluk ve 8 bölümlük Türkçe versiyonu, 5'li Likert ölçeği kullanılarak uygulandı. Anket, Nisan 2018 ile Kasım 2019 tarihleri arasında romatoloji, fizik tedavi, rehabilitasyon, endokrinoloji ve metabolizma hastalıkları uzmanı olan 188 klinisyene uygulandı. Çift yanıt veren 18 kişi çalışmadan çıkarıldı ve 170 katılımcının verileri analiz edildi.
Bulgular: Katılımcıların %21,8'i endokrinolog, %28,8'i romatolog, %49,4'ü ise fizik tedavi ve rehabilitasyon uzmanıdır. Faktör analizi, anket maddelerinin 0,33 ile 0,92 arasında faktör yüklerine sahip olduğunu gösterdi ve bu değerler 0,32 eşik değerinin üzerindedir. Genel Cronbach alfa değeri 0,855 olup yüksek iç tutarlılık göstermektedir. "Hastalığın ciddiyeti ve tedavi etkinliği" alt ölçeğinde uzmanlıklar arasında anlamlı fark bulunmazken, "sağlık sistemi ve maliyet" alt ölçeğinde romatologlar endokrinologlardan anlamlı derecede yüksek puan almıştır (p=0,034).
Sonuç: OSTREQ anketinin Türkçe versiyonu, osteoporoz tedavisi kararlarında dikkate alınan faktörleri değerlendirmede geçerli ve güvenilir bir araçtır. Minimal modifikasyonlarla, spesifik anti-osteoporotik ajanlarla ilgili klinisyenlerin görüşlerini değerlendirmek için de kullanılabilir ve sağlık hizmetleri ile ilaç sektörü için yol gösterici olabilir.
Anahtar kelimeler: Osteoporoz, anketler ve soru formları, tedavi

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Introduction

Osteoporosis is a progressive metabolic skeletal disease characterized by low bone mass and microarchitectural deterioration of bone, leading to an enhanced susceptibility to fractures (1). The prevalence of osteoporosis is growing with the aging of the world's population (2). It is a common skeletal pathology with an enormous potential burden of complications, especially among older individuals. The projections are that by the year 2035, the population of Türkiye will rise by 23% to 92.9 million and the population over 50 years will nearly double. The male population over 50 years will increase from 6.4 million to 13.9 million and females from 7 million to 15 million. Because osteoporotic hip fractures are so closely related to age, such fractures are forecasted to increase significantly by the year 2035, beyond that accountable by population growth alone (2). The goal of treatment is the improvement of the quality of life and health standard for patients suffering from osteoporosis and fractures, and for this, a tailored approach is considered optimum.

After that, physicians select the most appropriate regimen based on the patient's medical history and fracture risk assessment, as well as any previous anti-osteoporotic treatments. Meanwhile, the risk-benefit ratio must always be considered in this regard (3). In the management of osteoporosis, there are several lifestyle modifications that include adequate intake of vitamin D and calcium, proper nutrition, appropriate weight-bearing exercises, cessation of smoking, and fall prevention (4). The current study aimed to adapt the OSTREQ questionnaire by Makras et al. (5) into Turkish and to evaluate factors affecting clinicians' decisions regarding the treatment of osteoporosis among Turkish specialists in physical therapy and rehabilitation, endocrinology, and rheumatology.

Materials and Methods

Our study was conducted at İzmir Katip Çelebi University, Atatürk Training and Research Hospital between April 2018 and October 2019. Ethical approval was obtained from the Scientific Research Ethics Committee of İzmir Katip Çelebi University (decision no: 397, dated: 26.09.2019).

The survey was administered to 170 physicians, either in person or via e-mail. A total of 206 responses were collected; however, due to 18 participants submitting the survey twice, their responses were excluded from the study.

The aim of this study is to examine the Turkish adaptation of the OSTREQ questionnaire, developed by Markas et al. (5), for its applicability in Türkiye. The questionnaire includes eight sections: Health system, usage, cost, disease severity, treatment efficacy, safety profile, and pharmaceutical industry, with a total of 17 questions. The responses are evaluated on a 5-point Likert scale: "definitely inhibitory", "partially inhibitory", "neither inhibitory nor supportive", "partially supportive" and "definitely supportive".

Statistical Analysis

The statistical analysis of the study was performed using the IBM SPSS 22 statistical program. Since the data did not conform to a normal distribution, non-parametric tests were utilized. The normality of the data was assessed using histograms, plot charts (probability plots), skewness/kurtosis coefficients, and normality tests.

For the statistical analysis, Kruskal-Wallis, Cronbach's alpha, and confirmatory factor analysis (CFA) were conducted. A Type 1 error level of 5% was used for statistical significance, and a p-value of less than 0.05 was considered statistically significant. The CFA was performed using the AMOS SPSS 24 statistical program. To evaluate the construct validity and the fit of the tested model to the data, several indices were calculated: Chi-square, chi-square/degrees of freedom, comparative fit index (CFI), root mean square residual (RMR), normed fit index (NFI), root mean square error of approximation (RMSEA), goodness of fit index (GFI), and adjusted goodness of fit index (AGFI).

Results

When examining the specialties of the physicians participating in our study, it was found that 37 (21.8%) were endocrinologists, 49 (28.8%) were rheumatologists, and 84 (49.4%) were specialists in physical medicine and rehabilitation (Figure 1).

When examining the distribution of responses given by the physicians participating in our study to the questionnaire on criteria for osteoporosis treatment preferences, it was found that the top three items most frequently rated as "definitely inhibitory" were as follows:

- Cost (patient) (24.9%) (Figure 2)
- Usage (storage requirements) (18.8%) (Figure 3)
- Cost (health system) (12.9%) (Figure 4).

The top three items most frequently rated as "definitely supportive" were as follows:

- Disease severity (current osteoporotic fractures) (Figure 5)
- Treatment efficacy (fracture risk reduction) (Figure 6)
- Treatment efficacy (bone mineral density) (Figure 7).

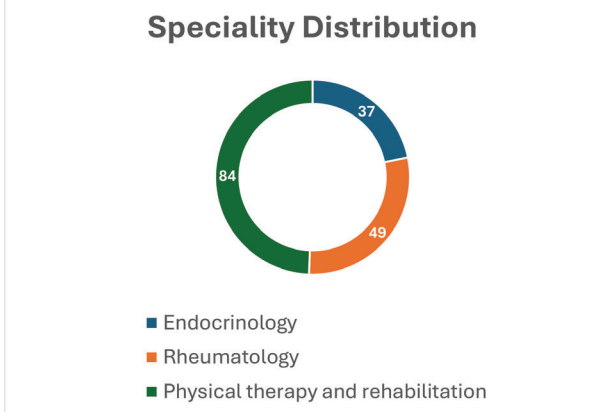

Figure 1. Speciality distribution

Validity and Reliability Analysis of the Questionnaire for the Evaluation of Factors Affecting Osteoporosis Treatment Selection

Factor Analysis

Factor analysis is a means through which the relationships between various factors are gauged. CFA, on the other hand, is a type of structural equation modeling that measures the relationship of one variable with all other observed variables. While a large number of goodness-of-fit indices is available in the literature, no consensus is arrived at as to which ones have to be satisfied. CFA tests the structural integrity of either a previously developed or a newly developed scale. It is recommended that when a previously validated scale is adapted into a new culture or language, CFA should be directly conducted without carrying out exploratory factor analysis. In CFA, the factor loadings

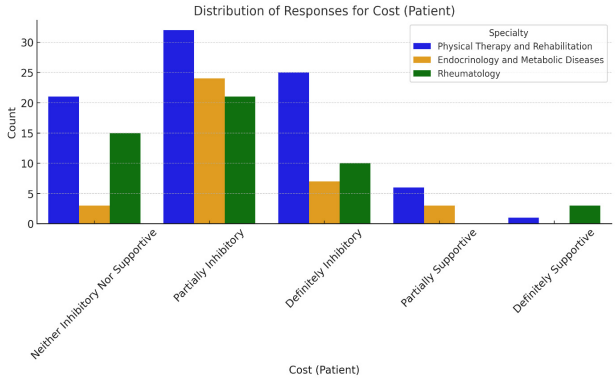

Figure 2. Distribution of responses for cost (patient)

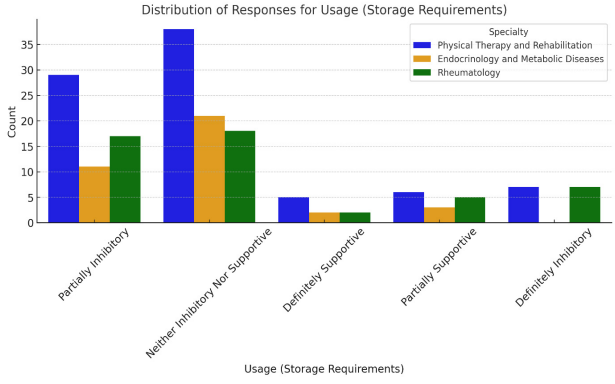

Figure 3. Distribution of responses for usage (storage requirements)

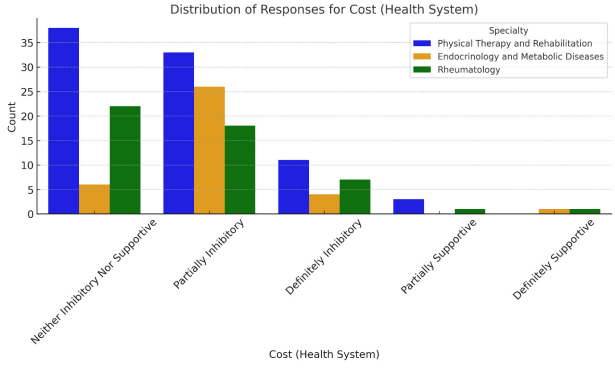

Figure 4. Distribution of responses for cost (health system)

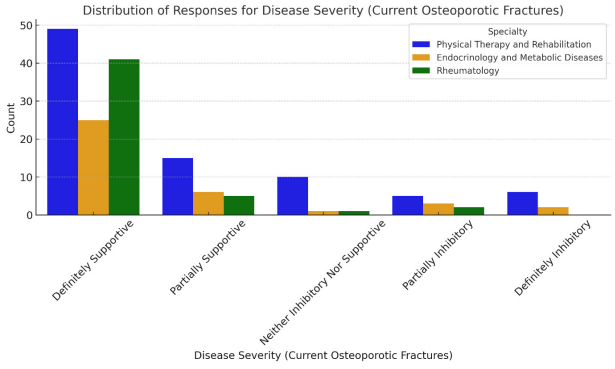

Figure 5. Distribution of responses for disease severity (current osteoporotic fractures)

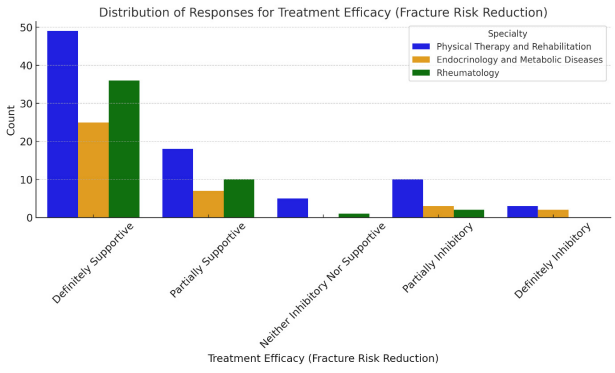

Figure 6. Distribution of responses for treatment efficacy (fracture risk reduction)

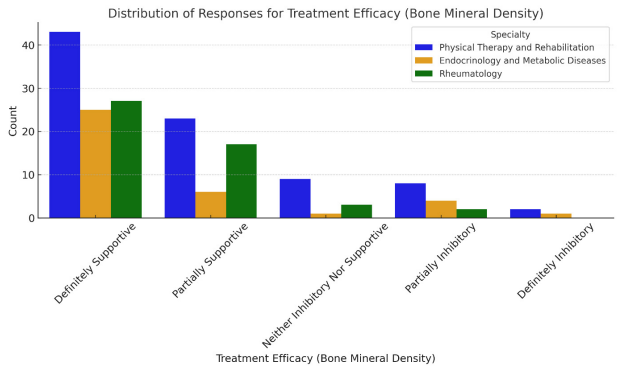

Figure 7. Distribution of responses for treatment efficacy (bone mineral density

should exceed 0.32 for validity. In the Turkish-adapted scale, factor loadings that ranged from 0.33 to 0.92 were above the threshold of acceptance of 0.32 (Figure 8).

The model fit of the key indices was assessed by χ^2/df (χ^2/df) (chi-square raito), RMSEA, GFI, AGFI, CFI, NFI and RMR. Accordingly acceptable fit was seen for χ^2/df, GFI, CFI, AGFI and RMR indices. On the other hand, it showed a poor fit in the NFI and RMSEA indices. In this respect, these indices revealed points of modification (Table 1).

Internal Consistency Reliability

The internal consistency of the clinicians' preference for osteoporosis treatment survey was evaluated using Cronbach's alpha, with subscale values ranging from 0.698 to 0.940 and an overall alpha of 0.855, indicating high reliability. No items significantly increased internal consistency upon removal. A Cronbach's alpha above 0.700 indicates reliability, and above 0.800 suggests high reliability. Additionally, t-tests for the top and bottom 27% groups showed significant differences for all items, with t-values between 2.711 and 10.030. Therefore, no items were removed based on factor analysis and internal consistency results.

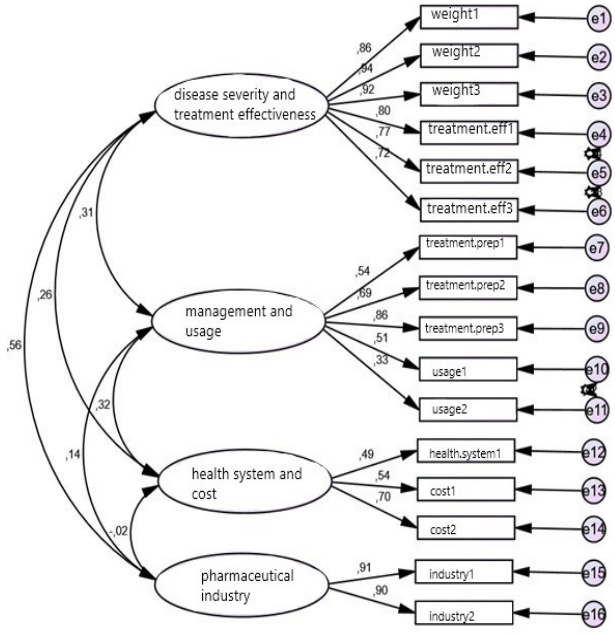

Figure 8. Diagram of confirmatory factor analysis for the evaluation of clinicians' preference criteria in osteoporosis treatment with a survey

Analysis of Physicians' Responses to the Osteoporosis Treatment Preference Survey Based on Their Areas of Specialization

In our study, the responses of specialist physicians to the osteoporosis treatment preference survey were analyzed according to their fields of specialization. No statistically significant differences were found between the subscales of disease severity and treatment efficacy, management and usage, and the pharmaceutical industry across specialties. However, a statistically significant difference was observed in the healthcare system and cost subscale across specialties (p=0.013) (Table 2).

In the post-hoc test (LSD) conducted to identify the group responsible for the significant difference, it was found that rheumatology specialists scored statistically significantly higher than endocrinology specialists in the healthcare system and cost subscale (p=0.034) (Table 3).

In our study, when the responses of specialist physicians to the Osteoporosis Treatment Preference Survey were analyzed according to their fields of specialization, no statistically significant differences were found in the total survey score across specialties (Table 4).

Discussion

Osteoporosis is a gradually advancing disease marked by reduced bone density, poorer bone quality, and cellular-level damage to bone structure. As life expectancy increases and the elderly population grows, the occurrence of osteoporosis is becoming more common worldwide and in Türkiye (2). This silent disease often is asymptomatic until fractures occur and, by this point, places significant burdens on both individuals and the economy.

Table 1. Evaluation of the fit indices of the clinicians' preference criteria survey in osteoporosis treatment

Index	Good fit	Acceptable fit	Survey of clinicians' preference criteria in osteoporosis treatment
CMIN/D (χ^2/SD)	<2	<5	**2.221**
GFI	>0.95	>0.85	**0.874**
CFI	>0.95	>0.90	**0.927**
NFI	>0.95	>0.90	0,875
AGFI	>0.95	>0.85	**0.864**
RMSEA	<0.05	<0.08	0.085
RMR	<0.05	<0.08	**0.063**

GFI: Goodness of fit index, CFI: Comparative fit index, NFI: Normed fit index, AGFI: Adjusted goodness of fit index, RMSEA: Root mean square error of approximation, RMR: Root mean square residual

Table 2. Comparison of sub-factors of the preference criteria questionnaire in osteoporosis treatment according to specialty area

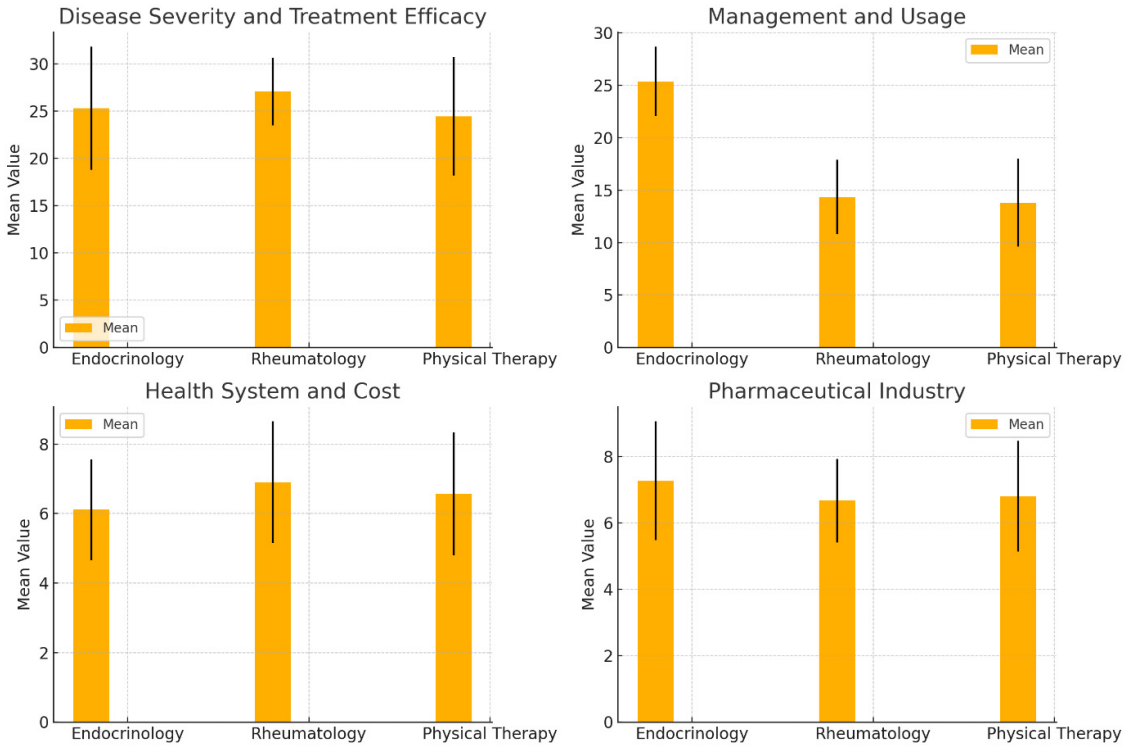

Table 3. Post-hoc test of health system and cost sub-dimension

		Mean difference	Standard deviation	p	95% Confidence interval	
					Lower limit	Upper limit
Endocrinology	Rheumatology	-0.78	0.37	**0.034**	-1.52	-0.05
	Physical therapy and rehabilitation	-0.46	0.33	0.169	-1.12	0.19
Rheumatology	Endocrinology	0.07	0.37	0.034	0.05	1.52
	Physical therapy and rehabilitation	0.32	0.30	0.287	-0.27	0.92
Physical therapy and rehabilitation	Endocrinology	0.46	0.33	0.169	-0.19	1.12
	Rheumatology	-0.32	0.30	0.287	-0.92	0.27

Table 4. Comparison of the total score of the preference criteria questionnaire in osteoporosis treatment according to specialty

		n	Mean	SD	x^2	p
Total survey score	Endocrinology	37	54.05	9.21	0.119	0.730
	Rheumatology	49	54.98	6.63		
	Physical therapy and rehabilitation	86	51.63	10.20		

SD: Standard deviation

Lifestyles involving proper nutrition, exercising that strengthens the bones, and fall prevention are some of the ways the disease is prevented and treated. In the use of pharmacological agents in managing the disease, clinicians consider many factors.

Management of osteoporosis needs to be highly individualized. When treatment is indicated, physicians should select the most appropriate regimen, considering the medical history of the patient, fracture risk, and previously applied anti-osteoporotic therapies. Maximum patient benefit should be assured while designing the therapeutic approach. Other than patient factors, starting, switching, or continuing a treatment is influenced by the physician's strategy, rules of the healthcare system, and the role of the pharmaceutical industry. Treatments for osteoporosis are varied, so that not all factors guiding physicians' choices are fully known. This study tried to explore these factors using a simple survey.

In response to the development of many fracture risk assessment surveys that identify those patients with reduced bone mass requiring treatment, several studies have been carried out that evaluate such surveys based on patient preferences related to osteoporosis treatment (6-8). However, these studies are based upon the response of the patients themselves. The present study aimed to predict the factors likely to influence the treatment decisions of physicians from three medical specialties actively involved in osteoporosis management in Türkiye. Either via e-mail or in person, participants were contacted from different centers across Türkiye.

The OSTREQ survey, developed by Makras et al. (5), was originally written in Greek and was translated into English by the authors. Then, the survey was translated from English into Turkish and administered to endocrinology and metabolic disease specialists, rheumatologists, and physical medicine and rehabilitation clinicians who play a primary role in osteoporosis treatment. In this study, CFA of the validity and reliability of the scale was performed, and its reliability was tested by internal consistency. Whereas in the original OSTREQ study (5), the factor loadings were between 0.65 and 0.90, in our study, the factor loadings of items were between 0.33 and 0.92, above the acceptable threshold of 0.32.

Whereas in the original OSTREQ study (5), Cronbach's alpha internal consistency reliability coefficients ranged from 0.78 to 0.93, in our study, the Cronbach's alpha coefficient was found to be 0.855. The reliability of a scale was indicated when the Cronbach's alpha value was 0.70 and above. Values of $0.80 \leq a < 1.00$ indicated high reliability. Based on these findings, it can be concluded that the internal consistency of the scale is adequate and it has been shown to be a reliable scale that can be used in Türkiye.

The confirmatory factor analysis, internal reliability analysis, and subgroup analysis for 27% of subgroups performed in our study indicated that the items in the Clinicians' Osteoporosis Treatment Preference Survey are discriminative, show construct validity, and are reliable. If items were deleted, Cronbach's alpha values and t-test observed for item discrimination between the lower and upper subgroups ranged from 0.833 to 0.859 ($p<0.001$). These ranged from 0.890 to 0.925 in the original OSTREQ study (5), $p<0.001$ for each.

Results of ANOVA of survey responses by specialty showed no statistical differences of subscales of disease severity, treatment efficacy and management or pharmaceutical industry use. A statistically significant difference was found in the healthcare system and cost subscale, $p=0.013$. LSD post-hoc tests revealed that rheumatology specialists ranked this area significantly higher than endocrinologists, $p=0.034$. There were no statistical differences in total survey scores among the specialties.

Conclusion

This study was developed as a general osteoporosis treatment survey; however, it can be easily adapted and used with minimal modifications to evaluate physicians' views on specific anti-osteoporotic agents. This study can also help healthcare reimbursement systems and pharmaceutical companies understand the parameters that guide physicians' preferences in osteoporosis treatment decisions.

Ethics

Ethics Committee Approval: Our study was conducted at İzmir Katip Çelebi University, Atatürk Training and Research Hospital between April 2018 and October 2019. Ethical approval was obtained from the Scientific Research Ethics Committee of İzmir Katip Çelebi University (decision no: 397, dated: 26.09.2019).

Informed Consent: Il participants were informed about the purpose of the study and provided their voluntary consent prior to participation. Participation was entirely voluntary, and responses were anonymized to ensure confidentiality.

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Footnotes

Authorship Contributions

Concept: B.Ö.P., Design: E.G.K., B.Ö.P., S.A., A.T., Data Collection or Processing: E.G.K., B.Ö.P., S.A., A.T., Analysis or Interpretation: E.G.K., Literature Search: E.G.K., Writing: E.G.K.

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

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Evaluating Psoas Muscle Index and Spinal Sagittal Alignment as Predictors of Fall Risk in Adults: A Comprehensive Analysis

Yetişkinlerde Düşme Riskinin Tahmin Edicileri Olarak Psoas Kas İndeksi ve Omurga Sagital Hizalanmasının Değerlendirilmesi: Kapsamlı Bir Analiz

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Abstract

Objective: This study aims to evaluate the psoas muscle index and spine sagittal alignment as predictors of fall risk in adults.

Materials and Methods: A total of 126 patients who visited the physical medicine and rehabilitation outpatient clinic between January and May 2024 were included. Standing lateral spine radiographs, lumbar magnetic resonance imaging (MRI), and lumbar computed tomography (CT) images were analyzed. Sagittal vertical axis, thoracic kyphosis, cervical and lumbar lordosis angles, pelvic incidence, sacral slope, lumbosacral angle, and pelvic tilt were measured. The psoas muscle index was calculated from lumbar MRI and CT images. Participants were grouped based on the Tinetti fall risk index, and differences in sagittal alignment and psoas muscle index were assessed.

Results: In this cross-sectional descriptive study, significant differences were found between fall risk groups in terms of gender and age. The medium-risk group had more women, while the high-risk group had more men and was older. Sagittal vertical axis, sacral slope, and pelvic tilt angle showed statistically significant differences between fall risk groups. Positive sagittal vertical axis was more common in medium- and high-risk groups than in the low-risk group. Sacral slope values were lower, and pelvic tilt angle was higher in the high-risk group compared to the low-risk group. Psoas muscle AP/ML values at the L4-5 level positively correlated with fall risk. A negative correlation was found between fall risk groups and anterior margin gap and center gap values at L3-4 and L2-3 levels. Additionally, psoas muscle position at L3-4 and L2-3 levels was more negative in high- and medium-risk groups.

Conclusion: Determining the relationship of these changes in psoas muscle analysis and spinal alignment with the risk of falling in adult individuals will enable the creation of appropriate rehabilitation strategies.

Keywords: Fall risk, pelvic parameters, psoas muscle index, spine sagittal alignment, spinopelvic sagittal balance

Öz

Amaç: Bu çalışmanın amacı yetişkinlerde düşme riskinin öngörücüleri olarak psoas kas indeksi ve omurga sagital hizalanmasını değerlendirmektir.

Gereç ve Yöntem: Ocak ve Mayıs 2024 arasında fiziksel tıp ve rehabilitasyon polikliniğini ziyaret eden toplam 126 hasta çalışmaya dahil edildi. Ayakta lateral omurga radyografileri, lomber manyetik rezonans görüntüleme (MRG) ve lomber bilgisayarlı tomografi (BT) görüntüleri analiz edildi. Sagital dikey eksen, torasik kifoz, servikal ve lomber lordoz açıları, pelvik insidans, sakral eğim, lumbosakral açı ve pelvik eğim ölçüldü. Psoas kas indeksi lomber MRG ve BT görüntülerinden hesaplandı. Katılımcılar Tinetti düşme risk indeksine göre gruplandırıldı ve sagital hizalama ve psoas kas indeksindeki farklılıklar değerlendirildi.

Bulgular: Bu kesitsel tanımlayıcı çalışmada, düşme risk grupları arasında cinsiyet ve yaş açısından anlamlı farklılıklar bulundu. Orta risk grubunda daha fazla kadın, yüksek risk grubunda ise daha fazla erkek ve daha yaşlıydı. Sagital dikey eksen, sakral eğim ve pelvik eğim açısı düşme riski grupları arasında istatistiksel olarak anlamlı farklılıklar gösterdi. Pozitif sagital dikey eksen orta ve yüksek riskli gruplarda düşük riskli gruba göre daha yaygındı. Sakral eğim değerleri düşüktü ve pelvik eğim açısı yüksek riskli grupta düşük riskli gruba göre daha yüksekti. Psoas kası AP/ML değerleri L4-5 seviyesinde düşme riski ile pozitif korelasyon gösterdi. Düşme riski grupları ile L3-4 ve L2-3 seviyelerinde anterior kenar boşluğu ve merkez boşluğu değerleri arasında negatif korelasyon bulundu. Ek olarak, psoas kası pozisyonu L3-4 ve L2-3 seviyelerinde yüksek ve orta riskli gruplarda daha negatifti.

Sonuç: Psoas kası analizi ve omurga hizalamasındaki bu değişikliklerin yetişkin bireylerde düşme riski ile ilişkisinin belirlenmesi uygun rehabilitasyon stratejilerinin oluşturulmasını sağlayacaktır.

Anahtar kelimeler: Düşme riski, pelvik parametreler, psoas kas indeksi, omurga sagital hizalaması, spinopelvik sagital denge

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Introduction

A fall is defined as an individual descending to a lower level than the ground or floor as a result of an involuntary change in position. The main factors that cause falls are divided into four groups: Biological, behavioral, environmental, and socioeconomic factors (1). Studies states that the frequency of falls increases with advancing age and level of weakness (1,2). In a study, the prevalence of falling in the previous year was found to be 25%, with a prevalence of 21.7% in men and 27.1% in women. Additionally, the prevalence of fear of falling was reported to be 41.5% (2). Falls result in negative consequences such as injury to the individual, decreased quality of life, prolonged hospital stays, and increased treatment costs, and are considered an important patient safety criterion worldwide (2).

Preventing falls, an important element of patient safety is a process that begins with diagnosing the risk of falling and evaluating the associated risk factors. The human spine maintains a relatively stable posture for minimal energy consumption when standing or exercising. The sagittal balance of the trunk is determined primarily by the alignment of the spine and pelvis, which is necessary to maintain normal spinal biomechanics. Proper lumbosacral alignment is crucial for optimal spinal function. If the spinal alignment and balance are disrupted, the human body must exert more effort to stand upright. Changes in spinal alignment can adversely affect body biomechanics, leading to pain, reduced quality of life, compromised sagittal balance, and an increased risk of falls (3,4). Sarcopenia, characterized by the loss of skeletal muscle mass and strength, is an important risk factor associated with the development of osteoporosis (5,6). Sarcopenia can be determined by the muscle mass of the extremities, walking speed, and grip strength (7).

The decrease in skeletal muscle mass, which seriously affects the daily behavioral ability and quality of life of individuals, also affects spinal alignment (8). This is because the musculoskeletal system interacts with each other through various chemical events at paracrine and endocrine levels. These chemical events secondary to aging can lead to decreased muscle strength and increased fracture incidence; nutritional deficiencies can accelerate bone loss and reduce muscle protein synthesis; decreased individual exercise and decreased neuromuscular function can indirectly affect muscle and bone anabolism (5). In addition, due to disc and ligament degeneration, spinal mechanical distribution often changes in elderly patients and paravertebral muscle strength decreases (8). Studies have shown that sagittal spinal misalignment and sarcopenia are associated with falls in older individuals (8,9). For this reason, measuring the overall alignment of the spine and evaluation the presence of sarcopenia allows individuals at high risk of falling to be identified.

Current literature predominantly focuses on fall risk assessment in individuals aged 65 and older, with limited investigation into younger adult populations. Furthermore, there is a noticeable gap in research exploring the effects of sarcopenia and sagittal spinal alignment which are both recognized as potential risk factors for falls. Therefore, this study aims to explore the potential association between the psoas muscle index, sagittal spinal alignment, and fall risk in adults.

Materials and Methods

This descriptive cross-sectional study was conducted at a Kütahya Health Sciences University Hospital Physical Medicine and Rehabilitation Clinic between January and May 2024. All data were collected by the same evaluator at the same facility. Approval for the study was obtained from the Local Ethical Committee (Kütahya Health Sciences University Non-Interventional Research Ethics Committee, no. 2023/05-07, dated: April 25, 2023). All individuals included in the study signed an informed consent form, stating that they participated in the study voluntarily.

Participant

This study included 126 patients aged 18 years and older who applied to our hospital's outpatient clinics with complaints of myalgia and who underwent lumbar magnetic resonance imaging (MRI), computerized tomography (CT) scans, and whole spine lateral radiographs due to low back and neck pain within the last year. The exclusion criteria for the study are as follows: (a) Refusal to participate in the study, (b) Inadequate communication ability, (c) Severe cognitive impairment, (d) History of any previous spinal and lower extremity operations, (e) Cobb angle >20° indicating any scoliotic deformity, spondylolisthesis, spinal tumor, infection, fracture, or trauma, (f) Participants with missing or unmeasurable radiographic imaging, (g) Knee flexion contracture (extension <0°), hip flexion contracture (extension <10°), or leg length difference (>1 cm), and (h) History of diseases causing balance problems.

After recording demographic data, all participants were assessed using the Tinetti Balance and Gait Questionnaire to determine their balance, walking abilities, and fall risk. The questionnaire has been validated for reliability and validity and its Turkish version study was conducted by Ağırcan (10), and Tinetti (11). The first 9 questions of this questionnaire focused on balance, while the next 7 questions pertain to walking. The questionnaire score is calculated as follows: the total score of the first 9 items determines the balance score, the total score of the next 7 items determines the walking score, and the sum of these scores provides the total score. A total score of 18 and below indicates a high risk of falling, a score of 19-24 points indicates a moderate risk of falling, and a score of 25 and above indicates a low risk of falling (10,11). The patients included in the study were assessed based on the questionnaire results and categorized into three groups: Low, medium, and high-risk groups.

Psoas muscle cross-sectional analysis and spine sagittal alignment evaluation were performed using whole spine lateral radiographs, MRI, and CT scans for all patients, and the results were compared between groups. The evaluation of spine sagittal alignment included examination of the sagittal vertical axis (SVA), thoracic kyphosis angle (TKA), lumbar lordosis angle (LLA), cervical lordosis angle, pelvic incidence (PI), sacral slope

angle (SSA), and pelvic tilt angle (PTA) (12,13) (Figures 1, 2). All radiographs were taken under standardized conditions with patients instructed to assume a comfortable standing position for lateral spine radiographs. Lumbar MRI and CT imaging data were utilized for psoas muscle cross-sectional analyses (14,15) (Figures 3, 4). In lumbar MRI, each variable was measured on T2-weighted axial images at the intervertebral disc-bisection levels of L2-3, L3-4 and L4-5. Since the psoas muscle shape and edges cannot be clearly distinguished at the L1-2 and L5-S1 levels, they were excluded from evaluation. Since the right psoas muscle may be affected by anatomical variability in the inferior vena cava and right common iliac vein, only the left psoas muscle was measured (15). In addition, the total volume of the psoas muscle was calculated from CT images by summing the cross-sectional areas of the right and left psoas muscles at the mid-level of the L3 vertebra and normalizing the value by the square of the individual's height (16). All measurements were conducted using software tools integrated into a picture archiving and communications system (PACS viewer).

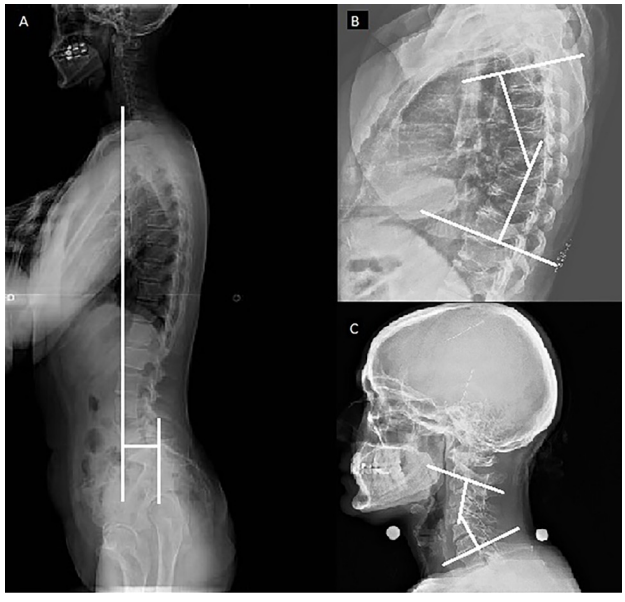

Figure 1. (A) Sagittal vertical axis (SVA): The line drawn vertically from the middle of the C7 vertebral body or the midpoint of the C7 interior endplate to the horizontal plane passing through the postero-superior corner of S1. Neutral sagittal balanece: Between 2 cm anterior or posterior of the postero-superior corner of the sacrum. Positive sagittal imbalance: >2 cm anterior to the postero-superior corner of S1. Negative sagittal imbalance: >2 cm posterior the postero-superior corner of S1. (B) Thoracic kyphosis angle (TKA): The angle between the horizontal line drawn on the upper edge of the T4 vertebra and the lines drawn perpendicular to the horizontal line drawn on the lower edge of the T12 vertebra. In measurements made when T7 is considered as the peak, the thoracic kyphosis angle should be between 20° and 50° on average. (C) Cervial lordosis angle (CLA): The angle between the horizontal line drawn on the lower edge of the C2 vertebra and the lines drawn perpendicular to the horizontal line drawn on the lower edge of the C7 vertebra. In the evaluation made by accepting C4 as the vertex, the cervial lordosis angle should be 25°-50°

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) 22 package program. Descriptive statistics are expressed as the mean and standard deviation for normally distributed continuous variables, and as number and percentage for categorical variables. Normally distributed continuous variables were analyzed using the "One-Way Analysis of Variance" between groups, while non-normally distributed continuous variables were compared between groups using the "Kruskal-Wallis H test". "Chi-square analysis" was used to compare categorical variables. In correlation analyses, if the data were normally distributed, the "Pearson correlation test" was preferred; if the data were not normally distributed, the "Spearman correlation test" was preferred. In the statistical analysis of the study, $p<0.05$ was considered significant. Correlation analyses were classified according to the coefficient (r) values as follows: 0-0.25 indicates a weak correlation, 0.25-0.50 indicates a moderate correlation, 0.50-0.75 indicates a strong correlation, and 0.75-1.00 indicates a very strong correlation.

Sample Size

To determine the appropriate sample size for this study, a power analysis was conducted using the G*Power 3.1.7 program (Kiel University, Kiel, Germany). Based on the study by Ishikawa et al. (17) which examined the relationships between spinal

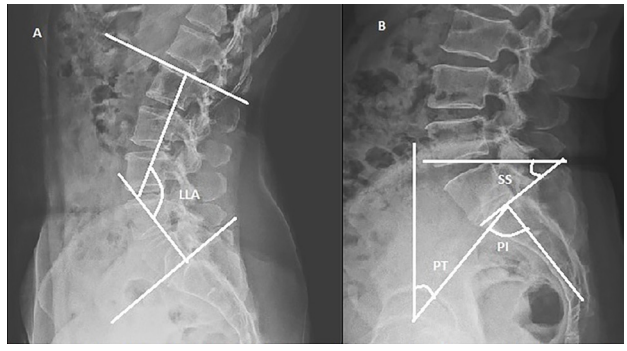

Figure 2. (A) Lumbar lordosis angle (LLA): The angle between the horizontal line drawn on the upper egde of the L1 vertebra and the lines drawn perpendicular to the horizontal line drawn on the upped egde of the S1 vertebra. Normal lumbar lordosis is between 40° and 70°, considering the L3-4 distance as the peak. (B) Saceal slope (SS) angle: The angle between the line drawn on the upper edge of the S1 vertebra and the horizontal line drawn from the midpoint of the upper edge of the S1 vertebra. (B) Pelvic tilt (PT) angle: The angle between the vertical line passing through the femoral head axis and the line connecting the femoral head axis to the upper midpoint of the S1 verebra. (B) Pelvic incidence (PI) angle: The angle between the perpendicular line passing through the upper midpoint of the S1 vertebra and the line connecting the femoral head axis to this midpoint. (B) Sagittal classification of back type: Type I: Lumbar apex in the middle od L5, SS angle in the spine <35 degrees; Type II: Lumbar apex inferior to L4, SS <35 degrees; Type III: Lumbar apex in the middle of L4, 35 < SD <45 degreees; Type III AP (anteverted): PI <50° and SS >35°; Type IV: Lumbar apex at the base of L3, SS >45 degrees

mobility, sagittal alignment, quality of life, and fall risk, the LLA in extension was identified as a key parameter due to its significant association with fall risk (p=0.038). Using the reported means and standard deviations of lumbar lordosis angles in extension the effect size (Cohen's d=0.81) was calculated. For a two-tailed t-test with a 5% type I error (α=0.05) and 80% power (1-β=0.80), the required sample size was calculated to be 47 participants per group (total=94). To enhance the study's robustness and account for potential participant dropouts, a total of 126 individuals were enrolled in the study.

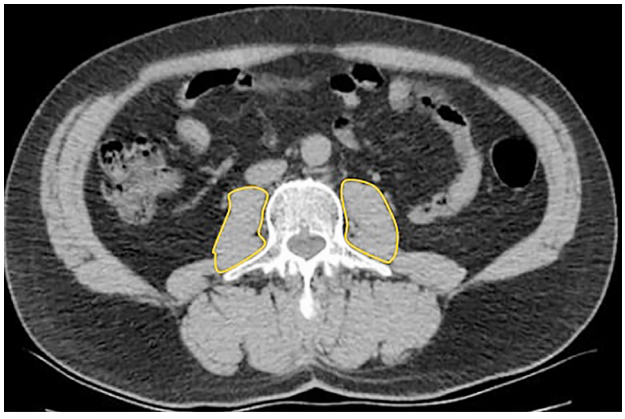

Figure 3. Psoas muscle index evaluation on lumbar computed tomography. The outer edge of the major psoas muscle was traced manually to assess the psoas cross-sectional area at the lumbar third vertebral level with the free hand region of interest. The sum of the left and right psoas cross-sectional area (cm^2) was divided by the square of the individual's height (m^2)

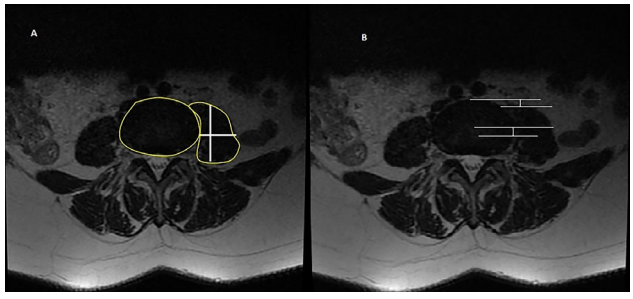

Figure 4. Anaysis of psoas muscle cross-sectional areas at L2-3, L3-4 and L4-5 intervertebral disc levels in lumber magnetic resonance imaging (A) Psoas muscle anteroposterior length/medial-lateral width raito and cross-sectional area (each measured cross-secitonal area is divided by the cross-sectional area of the intervertebral disc at the same level to minimize differences based on individual phyical characteristics and gender). (B) Evaluation of the position of the psoas muscle relative to the intervertebral disch in the axial plane. The measurement includes the verticla distance between the anterior edge of the psoas mucle and the anterior edge of the intervertebral disc, as weel as the vertical distance between the midpoints of the psoas muscle and the midpoints of the intervertebral disch. The distance is recorded ad positive (+) if the anterior edge or center of the psoas muscle is more anterior than the intervertebral disc, as negative (-) if it is further back

Results

Fall Risk and Demographic Data

Statistically significant differences were found between the fall risk groups regarding gender distribution and age. Post-hoc analyses showed a higher proportion of women in the medium-risk group compared to the high-risk group. Correlation analyses revealed a moderate negative correlation between age and Tinetti scores (Balance, Gait, and Total Scores) (r=-0.367, -0.324, and -0.366, respectively, and p<0.01). In addition, there was a moderate positive correlation between age and fall risk groups (r=0.392, p<0.01). There were no statistically significant differences between the fall risk groups in terms of weight, height, and BMI. All data are given in Table 1. Multivariate logistic regression analysis revealed that approximately 14.9% of the fall risk could be explained by demographic data. In these analyses, age was determined as a significant predictor of fall risk and was found to have a positive relationship; 11.1% of the fall risk could be explained by age alone (B=0.018, p=0.001).

Fall Risk and Spinal Alignment

SVA was statistically significantly different between the fall risk groups, with positive SVA being significantly more common in the moderate and high-risk groups compared to the low-risk group. Correlation analyses revealed a statistically significant weak positive correlation between SVA and Tinetti gait score (r=0.208, p=0.019), but no significant association with other Tinetti scores. Statistically significant differences were also found between the SSA and risk groups; the mean SSA was significantly lower in the high-risk group compared to the low-risk group. Furthermore, significant differences were observed between groups based on the Sagittal back type classification; Type II back type was more common in the high-risk group, while Type I back type was less common. A statistically significant association was found between the PTA and the fall risk groups, and post-hoc analyses revealed that this angle was significantly higher in the high-risk group compared to both the low-risk and moderate-risk groups. In correlation analyses, statistically significant but moderate negative correlations were found between the PTA and the Tinetti balance score, Tinetti gait score, and Tinetti total score (r=-0.332, -0.320, -0.308, respectively; p<0.01). In the assessment of spinopelvic (PI-LL) mismatch, no significant difference was observed between the groups in terms of mean PI-LL values. However, the distribution of spinopelvic mismatch levels between the fall-risk groups showed that the rate of high spinopelvic mismatch was greater in the high-risk group. Additionally, a statistically significant but weak negative correlation was found between the PI-LL Difference and the Tinetti total score (r=-0.126, p<0.01). All data are given in Table 2. Multivariate logistic regression analysis revealed that spine and pelvic measurement variables could explain 22.6% of the fall risk. In these analyses, PI-LL difference was determined to be a predictor of fall risk and showed a negative relationship; 4.4% of the fall risk can be explained by PI-LL Difference alone

Table 1. Relationship between fall risk groups and demographic data

	Total (n=126)	Low-risk fall group (n=42)	Medium-risk fall group (n=42)	High-risk fall group (n=42)	p-value
Gender					**0.014#**
Female (n/%)	105 (83.3%)	35 (83.3%)	40 (95.2%)	30 (71.4%)	
Male (n/%)	21 (16.7%)	7 (16.7%)	2 (4.8%)	12 (28.6%)	
Age (years) (mean ± SD)	59.98±13.59	55.26±11.72	58.38±13.57	66.31±13.24	**<0.001¥**
Height (m) (mean ± SD)	163.65±7.34	163.55±7.03	161.76±5.67	165.64±8.64	0.127¥
Weight (kg) (mean ± SD)	74.93±10.96	74.67±13.72	73.31±9.86	76.81±8.63	0.189¥
BMI (mean ± SD)	28.06±4.29	27.93±5.01	28.07±3.94	28.15±3.95	0.955¥
Normal ideal (18.5-24.9) (n/%)	34 (27%)	13 (31%)	12 (28.6%)	9 (21.4%)	0.844#
Overweight (25.0-29.9) (n/%)	57 (45.2%)	16 (38.1%)	19 (45.2%)	22 (52.4%)	
First degree obesity (30.0-34.9) (n/%)	27 (21.4%)	9 (21.4%)	9 (21.4%)	9 (21.4%)	
Second degree obesity (35.0-39.9) (n/%)	8 (6.3%)	4 (9.5%)	2 (4.8%)	2 (4.8%)	

Data presented as mean (±SD) or number (n/%) of patients. BMI: Body mass index, SD: Standard deviation, The p-value refers to the difference between the groups, p<0.05 statistically significant. #: Chi-square test, ¥: Kruskal-Wallis-H test

(B=-0.046, p=0.009). Similarly, the SSA explains 7.9% of the fall risk, with a significant negative association between increasing SSA and decreasing fall risk (B=-0.037, p=0.011). PTA explains 10.4% of the fall risk and shows a positive association; that is, as the PTA increases, the risk of falling also increases (B=0.028, p<0.001).

Fall Risk and Psoas Muscle Measurements at Various Levels on CT and MRI

A difference was found between the groups in the mean anteroposterior/mediolateral (AP/ML) values at the L4-5 level of the psoas muscle, and it was determined that this variable showed a statistically significant low positive correlation with the risk of falling (r=0.227). This value was highest in the high-risk fall group and lowest in the low-risk fall group. A significant difference was observed between the groups in the mean cross-sectional area (CSA) values at the L4-5 and L2-3 levels of the psoas muscle, while a borderline significant difference was found between the groups in the mean CSA at the L3-4 level. At all levels, the highest mean CSA values were found in the low-risk fall group, and the lowest mean CSA values in the moderate risk fall group. A statistically significant difference was found between the groups in terms of psoas muscle index (PMI), with the highest PMI value in the low-risk fall group and the lowest in the moderate risk fall group. At the L3-4 and L2-3 levels, a statistically significant moderate negative correlation was found between the groups for both the anterior margin gap and center gap (r=-0.293, -0.293, -0.339, -0.343). More negative Anterior Margin and Center Gap values were observed at these levels in the high risk fall group. A statistically significant difference was also found between the groups in the position of the psoas muscle at the L3-4 and L2-3 levels, with more negative positions detected in the moderate and high risk groups at both levels. All data are given in Table 3.

Multivariate logistic regression analysis revealed that variables at the L4-5 level explained 8.5% of the fall risk, though this result was borderline significant (p=0.056). Specifically, the mean AP/ML values at the L4-5 level had a statistically significant positive effect on fall risk, accounting for 5% of the risk, with an increase in AP/ML values leading to a higher fall risk (B=0.724, p=0.012). At the L3-4 level, variables explained 13.2% of the fall risk (p=0.004), with mean CSA values demonstrating a statistically significant negative effect, reducing the fall risk by 3.5% as CSA values increased (B=-0.062, p=0.036). Additionally, the position of the psoas muscle relative to the disc at L3-4 had a significant negative impact on fall risk, accounting for 5.5% of the risk, with a positive displacement in muscle position decreasing fall risk (B=-0.514, p=0.008). At the same level, the mean anterior margin gap (B=-0.052, p=0.002) and center gap (B=-0.047, p<0.001) also showed statistically significant negative effects on fall risk, explaining 7.4% and 9.6% of the risk, respectively. Meanwhile variables at the L2-3 level were found to explain 18.8% of the fall risk (p<0.001), with both the mean anterior margin gap (B=-0.421, p<0.001) and center gap (B=-0.414, p<0.001) having statistically significant negative effects, leading to a decreased fall risk as these values increased. Furthermore, the position of the psoas muscle relative to the disc at the L2-3 level had a statistically significant negative effect on fall risk, explaining 13.3% of the risk (B=-0.364, p=0.008).

The Relationship Between the Psoas Muscle and Sagittal Alignment Parameters, and Its Impact on Fall Risk

The relationship between the psoas muscle and sagittal alignment parameters, and its impact on fall risk our study evaluated the relationships between psoas muscle measurements at specific spinal segments and various spinal and pelvic alignment parameters. Significant differences and correlations were

Table 2. Relationship between fall risk groups and spinal alignment

	Total (n=126)	Low-risk fall group (n=42)	Medium-risk fall group (n=42)	High-risk fall group (n=42)	p-value
SVA					**0.016#**
Positive (n/%)	48 (38.1%)	9 (21.4%)	19 (45.2%)	20 (47.6%)	
Neutral (n/%)	49 (38.9%)	25 (59.5%)	13 (31%)	11 (26.2%)	
Negative (n/%)	29 (23%)	8 (19.1%)	10 (23.8%)	11 (26.2%)	
TKA					
Mean ± SD	39.13±12.23	37.33±8.15	40.89±13.23	39.16±14.44	0.413*
Decreased (n/%)	8 (6.3%)	1 (2.4%)	4 (9.5%)	3 (7.1%)	0.063#
Normal (n/%)	98 (77.8%)	39 (92.9%)	28 (66.7%)	31 (78.3%)	
Increased (n/%)	20 (15.9%)	2 (4.8%)	10 (23.8%)	8 (19%)	
LLA					
Mean ± SD	48.72±13.36	48.76±13.19	51.29±12.93	46.11±13.78	0.092¥
Decreased (n/%)	32 (25.4)	11 (26.2%)	7 (16.7%)	14 (33.3%)	0.459#
Normal (n/%)	71 (56.3%)	22 (52.4%)	27 (64.3%)	22 (52.4%)	
Increased (n/%)	23 (18.3%)	9 (21.4%)	8 (19%)	6 (14.3 %)	
CLA					
Mean ± SD	26.07±12.56	22.86±12.14	27.87±13.06	27.49±12.12	0.125*
Decreased (n/%)	50 (39.7%)	20 (47.6%)	14 (33.3%)	16 (38.1%)	0.485#
Normal (n/%)	72 (57.1%)	22 (52.4%)	26 (61.9%)	24 (57.1%)	
Increased (n/%)	4 (3.2%)	0 (0%)	2 (4.8%)	2 (4.8%)	
PI					
Mean ± SD	56.77±11.31	56.19±12.51	55.95±12.03	58.16±9.29	0.621*
Decreased (n/%)	25 (19.8%)	7 (16.7%)	12 (28.6%)	6 (14.3%)	0.086#
Normal (n/%)	27 (21.4%)	14 (33.3%)	5 (11.9%)	8 (19%)	
Increased (n/%)	74 58.7%)	21 (50%)	25 (59.5%)	28 (66.7%)	
SSA					
Mean ± SD	32.83±9.41	34.94±9.35	33.61±8.55	29.93±9.76	**0.035¥**
Decreased (n/%)	76 (60.3%)	24 (57.1%)	22 (52.4%)	30 (71.4%)	**0.040#**
Normal (n/%)	35 (27.8%)	10 (23.8%)	17 (40.5%)	8 (19%)	
Increased (n/%)	15 (11.9%)	8 (19%)	3 (7.1%)	4 (9.5%)	
Sagittal classification of back type					
Type I	13 (10.3%)	7 (16.7%)	5 (11.9%)	1 (2.4%)	**<0.01#**
Type II	62 (49.2%)	17 (40.5%)	15 (35.7%)	30 (71.4%)	
Type III	30 (23.8%)	9 (21.4%)	14 (33.3%)	7 (16.7%)	
Type IIIAP	6 (4.8%)	1 (2.4%)	5 (11.9%)	0 (0%)	
Type IV	15 (11.9%)	8 (19%)	3 (7.1%)	4 (9.5%)	
Pelvic tilt angle					
Mean ± SD	24.49±9.52	21.67±8.65	22.62±8.91	29.17±9.36	**0.01¥**
Decreased (n/%)	9 (7.1%)	4 (9.5%)	5 (11.9%)	0 (0%)	**<0.01#**
Normal (n/%)	30 (23.8%)	16 (38.1%)	8 (19%)	6 (14.3%)	
Increased (n/%)	87 (69.1%)	22 (52.4%)	29 (69.1%)	36 (85.7%)	
Spinopelvic (PI-LL) mismatch					
Mean ± SD	8.04±13.14	7.42±12.02	4.66±9.94	12.05±15.95	**0.066¥**
Low-normal mismatch (n/%)	76 (60.3%)	28 (66.7%)	31 (73.8%)	17 (40.5%)	**<0.01#**
Medium mismatch (n/%)	26 (20.6%)	6 (14.3%)	9 (21.4%)	11 (26.2%)	
High mismatch (n/%)	24 (19.1%)	8 (19%)	2 (4.8%)	14 (33.3%)	

Data presented as mean (±SD) or number (n/%) of patients. CLA: Cervical lordosis angle, LLA: Lumbar lordosis angle, PI: Pelvic incidence, SSA: Sacral slope angle, SVA: Sagittal vertical axis, TKA: Thoracic kyphosis angle. The p-value refers to the difference between the groups, p<0.05 statistically significant. *: ANOVA, #: Chi-square test, ¥: Kruskal-Wallis-H test

found between the psoas muscle and TKA, PI, PTA, SSA, and PI-LL mismatch. A positive correlation was identified between the AP/ML ratio of the psoas muscle at the L4/5 level and the TKA (r=0.178, p=0.046). Conversely, a negative correlation was found between TKA and the anterior gap of the psoas muscle at the L3/4 and L2/3 levels (p=0.045, 0.011; r=-0.179, -0.226, respectively). A statistically significant positive correlation was observed between the CSA of the psoas muscle at the L3/4 level and the PI (r=0.180, p=0.044). When analyzed across different PI groups, the AP/ML ratio at the L2/3 level showed a significant difference between groups (p<0.01), with individuals with a higher PI angle exhibiting a greater AP/ML ratio at this level. Significant positive correlations were found between PTA and the CSA of the psoas muscle at the L3/4 and L4/5 levels (r=0.197, 0.242; p=0.027, <0.01). Additionally, a negative correlation was observed between PTA and the anterior gap of the psoas at the L2/3 and L3/4 levels (r=-0.183, -0.194; p=0.040, 0.030). Significant differences were noted between PTA groups concerning the CSA of the psoas muscle at the L4/5 and L3/4 levels (p=0.012, 0.037). Specifically, individuals with a high PTA showed an increase in psoas muscle CSA at these levels. Across different SSA groups, significant differences were observed in the anterior gap at the L4/5 level (p=0.043), with individuals with a higher SSA showing a greater anterior gap at this level. The CSA of the psoas muscle at the L3/4 and L4/5 levels and the PMI were significantly positively correlated with the PI-LL mismatch (r=0.199, 0.220, 0.182; p=0.026, 0.013, 0.041, respectively). In addition, significant differences in psoas muscle CSA at the L2/3

Table 3. Relationship between fall risk groups and psoas muscle measurements at various levels on CT and MRI

	Total (n=126)	Low-risk fall group (n=42)	Medium-risk fall group (n=42)	High-risk fall group (n=42)	p-value
AP/ML ratio (mm)					
L4-5 Level (mean ± SD)	1.18±0.25	1.13±0.20	1.14±0,26	1.27±0.27	**0.015¥**
L3-4 Level (mean ± SD)	1.73±0.45	1.81±0.51	1.70±0.44	1.68±0.40	0.486¥
L2-3 Level (mean ± SD)	2.51±0.62	2.65±0.74	2.37±0.53	2.51±0.55	0.323*
CSA (cm²)					
L4-5 Level (mean ± SD)	6.45±3.78	7.82±4.59	5.26±2.77	6.26±3.36	**<0.01¥**
L3-4 Level (mean ± SD)	3.59±2.49	4.51±3.32	2.89±1.53	3.38±2.02	**0.060¥**
L2-3 Level (mean ± SD)	1.521.17	1.91±1.59	1.19±0.73	1.47±0.89	**<0.01¥**
PMI at the L3 vertebra level (cm²/m²)					
Mean ± SD (min-max)	4.07±3.27	5.044.32	2.98±1.60	4.19±3.03	**0.041¥**
Anterior margin gap (mm)					
L4-5 Level (mean ± SD)	-0.06±6,95	-1.88±5.04	-0.89±6.48	-0.34±7.54	0.800¥
L3-4 Level (mean ± SD)	-3.47±4.28	1.06±6.82	-3.84±3.39	-4.70±3.84	**<0.01¥**
L2-3 Level (mean ± SD)	-3.19±2.71	-1.65±3.66	-3.48±1.69	-4.44±1.38	**0.001¥**
Center gap (mm)					
L4-5 Level (mean ± SD)	-0.23±6.77	0.90±6.53	-1.15±6.48	-0.44±7.27	0.546¥
L3-4 Level (mean ± SD)	-3.77±5.41	-1.48±6.15	-4.283.96	-5.575.17	**<0.01¥**
L2-3 Level (mean ± SD)	-2.20±1.77	-1.23±2.44	-2.35±1.07	-3.02±0.89	**<0.001¥**
Position of the psoas muscle					
L4-5 Level (n/%)					0.211#
Negative	64 (50.8%)	17 (40.5%)	25 (59.5%)	22 (52.4%)	
Positive	62 (49.2%)	25 (59.5%)	17 (40.5%)	20 (47.6%)	
L3-4 Level (n/%)					**0.010#**
Negative	105 (83.3%)	29 (69%)	38 (90.5%)	38 (90.5%)	
Positive	21 (16.7%)	13 (31%)	4 (9.5%)	4 (9.5%)	
L2-3 Level (n/%)					**<0.001#**
Negative	114 (90.5%)	31 (73.8%)	41 (97.6%)	42 (100%)	
Positive	12 (9.5%)	11 (26.2%)	1 (2.4%)	0 (0%)	

Data presented as mean (±SD) or number (n/%) of patients. AP: Anterior-posterior, CSA: Cross-sectional area, CT: Computed tomography, L: Lumbar, ML: Medial lateral, MRI: Magnetic resonance imaging, PMI: Psoas muscle index, SD: Standard deviation, The p-value refers to the difference between the groups, p<0.05 statistically significant. #: Chi-square test, ¥: Kruskal-Wallis-H test

level were observed among PI-LL mismatch groups (p=0.041), with individuals with a high spinopelvic mismatch showing a decrease in psoas muscle CSA at this level.

Discussion

It is essential to diagnose fall risk and assess the associated risk factors to prevent falls. Research has demonstrated that sagittal spinal misalignment and sarcopenia are linked to an increased risk of falls in older adults, aiding in the identification of individuals at high risk (8,9). Therefore, in our study, we examined the relationship between sagittal alignment, psoas muscle cross-sectional analysis, and fall risk across groups classified by the Tinetti balance and gait questionnaire.

Fall Risk and Demographic Data

Studies have reported that risk factors for falls in older adults include advanced age, female gender, physical frailty, muscle weakness, unsteady gait and balance, impaired cognition, and depressive symptoms (18,19). Consistent with this, our study found statistically significant differences in gender distribution and age among different fall risk groups. Specifically, a higher proportion of females was observed in the medium-risk group, while the high-risk group had a greater proportion of males. Additionally, a significant negative correlation was found between age and Tinetti scores (balance, gait, and total), alongside a positive correlation between age and fall risk, indicating that as age increases, physical performance decreases, leading to higher fall risk. Regression analyses further underscored the importance of age in predicting fall risk, suggesting that age alone accounts for a significant portion of the risk. This highlights the need to prioritize age as a key factor in fall prevention strategies. Additionally, one study reported a positive correlation between age and the risk of falls and fracture incidence but found no significant differences in age, gender, body weight, or height between fallers and non-fallers (17). Similarly, in our study, no significant differences were observed among the fall risk groups in terms of weight, height, and BMI.

Fall Risk and Spinal Alignment

Mechanical limitations in lumbar extension, often due to back muscle weakness and/or vertebral deformities, can result in a rigid spine, decreased lumbar lordosis, and increased thoracic or thoracolumbar kyphosis. These spinal alterations are associated with a greater risk of falls, as they lead to an increased spinal and whole-body curvature, an anterior shift in the center of gravity, postural instability, and restricted horizontal gaze. To compensate for these changes and restore postural stability, compensatory mechanisms such as posterior pelvic tilt, hip extension, and knee flexion are adopted. However, the resulting knee-flexed posture demands increased energy expenditure from the lower extremity muscles during standing and walking, leading to fatigue and, consequently, a higher risk of falls. Furthermore, spinal misalignment reduces spinal mobility, limiting the body's ability to respond effectively to postural sway caused by external forces, further contributing to fall risk (17,20,21). The following radiological parameters have been identified in studies as significant risk factors for falls or fractures: decreased TKA (22), decreased LLA (20-23), decreased lumbar range of motion, decreased SSA, increased TKA/LLA ratios, increased PI and PTA (24), and increased SVA.

Our study examined the distribution of different spine and pelvic parameters among fall risk groups and evaluated the possible relationships between these parameters and fall risk. The findings show that spine and pelvic alignment features exhibit certain patterns, especially in high fall risk groups, and these patterns may be associated with balance and gait dysfunctions.

SVA is an important parameter reflecting global spinal sagittal balance. In a study, it has shown that individuals who experience falls have poorer body balance, spinal sagittal alignment, muscle strength, and walking speed compared to those who do not fall (23). Studies have shown that in patients with osteoporotic vertebral compression fractures, the center of gravity of the body moves forward due to the compression of the fractured vertebral body and the increase in kyphosis deformity. Consequently, it was found that the SVA in these patients is higher than in healthy individuals (25,26). In our study, SVA was significantly different among fall-risk groups, with a higher prevalence of positive SVA in the moderate and high-risk groups compared to the low-risk group. This suggests that individuals at higher risk of falling may exhibit more pronounced postural deviations, potentially contributing to an increased risk of falls. Regarding the relationship between SVA and the Tinetti Gait Score, there was a statistically significant positive correlation, indicating that walking performance tends to decrease as SVA increases. This finding underscores the importance of spinal alignment in understanding the risk of falls associated with walking performance.

In their study, Imagama et al. (23) found a negative correlation between SSA and walking speed. They also indicated that optimal spinal sagittal alignment can enhance body balance and reduce the risk of falls by increasing muscle strength and improving 10-meter walking speed (23). Similarly, in our study, it was found statistically significant differences in SSA across fall-risk groups, with the high-risk group exhibiting a significantly lower mean SSA compared to the low-risk group. This suggests that individuals in the high-risk category may have more pronounced spinal misalignments, which could contribute to their increased risk of falling.

Maintaining balanced spinal sagittal alignment is essential for preventing falls, given its strong connection to back muscle strength, body stability, and clear forward vision (23,24). The sagittal back type classification used in evaluating normal sagittal alignment was determined according to SSA and PI, and five subtypes were defined (13). Upon reviewing the literature, we did not find any studies evaluating the relationship between sagittal back types and fall risk. In our study, significant differences were observed among the fall-risk groups based on the Sagittal back type classification. Specifically, Type II back type

was more prevalent in the high-risk group, while Type I back type was less common. These findings suggest that variations in sagittal back types may be associated with differing fall risk.

Lumbosacral alignment, particularly LLA, significantly impacts the quality of life, sagittal balance, and fall risk in the geriatric population (27,28). Studies indicate that individuals with a history of falls exhibit reduced LLA compared to those without, and a loss of lumbar lordosis is linked to increased fall risk (17,21). For optimal spinal balance, the PTA should be less than half of the PI, while the SSA should exceed half of the PI (29). Additionally, the spinopelvic mismatch, defined as the difference between PI and LL, indicates normal alignment when the difference is less than 10 degrees; a difference greater than 10 degrees suggests malalignment or mismatch (30). Changes in pelvic position play a crucial role in compensating for spinal imbalance. The occurrence of osteoporotic vertebral compression fractures leads to a decrease in lumbar lordosis and an increase in C7-SVA, resulting in forward trunk lean. To maintain spinal balance, compensatory posterior pelvic rotation occurs, accompanied by corresponding adjustments in the hip and knee joints. Sagittal imbalance arises when spinal kyphosis and hip degeneration in elderly patients exceed the capacity of these compensatory mechanisms (31,32). In patients with sagittal imbalance, loss of LLA is a key factor that triggers the compensation mechanism, while PI reflects the compensatory capacity to maintain overall spinal balance and reduce forward trunk bending. To achieve balance between the spine and pelvis, thoracic kyphosis is reduced, and pelvic tilt is increased, which helps to pull the trunk backward and align the center of gravity with the midline (33,34).

In our study, statistically significant but moderate negative relationships were found between PTA and various measures of balance and gait, indicating that increased PTA is associated with decreased performance in these parameters. Regarding spinopelvic mismatch, no significant differences were found in mean values between the groups. However, the distribution of spinopelvic mismatch levels across fall-risk groups demonstrated a higher prevalence of spinopelvic mismatch in those at greater risk for falls. A weak negative correlation was also identified between spinopelvic alignment and overall functional scores, suggesting that misalignment may contribute to impaired balance and gait. Multivariate logistic regression analysis revealed that spinal and pelvic alignment measurements could account for a portion of the overall fall risk. Specifically, PI-LL difference emerged as a predictor of fall risk, with greater mismatch linked to a higher risk of falling. Similarly, the SSA exhibited a negative association with fall risk, where improved sacral alignment was linked to a lower likelihood of falls. Conversely, increased PTA was positively associated with fall risk, implying that greater pelvic tilt contributes to a higher likelihood of falls. Moreover, significant differences were observed between fall-risk groups in terms of spinal and pelvic alignment characteristics, including sagittal classification, pelvic tilt, and spinopelvic alignment. These results suggest that pelvic and spinal alignment variables, particularly PI-LL difference, SSA, and PTA, are critical factors in predicting fall risk. Additionally, the findings highlight a strong relationship between these alignment parameters and dysfunctions in balance and gait, emphasizing the interrelated nature of posture and fall risk.

Fall Risk and Psoas Muscle Measurements at Various Levels on CT and MRI

Sarcopenia is a progressive and systemic skeletal muscle disorder characterized by a decline in muscle mass and function (35). The European Working Group on Sarcopenia in Older People advocates the use of advanced imaging techniques, such as CT and MRI, as the preferred modalities for assessing muscle mass and fat infiltration associated with sarcopenia (35). A study has stated that measurements at a single anatomic site, such as the extremities or abdominal muscles, can provide a reasonably accurate measure of whole-body muscle mass in the assessment of muscle mass (36). Appendicular muscle mass, which includes limb muscles, is strongly influenced by an individual's activity level. In contrast, the measurement of psoas and abdominal muscle mass via CT or MRI has gained prominence in sarcopenia assessment, as these muscle groups are considered less dependent on physical activity levels (35-37). In addition, the CSA of the right and left psoas muscle, particularly at the mid-level of the L3 vertebra, when normalized to the individual's height squared, has been shown to correlate strongly with total skeletal muscle volume (18).

Studies have reported that sarcopenia is associated with functional impairment, and physical disability, and its negative effects on balance and muscle strength increase the risk of falls and, consequently, the likelihood of complications related to osteoporotic fractures (38,39). In addition, several studies have reported an association between spinal sagittal malalignment and decreased muscle mass in patients with spinal conditions, suggesting that reduced muscle mass may contribute to the underlying mechanism of spinal sagittal malalignment in patients without vertebral fractures (39,40). However, the decrease in appendicular skeletal muscle mass index was found to not affect sagittal spinal malalignment (39,40). Miyakoshi et al. (41) evaluated the factors contributing to spinal mobility in postmenopausal osteoporotic patients. They found that age, lumbar kyphosis angle, back extensor strength, lumbar paravertebral muscle thickness measured using ultrasound, and the number of vertebral fractures were significantly associated with total spinal range of motion. One study reported that PT is significantly correlated with the lumbar paraspinal muscle CSA (42), while another study found that the paraspinal functional cross-sectional area—calculated by subtracting the fat tissue area from the CSA on magnetic resonance imaging—was lower in the sagittal imbalance group (43).

In literature, PMI values have been standardized in certain studies based on age and gender (37,44). However, in our study, the psoas muscle was evaluated across different age groups within fall risk categories, and as such, group differences were assessed instead of applying standardized values for specific age or gender

cohorts. The low-risk group was generally found to have lower AP/ML ratios, larger CSA values, and fewer negative gaps; while the high risk group had higher AP/ML ratios, smaller CSA values at certain levels, and more negative gaps. These findings suggest that certain anatomical and muscle mass characteristics may be associated with the risk of falling. These findings show that the characteristics of the psoas muscle at different anatomical levels are significantly associated with the risk of falling. In particular, variables such as the AP/ML ratio of the psoas muscle at the L4-5 level stand out as factors that increase the risk of falling. At the same time, the psoas muscle characteristics at the L3-4 and L2-3 levels, especially CSA and gap measurements, were determined as factors that reduce the risk of falling. These results suggest that the anatomical structure and muscle mass of the psoas muscle may have a significant effect on the risk of falling in individuals. Such findings suggest that measurements of the psoas muscle can be used in the assessment and management of the risk of falling in elderly individuals. At the same time, these data may help identify potential areas of intervention to develop strategies to reduce the risk of falling.

The Relationship Between the Psoas Muscle and Sagittal Alignment Parameters, and Its Impact on Fall Risk

Our findings highlight that the size, shape, and positioning of the psoas muscle significantly influence thoracic curvature, pelvic orientation, and overall sagittal balance, which are essential for postural stability. A positive correlation was observed between the AP/ML ratio of the psoas muscle at the L4/5 level and TKA. This finding suggests that structural adaptations at this level, possibly to enhance lateral stability, are associated with a more pronounced thoracic kyphosis. In contrast, a negative correlation between TKA and the anterior gap of the psoas at the L2/3 and L3/4 levels indicates that increased anterior muscle spacing may counteract excessive thoracic curvature. The CSA of the psoas muscle at the L3/4 level was positively correlated with PI, indicating that larger psoas muscles may influence pelvic orientation and the spine-pelvis relationship. Furthermore, individuals with higher PI also exhibited a greater AP/ML ratio, suggesting a shift in postural strategies driven by altered pelvic alignment. Our results demonstrate that individuals with a higher SSA tend to have a larger anterior gap at the L4/5 level, suggesting that changes in SSA affect lumbar segment positioning and spinal mechanics. A positive correlation was found between PTA and the CSA of the psoas at both L3/4 and L4/5 levels, indicating that increased muscle volume may serve as a compensatory mechanism to support altered pelvic tilt. Conversely, a negative correlation between PTA and the anterior gap at the L2/3 and L3/4 levels suggests that greater anterior spacing could reduce pelvic tilt, promoting a more balanced posture. Our study found a positive correlation between the CSA of the psoas at L3/4 and L4/5 levels and the PI-LL mismatch, indicating that larger muscle size may contribute to spinopelvic imbalance. Additionally, individuals with significant spinopelvic mismatch exhibited reduced psoas CSA at the L2/3 level, possibly reflecting muscle atrophy or functional decline due to chronic misalignment. This reduction may impair core stability and increase the risk of falls. Our findings, similar the literature (39-43), demonstrate that specific structural characteristics of the psoas muscle are significantly associated with sagittal alignment parameters, including TKA, PI, PTA, SSA, and the PI-LL mismatch, and emphasize the importance of the psoas muscle in regulating sagittal alignment and postural balance.

Study Limitations

Our study has some limitations. Since participants were assessed solely for fall risk, their fall history was not questioned. Additionally, lower extremity alignment disorders secondary to sagittal alignment disorders of the spine were not evaluated. However, the strengths of our study include the assessment of fall risk in young adults and the consideration of preventable factors that increase fall risk, such as spinal alignment disorders and psoas muscle measurements.

Conclusion

Our findings suggest that the presence of sarcopenia and sagittal malalignment contribute significantly to fall risk. Additionally, the influence of the psoas muscle on spinopelvic alignment highlights its crucial role in maintaining postural balance and underscores the need for considering muscular factors in evaluating fall risk and sagittal imbalance. Evaluating these variables could provide crucial insights for fall risk prediction and the development of preventive strategies in clinical practice. Treatment efforts should focus on improving muscle mass, strength, and overall physical condition. Screening patients for spinal malalignment and sarcopenia, followed by the implementation of functional exercise therapy aimed at restoring spinal mobility and enhancing muscular strength, may help reduce the incidence of falls.

Ethics

Ethics Committee Approval: Approval for the study was obtained from the Local Ethical Committee (Kütahya Health Sciences University Non-Interventional Research Ethics Committee, no. 2023/05-07, dated: April 25, 2023).

Informed Consent: All individuals included in the study signed an informed consent form, stating that they participated in the study voluntarily.

Footnotes

Authorship Contributions

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

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Sonographic Degree of Arterial Stiffness and Inflammatory Markers in Postmenopausal Osteoporosis

Postmenopozal Osteoporozda Arteriyel Sertlik ve Enflamatuvar Belirteçler

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Abstract

Objective: Arterial stiffness is used to diagnose and follow-up on many diseases. Although a specific interaction exists between osteoporosis and atherosclerosis, the correlation between arterial stiffness and osteoporosis has yet to be clearly established, and previous findings have been inconsistent. In this study, we aimed to determine whether a correlation exists between laboratory values employed in the diagnosis and follow-up of osteoporosis and arterial stiffness parameters.
Materials and Methods: The cases were categorized as osteopenia, osteoporosis and control groups according to dual X-ray absorbsiometry findings. Arterial stiffness parameters (compliance, diastolic wall stress, elastic modulus, and distensibility) were assessed based on sonographic findings (intima-media thickness, systolic diameter, and diastolic diameter) for 108 postmenopausal women (46 with osteopenia, 38 with osteoporosis, and 24 controls). Laboratory findings employed in the diagnosis and follow-up of osteoporosis and inflammatory indicators were recorded. The groups were compared based on these parameters.
Results: The arterial stiffness parameters of intima-media thickness and compliance were significantly different between the patient and control groups (p=0.003 and p=0.034, respectively).
Conclusion: The incidence of arterial stiffness increased in patients with osteoporosis, as observed using ultrasonography-an easily accessible diagnostic tool. Inflammatory indicators increased in both osteoporosis and arterial stiffness cases.
Keywords: Osteoporosis, arterial stiffness, inflammation

Öz

Amaç: Arteriyel sertlik birçok hastalığın teşhisi ve takibinde kullanılır. Osteoporoz ve ateroskleroz arasında belirli bir etkileşim olmasına rağmen, arteriyel sertlik ile osteoporoz arasındaki korelasyon henüz net olarak belirlenmemiştir ve önceki bulgular değişkendir. Bu çalışmada, osteoporozun teşhisi ve takibinde kullanılan laboratuvar değerleri ile arteriyel sertlik parametreleri arasında bir korelasyon olup olmadığını belirlemeyi amaçladık.
Gereç ve Yöntem: Olgular, dual X-ray absorbsiometri bulgularına göre osteopeni, osteoporoz ve kontrol grupları olarak kategorize edildi. Arteriyel sertlik parametreleri (uyum, diyastolik duvar gerilimi, elastik modül ve gerilebilirlik), 108 postmenopozal kadın (46 osteopeni, 38 osteoporoz ve 24 kontrol) için sonografik bulgulara (intima-media kalınlığı, sistolik çap ve diyastolik çap) dayanarak değerlendirildi. Osteoporozun teşhisi ve takibinde kullanılan laboratuvar bulguları ve enflamatuvar göstergeler kaydedildi. Gruplar bu parametrelere göre karşılaştırıldı.
Bulgular: İntima-media kalınlığı ve uyumun arteriyel sertlik parametreleri hasta ve kontrol grupları arasında önemli ölçüde farklıydı (sırasıyla p=0,003 ve p=0,034).
Sonuç: Osteoporozlu hastalarda arteriyel sertliğin görülme sıklığı, kolayca erişilebilen bir tanı aracı olan ultrasonografi kullanılarak gözlemlendiği gibi arttı. Hem osteoporoz hem de arteriyel sertlik olgularında enflamatuvar göstergeler artış gösterdi.
Anahtar kelimeler: Osteoporoz, arteriyel sertlik, enflamasyon

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Introduction

Osteoporosis is characterized by low bone mineral density and is a leading determinant of cardiovascular mortality, especially in postmenopausal women (1). Osteoporosis and atherosclerosis are the most common diseases that affect postmenopausal women. A certain degree of interaction exists between osteoporosis and vascular sclerosis; however, the underlying mechanisms remain unknown (2).

Arterial stiffness (AS) is an index of subclinical atherosclerosis. It is a dynamic characteristic, contingent upon the function and structure of the major arteries. Its clinical significance as a primary predictor of cardiovascular diseases has been well established in older adults and in various clinical conditions (rheumatoid arthritis, osteoarthritis, diabetes mellitus, vasculitis and hypertension) (3-5).

AS defines the viscoelastic properties of the arterial wall. The elasticity of large and medium arteries is critical for maintaining cardiovascular health. A decrease in flow pulsatility, associated with the elasticity of these arteries, ensures constant flow from the heart at the capillary level, maintaining steady perfusion in vital organs (6). A decrease in elasticity leads to a similar outcome at the periphery. However, it can also induce left ventricular hypertrophy through a decrease in pulse wave reflection (7). AS, which was emphasized as a pathological process in previous studies, develops against elasticity (8). Although a specific interaction exists between osteoporosis and atherosclerosis, the correlation between AS and osteoporosis has yet to be clearly established, and previous findings have been inconsistent. Pulse wave velocity (PWV) measurements have been used to demonstrate this correlation in previous studies (9,10).

Additionally, inflammatory processes have been described as risk factors for atherosclerosis and osteoporosis (11). A systematic review demonstrated the role of inflammation in the association between cardiovascular disease and osteoporosis (12). In addition to the correlation between osteoporosis and inflammatory markers, AS is associated with pro-inflammatory cytokines (13).

In the present study, we aimed to evaluate the correlations between the parameters of compliance, distensibility, diastolic wall stress and elastic modulus calculated using formulas based on sonographic carotid intima-media thickness (cIMT) and osteoporosis and inflammatory laboratory markers in postmenopausal osteoporosis patients.

Materials and Methods

Ethical Approval

This study was approved by the Medical Faculty Local Ethics Committee of a Kahramanmaraş Sütçü İmam University (2018/13; decision no: 14). This study was conducted in accordance with the principles outlined in the Declaration of Helsinki. Informed consent was obtained from all patients prior to the study.

Study Design

A total of 108 postmenopausal women aged 45-70 years who applied to the physical therapy and rehabilitation clinic with complaints of back pain, shortening of height, general body pain and posture disorder were included in the study. All women were experiencing natural menopause. The cases were categorized as osteopenia, osteoporosis and control groups according to dual X-ray absorbsiometry findings. All patients underwent ultrasonography performed by an experienced radiologist using the same device. The group findings were analyzed.

Osteopenia and Osteoporosis Diagnosis

Bone mineral density was measured with Hologic QDR 4500 device (Bedford, MA). The measurements were conducted anteroposterior to the lumbar vertebrae (L1-L4) and proximal to the femur. The findings were categorized based on World Health Organization criteria into the following three groups (14): Group 1 (normal control group): T-scores >-1 standard deviation, n=24; Group 2 (osteopenia group): T-scores range from -1 and -2.5 standard deviation, n=46; and Group 3 (osteoporosis group): T-scores <-2.5 standard deviation, n=38.

Exclusion Criteria

Patients with osteoporosis other than postmenopausal osteoporosis and those with concomitant diseases (diabetes mellitus, hypertension, metabolic disease, blood disease, acute/chronic infection, or inflammatory disease) were excluded. In addition, the study did not include patients receiving antiresorptive or bone-building drugs or vitamin D supplements. The control group cases had similar characteristics to the osteoporosis and osteopenia cases. In terms of the homogeneity of the control group, those with cardiovascular/hematological diseases, those with rheumatological diagnoses, and those with a history of bone metabolism disorders were not included in the study.

Carotid Doppler Measurement

The procedures were performed with women placed in the supine position. A high-resolution ultrasonography system (Aplio 400™, Toshiba Medical Systems Corporation, Tochigi, Japan) and broadband linear probe were applied. Blood vessel IMT and diastolic (DD) and systolic (SD) lumen diameters were measured after the probe was inserted 2 cm anterior to the bifurcation of the left carotid artery. Screen magnification was performed to improve accuracy in the B-mode IMT measurement. Measurements were conducted after at least three similar waveforms were observed without artifacts in SD and DD measurements of the M-mode images. Pulse pressure (systolic pressure, diastolic pressure, ΔP) was measured with an automatic sphygmomanometer (OCR Vitagnost 2015, MARS, Taiwan). The AS parameters of the vessel were calculated using the following formulas (15).

- Cross-sectional compliance = (π.[SD2-DD2])/(4.ΔP)
- Cross-sectional distensibility= (SD2-DD2)/(DD2.ΔP)
- Diastolic wall stress = (DD/[2.IMT]).([systolic pressure+SD]/2)
- Elastic modulus = (3/[1+{cross-sectional area of lumen/cross-sectional area of wall}])/cross-sectional distensibility.

Statistical Analysis

Values are evaluated as mean + standard deviation. Analysis of variance was applied for group comparisons. Tukey's honestly significant difference was employed for intragroup comparisons. Beta coefficients with a 95% confidence interval were used in the analyses. Statistical tests were conducted using Statistical Package for Social Sciences (version 22.0; IBM Statistics for Windows version 17, IBM Corporation, Armonk, NY), and the significance level was set at p<0.05.

Results

No statistically significant difference was observed between the control group cases and the osteoporosis and osteopenia cases in terms of age, body mass index (BMI), systolic and diastolic blood pressure values (Table 1).

BMI and mean age of the cases are presented in Table 1. Vitamin D levels were significantly lower in the osteoporosis group than in the control group (p=0.029). Low-density lipoprotein cholesterol levels were also lower in the osteoporosis group than in the control group (p=0.025). Data for other biochemical parameters are presented in Table 2.

Platelet lymphocyte ratio (PLR) and neutrophil to lymphocyte ratio (NLR) were significantly higher in the osteoporosis group than in the control group (p=0.007 and p=0.016, respectively). The comparison of inflammatory values between the groups is presented in Table 3. The women were categorized based on weight as follows: Normal weight (group 1, n=63; BMI ≤29.9 kg/m^2) and obese (group 2, n=45; BMI ≥30 kg/m^2). The correlation between BMI and vascular morphology indicators was used to analyze between-group differences. Statistically significant differences were observed between the groups based on cIMT (p=0.024, p=0.150, p=0.143, and p=0.273, respectively; Table 4). Analysis of vascular morphology based on age revealed that vascular morphological properties were negatively affected by advanced age, especially in the osteoporosis group (all p<0.01). Although vascular morphology was negatively affected by age in the control group, no statistical difference was observed (all p>0.05; Table 5). A statistically negative correlation was observed for NLR and all AS parameters (all p<0.01).

Evaluation of factors that affected vascular morphological parameters with correlation analysis revealed a positive correlation between cIMT and osteoporosis (r=0.316, p<0.001) and increase in BMI (r=0.329, p<0.001) and NLR (r=0.282, p<0.003). However, a negative correlation was observed between cIMT and lymphocyte ratio (r=-0.264, p<0.006; Table 5).

Table 1. Baseline characteristics of the study participants

Characteristic	Control (n=24)	Osteopenia (n=46)	Osteoporosis (n=38)	p-value
Age (years)	55.75±6.63	60.04±8.65	60.50±8.04	0.056
BMI (kg/m^2)	32.52±3.27	30.90±4.81	29.66±4.26	0.043
SBP (mmHg)	123.75±16.10	126.95±21.01	125.3±24.59	0.827
DBP (mmHg)	77.50±4.42	77.60±10.04	79.47±11.31	0.619

BMI: Body mass index, SBP: Systolic blood pressure, DBP: Diastolic blood pressure

Table 2. Comparison of biochemical and hormonal parameters between the study groups

Characteristic	Control (n=24)	Osteopenia (n=46)	Osteoporosis (n=38)	p-value
Vitamin D (mg/dL)	26.82±31.32	18.82±13.12	12.53±7.63	0.029
Calcium (mg/dL)	9.6±0.37	9.54±0.37	9.45±0.50	0.213
Total cholesterol (mg/dL)	241.60±10.91	214.00±32.92	214.54±19.98	0.040
HDL-cholesterol (mg/dL)	47.00±9.48	48.88±9.00	48.30±7.74	0.837
Triglycerides (mg/dL)	128.37±15.37	129.78±28.43	117.93±17.22	0.179
LDL-cholesterol (mg/dL)	206.00±18.47	179.28±19.27	181.75±30.38	0.035
ALP	266.66±157.40	179.70±74.30	148.21±81.13	0.011
TSH	86.50±32.17	83.62±23.86	73.32±27.66	0.206
FT4	3.50±4.43	1.70±1.53	1.19±0.99	0.003
Vitamin B12	1.20±0.10	1.17±0.17	1.14±0.29	0.745
Ferritin	446.60±143.39	461.83±388.54	394.40±155.90	0.618

HDL: High-density lipoprotein, LDL: Low-density lipoprotein, ALP: Alkaline phosphatase, TSH: Thyroid-stimulating hormone, FT4: Free thyroxine, ANOVA: Analysis of Variance, HSD: Honestly significant difference

Table 3. Comparison of inflammatory and hematological parameters between the study groups

Characteristic	Control (n=24)	Osteopenia (n=46)	Osteoporosis (n=38)	p-value
CRP	5.41±2.33	5.99±5.65	6.45±4.82	0.770
Neutrophil percentage	51.71±6.28	57.14±9.07	58.14±11.01	0.025
Lymphocyte percentage	37.66±6.49	31.94±7.20	30.63±8.39	0.002
Platelet (K/µL)	262.62±42.17	262.00±39.95	276.21±58.19	0.356
NLR	1.24±0.38	2.00±1.06	2.20±1.21	0.016
PLR	7.07±1.15	8.83±3.33	10.08±4.68	0.007

CRP: C-reactive protein, NLR: Neutrophil lymphocyte ratio, PLR: Platelet lymphocyte ratio

Table 4. Comparison of vascular stiffness parameters

Characteristic	Control (n=24)	Osteopenia (n=46)	Osteoporosis (n=38)	p-value
Intima-media thickness (mm)	0.623±0.089	0.649±0.125	0.725±0.142	0.003
Compliance	0.058±0.037	0.071±0.045	0.116±0.156	0.034
Elastic modulus (N/m²)	746.42±505.28	571.72±514.21	502.80±264.00	0.048
Distensibility (mmHg 1×10³)	0.0020±0.001	0.0026±0.002	0.0037±0.004	0.028

ANOVA: Analysis of Variance, HSD: Honestly significant difference

Table 5. Evaluation of factors associated with vascular morphological structure

	Intima-media thickness (mm)		Compliance		Distensibility (mmHg 1×10³)		Elastic modulus (N/m²)	
	Ratio	p-value	Ratio	p-value	Ratio	p-value	Ratio	p-value
Osteoporosis	0.316	0.001	0.185	0.063	0.181	0.068	-0.163	0.091
Age	0.649	0.001	0.385	0.001	0.385	0.001	-0.425	0.001
BMI	0.329	0.001	0.220	0.026	0.256	0.009	-0.240	0.012
SBP	0.438	0.001	0.286	0.004	0.374	0.001	-0.386	0.001
Ca	0.030	0.755	0.116	0.245	0.234	0.018	-0.184	0.050
Vitamin D	0.120	0.217	0.182	0.068	0.255	0.010	-0.201	0.037
HDL (mg/dL)	-0.039	0.777	0.298	0.027	0.294	0.029	0.214	0.117
LDL (mg/dL)	0.418	0.002	0.042	0.768	0.106	0.449	-0.304	0.002
Neu %	0.268	0.006	0.290	0.003	0.359	0.001	-0.172	0.189
Lymp %	-0.264	0.006	-0.304	0.002	-0.306	0.002	0.267	0.006
NLR	0.282	0.003	0.304	0.002	0.336	0.001	-0.292	0.002

Ca: Calcium, BMI: Body mass index, SBP: Systolic blood pressure (mmHg), HDL: High-density lipoprotein, LDL: Low-density lipoprotein, Neu %: Neutrophil percentage, Lymp %: Lymphocyte percentage, NLR: Neutrophil to lymphocyte ratio

Discussion

The primary findings of our study were as follows: Vitamin D and low-density lipoprotein cholesterol levels were significantly lower in the osteoporosis group than in the control group, as expected; inflammatory markers (NLR and PLR) were significantly higher in the osteoporosis group than in the control group; AS markers (IMT and compliance) were significantly higher in the osteoporosis group than in the control group; among AS markers, only IMT correlated with obesity; all AS markers declined with age; and all AS markers were negatively affected by the increase in NLR.

Empirical studies have highlighted several factors affecting disease development in bones and arteries (16). NLR and PLR are indicators of systemic inflammatory response (17). Inflammatory markers modulate bone formation and resorption by activating osteoclasts that surround cytokines (18). Thus, a systemic inflammatory process may be a mechanism shared by the development of low bone mass and atherosclerosis (16). The high incidence of postmenopausal osteoporosis accompanied by several inflammatory diseases (Crohn's disease, ulcerative colitis, spondyloarthropathy, rheumatoid arthritis, and systemic lupus erythematosus) reported in the literature reveals a correlation between chronic inflammation and

postmenopausal osteoporosis (19). Furthermore, a systematic review highlighted the role of inflammation in the correlation between cardiovascular disease and osteoporosis (12). Owing to the correlation between osteoporosis and inflammatory markers, AS is also associated with proinflammatory cytokines (13). The present study demonstrates that the data were significant and align with the data results reported in the literature within the same patient group.

The prevalence of osteoporosis increases with age (20). Atherosclerosis also progresses with age, and its risk increases significantly after menopause in women (21). The degree of vascular calcification is significantly associated with the changes in bone density, suggesting that vascular sclerosis and low bone mass are associated with pathological conditions (22). The data reported in the literature were significant and aligned with the observations made within the same patient group.

AS measurement is a non-invasive procedure, with two types of measurement techniques. The qualitative technique estimates stiffness using arterial waveform analysis and diameter measurements. The quantitative technique estimates stiffness using parameters such as compliance, diastolic wall stress, distensibility, and elastic modulus based on sonographic cIMT calculations. Compliance is the absolute change in diameter with an increase in pressure. Diastolic wall stress indicates the force on the vessel wall area during diastole. Distensibility is the proportional change in diameter due to an increase in pressure. The elastic modulus describes the characteristics of the wall, independent of the arterial architecture. IMT is a structural property, while compliance, distensibility, diastolic wall stress, elastic modulus, and PWV are functional properties (23). PWV is a broad regional indicator of AS along a particular arterial length. Compliance, diastolic wall stress, distensibility, and elastic modulus are local AS markers in more restricted areas (24).

An increase in AS precedes atherosclerosis and is considered an early marker of systemic atherosclerosis. AS is an independent guiding guide of morbidity and mortality in cardiovascular disease. An association between an increase in AS and cardiovascular events has been demonstrated in high-risk groups (e.g., those with chronic kidney disease or hypertension) and the general population without a diagnosis (25). Mangiafico et al. (26) reported that AS measured using artificial intelligence increased in postmenopausal osteoporotic women. In the present study, we measured AS based on parameters formulated using sonographic IMT and demonstrated a correlation between AS and osteoporosis.

Osteoporosis and cardiovascular diseases aggravate with age and share common risk factors. Although the interaction between osteoporosis and vascular sclerosis exists, the underlying mechanisms remain unknown. Vascular calcification is a well-established mechanism (2). Arterial wall calcification is expected to increase AS without affecting subclinical measures of atherosclerosis, including cIMT. Bone mass loss in postmenopausal women and patients undergoing hemodialysis is associated with high AS (26). Furthermore, osteoporosis and atherosclerosis share certain risk factors such as hypertension, smoking, and a sedentary lifestyle (27).Estrogen could be a critical factor in the association between bone mineral loss and AS. Its receptors have been found in osteoblasts, osteoclasts, and the vasculature. Its deficiency is a risk factor for cardiovascular diseases and bone loss, with bone mass decreasing with age, independent of sex. Specifically women are at higher risk, especially after menopause when bone mass declines rapidly owing to decreased estrogen levels (28). Cross-sectional studies have demonstrated that estrogen deficiency during menopause is associated with increased AS (29). The present study demonstrated this correlation in postmenopausal women, a potentially estrogen-deficient group.

Study Limitations

The main limitations of the present study include the small sample size and lack of dietary calcium and vitamin D content analysis. Furthermore, although the patient group included postmenopausal women, the lack of estrogen measurements may have limited specific findings. In addition, another important factor that could affect the relationship between osteoporosis and AS is estrogen levels (30). The fact that estrogen levels were not included in our study may have been a limiting factor in understanding the relationship between osteoporosis and AS. In further studies investigating the relationship between osteoporosis and AS, evaluating estrogen levels and related hormonal parameters will contribute to the literature.

Conclusion

With advancing age, AS is an essential indicator of cardiovascular disease in postmenopausal women with osteoporosis. AS can be identified using ultrasonography, which is an inexpensive and simple method. Inflammatory parameters may serve as indicators of both osteoporosis and AS.

Ethics

Ethics Committee Approval: This study was approved by the Medical Faculty Local Ethics Committee of a Kahramanmaraş Sütçü İmam University (2018/13; decision no: 14). This study was conducted in accordance with the principles outlined in the Declaration of Helsinki.

Informed Consent: Informed consent was obtained from all patients prior to the study.

Footnotes

Authorship Contributions

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

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Assessment of the Relationship Between Sarcopenia and Body Composition, Nutrition, Physical Performance, and Functional Status in Older Adults

Yaşlılarda Sarkopeni ile Vücut Kompozisyonu, Beslenme, Fiziksel Performans ve Fonksiyonel Durum Arasındaki İlişkinin Değerlendirilmesi

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Abstract

Objective: The aim of this study was to evaluate the presence of sarcopenia in elderly patients and to examine its relationship with body composition, nutritional status, muscle strength and physical performance.

Materials and Methods: In this cross sectional study, patients aged 60 and older who attended the physical medicine and rehabilitation outpatient clinic of a university hospital between June 2018 and June 2019 were enrolled. Demographic and anthropometric data were collected. Sarcopenia was screened using the SARC F questionnaire (score ≥4), while muscle mass was evaluated by bioelectrical impedance analysis. Functional parameters were assessed using hand grip strength, a 4 meter gait speed test, the chair sit to stand test (CSST), balance tests, and the short physical performance battery. Nutritional status was evaluated using the full mini nutritional assessment, and physical activity was measured using the Turkish version of the physical activity scale for the elderly.

Results: The overall prevalence of sarcopenia was 41.0%, with no significant gender differences. SARC F scores were significantly associated with several physical performance measures, notably balance and chair stand test performance. Logistic regression analysis demonstrated that better balance and CSST performance were inversely associated with high SARC F scores, while a higher body mass index increased the likelihood of a high SARC F score.

Conclusion: Although the SARC F questionnaire effectively identifies key characteristics of sarcopenia and correlates with certain functional measures, its utility as a standalone diagnostic tool remains limited. Comprehensive assessment including muscle mass and strength evaluations is recommended for a definitive diagnosis.

Keywords: Body composition, geriatrics, nutrition assessment, physical performance, sarcopenia

Öz

Amaç: Bu çalışmanın amacı, yaşlı hastalarda sarkopeni varlığını değerlendirmek ve bunun vücut kompozisyonu, beslenme durumu, kas kuvveti ve fiziksel performans ile ilişkisini incelemektir.

Gereç ve Yöntem: Kesitsel olarak planlanan bu çalışmaya, Haziran 2018 ile Haziran 2019 tarihleri arasında bir üniversite hastanesinin fiziksel tıp ve rehabilitasyon polikliniğine başvuran 60 yaş ve üzeri hastalar dahil edilmiştir. Katılımcıların demografik ve antropometrik verileri kaydedilmiştir. Sarkopeni taraması SARC-F anketi (skor ≥4) ile yapılmış; kas kütlesi, biyoyelektrik impedans analizi ile değerlendirilmiştir. Fonksiyonel parametreler el kavrama kuvveti, 4 metrelik yürüme hızı testi, sandalyeden otur-kalk testi, denge testleri ve kısa fiziksel performans bataryası ile ölçülmüştür. Beslenme durumu, mini nutrisyonel değerlendirme tam formu ile değerlendirilmiş; fiziksel aktivite düzeyi ise yaşlılar için fiziksel aktivite ölçeğinin Türkçe versiyonu kullanılarak belirlenmiştir.

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Bulgular: Sarkopeni prevalansı genel olarak %41,0 olarak saptanmış olup, cinsiyetler arasında anlamlı bir fark bulunmamıştır. SARC-F skorları, özellikle denge ve sandalyeden kalkma testi performansı olmak üzere, çeşitli fiziksel performans ölçütleriyle anlamlı ilişki göstermiştir. Lojistik regresyon analizinde, daha iyi denge ve sandalyeden otur-kalk testi performansının yüksek SARC-F skoru ile ters orantılı olduğu; daha yüksek vücut kitle indeksinin ise yüksek SARC-F skoru ile ilişkili olduğu bulunmuştur.
Sonuçlar: SARC-F anketi, sarkopeninin temel özelliklerini belirlemede etkili olmakla birlikte, tek başına tanısal bir araç olarak kullanımı sınırlıdır. Kesin tanı için kas kütlesi ve kas kuvveti değerlendirmelerini içeren kapsamlı bir yaklaşım önerilmektedir.
Anahtar kelimeler: Vücut kompozisyonu, geriatri, beslenme değerlendirmesi, fiziksel performans, sarkopeni

Introduction

Sarcopenia is an age-related muscle mass decline that may be accompanied by loss of muscle strength and/or function (1). Although the first naming made by Rosenberg meant a decrease in muscle mass (2), the concept of "sarcopenia" has now become much more comprehensive (1,3). In addition to the decrease in muscle mass, loss of muscle strength, decrease in functionality and balance problems observed in the geriatric population are discussed within the scope of sarcopenia as a result of this approach (1,3). Besides the elements assessed within the context of sarcopenia, additional concerns that warrant attention include factors contributing to sarcopenia like malnutrition, chronic diseases, and mental problems (3,4). Regardless of the etiology and subsequent consequences, sarcopenia is an increasingly important concern in the geriatric population (1,3,4).

The concept of sarcopenia is being increasingly encountered in both clinical practice and research, spanning beyond the realm of geriatrics to encompass various other medical specialties (5-7). Inter/multidisciplinary approaches and consensuses aim to better define sarcopenia (8,9). The European Working Group on Sarcopenia in Older People 2 (EWGSOP2) published a consensus in 2019. This consensus presented an algorithm for the diagnosis of sarcopenia that addresses muscle strength, muscle quality, and physical performance (8). According to this algorithm, grip strength and chair stand test for muscle strength; the use of dual-energy X-ray absorptiometry, bioelectrical impedance analysis (BIA), computed tomography and magnetic resonance imaging for muscle quality was recommended. In order to determine the severity of sarcopenia, physical performance tests the short physical performance battery (SPPB), timed-up and go test and 4-meters walk test were recommended (8). First, muscle strength (e.g., grip strength) is assessed if the initial screening is positive or if there is clinical suspicion. The presence of muscle weakness raises suspicion of sarcopenia, prompting further evaluation. Subsequently, skeletal muscle mass is measured, and a reduction confirms the diagnosis of sarcopenia. Severe sarcopenia is identified when decreased physical performance (e.g., gait speed) is observed alongside reduced muscle strength and skeletal muscle mass (10).

Although these assessments are necessary for a detailed examination, a short and inexpensive test is needed for clinicians and their patients. The SARC-F, used by EWGSOP and many other study groups, was developed to screen for sarcopenia and identify people at risk (11). The Turkish validity study of this short questionnaire, which takes its name from the initials of its 5 components (strength, assistance with walking, rise from a chair, climb stairs and falls), has been previously conducted (12). Many factors such as chronic inflammatory diseases, endocrine disorders, advanced organ failure, malnutrition, hospitalization and sedentary life can cause the development of sarcopenia (13,14). All these related factors can manifest variously in different populations (15,16). According to recent studies, it is thought that the process of decrease in muscle mass and progression to sarcopenia, which is thought to accelerate from the age of 40, should be emphasized starting from the age of 60 (8,16,17). There are few sarcopenia-focused studies evaluating Turkish patients over the age of 60 (17-20). Although the number of these studies is increasing day by day, there is a need for studies that consider geriatric patients in multiple aspects such as body composition, physical performance and nutritional status (12,13,21).

Our study differs from previous research in that it includes individuals over the age of 60 and patients who applied to a physical medicine and rehabilitation (PMR) center. While current literature commonly focuses on individuals over the age of 65 and the general elderly population, our study is distinctive in its inclusion criteria (13,14). Moreover, it stands out as a multidisciplinary effort in which physicians and dietitians collaborated to evaluate sarcopenia alongside parameters such as muscle strength, physical function, body composition, and nutritional status (22).

The aim of this study was to evaluate the prevalence of sarcopenia in patients over 60 years of age with SARC-F and EWGSOP criteria and to investigate the relationship between SARC-F scores and body composition and nutritional parameters, muscle strength, functional status and physical performance scores.

Materials and Methods

Study Design and Population

The study was conducted at the PMR outpatient clinic of a university hospital and was a single-center, cross-sectional observational study. Certain stages, such as body composition and nutritional evaluation, were performed at the nutrition and dietetics department of the same university. Patients aged 60 and over who applied to the outpatient PMR clinic for any reason between June 2018 and June 2019 were included in the study. Exclusion criteria were as follows: not being literate in Turkish, having a terminal stage chronic disease, unable to walk, having a cognitive disorder, having a diagnosis of severe or

advanced psychological disease, and using electronic or metallic implants such as a pacemaker. Consent was obtained from all participants, and all evaluations were conducted by competent physicians and dietitians in their respective fields. The study was approved by the Ethical Committee of Hacettepe University (approval no: GO 18/294-07, date: 20.03.2018).

Demographic and anthropometric data comprising age, gender, body weight (kg), height (m), mid-upper arm circumference (MUAC, cm), and calf circumference (CC, cm) were recorded. Clinical data containing previously diagnosed medical conditions, medicine usage, smoking and alcohol consumption were questioned and recorded.

Anthropometric Measurements and Body Composition

All measurements were conducted by a trained dietitian using standardized techniques: the height was measured using a standard stadiometer (Seca, Marsden, UK) while the participant was standing barefoot on the Frankfurt plane. Body mass index (BMI, kg/m²) was calculated using weight and height measurements. MUAC and CC were measured using a non-stretched measuring tape with an accuracy of 0.1 cm (23). According to the World Health Organization (24), BMI was classified into four categories: "underweight" (<18.50 kg/m²), "normal weight" (18.50-24.99 kg/m²), "overweight" (25.00–29.99 kg/m²), and "obese" (>30.00 kg/m²).

Handgrip strength was measured using a digital handgrip dynamometer (Takei TKK-5401, Japan). The measurement was performed three times on the dominant hand while the participant was in a standing position, and the mean value of these measurements was recorded. Hand grip strength (HGS) measures the maximal voluntary force of the hand muscles and is a reliable indicator of overall muscle strength (25).

Body weight, fat mass, fat-free mass, body fat percentage, and total body water were determined using a multi-frequency bioelectrical impedance analyzer (Tanita MC980, Tokyo, Japan). Measurements were conducted in the early morning after a fasting period of at least 4 hours, following urination 30 minutes prior to the procedure. Participants were barefoot during the measurement to ensure proper contact with the device's electrodes.

Fat-free mass was evaluated using two methods: either through height adjustment (m²) according to guidelines such as EWGSOP2, the International Working Group on Sarcopenia, and the Society on Sarcopenia, Cachexia, and Wasting Disorders, or by utilizing BMI, as proposed in the Foundation for the National Institutes of Health definition (8,9,26).

Questionnaire Assessments

The SARC-F questionnaire was administered to all patients. This questionnaire consists of five questions and evaluates muscle strength, need for assistance in walking, rising up from a chair, climbing stairs, and falls (11). Each component is scored between 0-2, and the total score of the SARC-F query varies between 0-10. Scores ≥4 are predictive of sarcopenia and are reported as an indicator of poor prognosis, emphasizing the need for further detailed examination in these elderly people (27).

The SPPB is a validated composite tool used to assess lower extremity function in older adults. It comprises three primary components: a balance test, a gait speed test, and a chair stand test. Each component is scored individually, and the sum of these scores provides an overall measure of physical performance. Each of the three tests is scored on a scale from 0 to 4, with a higher score representing better performance. The individual scores are summed to produce a total SPPB score ranging from 0 (worst performance) to 12 (best performance). This composite score provides an overall assessment of lower extremity function and has been shown to predict adverse outcomes such as disability, hospitalization, and mortality (28).

In the Balance test, participants are asked to maintain three standing positions of increasing difficulty: the side-by-side stand, the semi-tandem stand, and the tandem stand. Each position is held for up to 10 seconds (28). The ability to maintain these positions without losing balance is indicative of static balance capacity. The balance test helps identify individuals at risk for falls and is a critical component of overall physical function (29).

The Gait Speed test measures the time required for a participant to walk a set distance, typically 4 meters, at their usual walking pace. The test is performed twice, and the best time is recorded. Gait speed serves as a proxy for mobility, muscle strength, and overall functional status, with slower speeds being associated with increased risk of disability and mortality (30).

The full version of the mini nutritional assessment (MNA) was utilized for the nutritional assessment (31). This 18-item assessment comprises two stages: an initial screening employing the MNA-Short Form, encompassing 6 items, followed by a supplementary 12-item evaluation. A total score ≥24 indicates normal nutritional status, 17-23.5 signifies an elevated risk of malnutrition, and <17 indicates the presence of malnutrition (31). MNA is a scale that includes anthropometric measurements (BMI, mid-arm and calf circumference) and main questions about nutrition and is widely and reliably used in the Turkish elderly population (19).

Additionally, the Turkish version of the physical activity scale for the elderly scale was used to evaluate physical activity in elderly patients (32).

HGS, 4-meter gait speed test, chair sit-to-stand test, balance test, and SPPB were used as functional parameters (12,33,34). Sarcopenia was diagnosed according to the criteria established by the European Working Group on Sarcopenia in Older People (EWGSOP). According to EWGSOP, sarcopenia is defined by the presence of low muscle mass combined with low muscle strength or low physical performance. Low muscle mass was determined using the skeletal muscle mass index (appendicular skeletal muscle mass/height²) evaluated by BIA (Tanita MC980, Tokyo, Japan), with cut-off points established as <8.87 kg/m² for men and <6.42 kg/m² for women. Low muscle strength was accepted as handgrip strength measured with a hand dynamometer (Takei TKK-5401, Japan), with cut-off values

of <30 kg for men and <20 kg for women. Low physical performance was defined by a 4-meter gait speed test, with a speed of <0.8 m/s (35).

Statistical Analysis

The statistical evaluation of the data was completed using SPSS version 25 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro-Wilk test. Continuous data were expressed as mean ± standard deviation, while categorical variables were reported as frequencies and percentages. Comparisons between groups were performed using the Student's t-test for normally distributed data or the Mann-Whitney U test for non-parametric data. Categorical variables were analyzed using the chi-square test. Pearson's or Spearman's correlation coefficients were calculated to evaluate relationships between variables, depending on data distribution. Logistic regression analysis was performed to identify independent predictors of high SARCF scores (≥4). A two-tailed p-value of <0.05 was considered statistically significant.

Results

Demographic Characteristics of Patients

The demographic characteristics of the patient population revealed notable trends (Table 1). The mean age was significantly higher in males (68.9±6.6 years) compared to females (65.3±4.5 years) (p=0.044). While there was no significant difference in BMI between genders (p=0.065), females had a slightly higher mean BMI (31.5±5.3 kg/m²) compared to males (28.5±5.6 kg/m²).

Regarding lifestyle factors, the proportion of former smokers was notably higher among males (73.0%) compared to females (40.0%). Alcohol consumption was infrequent in both genders, with no significant difference observed (p=0.738).

When considering chronic disease prevalence, no significant gender disparity was observed (p=0.283). However, females exhibited a slightly higher prevalence of having three or more chronic conditions (28.6%) compared to males (6.7%). The occurrence of falls was more frequent among males (26.7%) than females (9.5%) (p=0.063).

Table 1. Demographic characteristics of patients

Characteristics	Female (n=63)	Male (n=15)	All patients (n=78)	p
Age (years), $\bar{x}$ ± SD	65.3±4.5	68.9±6.6	66.1±5.1	**0.044***
BMI (kg/m²), $\bar{x}$ ± SD	31.5±5.3	28.5±5.6	30.9±5.4	0.065
SARC-F, $\bar{x}$ ± SD	2.2±1.9	1.9±1.8	2.1±1.9	0.605
Smoking status, n (%)				0.058
Current	8 (12.7)	4 (26.7)	12 (15.4)	
Former	46 (73.0)	6 (40.0)	52 (66.7)	
Never	7 (11.1)	4 (26.7)	11 (14.1)	
Alcohol consumption, n (%)				0.738
Yes	3 (4.8)	1 (6.7)	4 (5.1)	
No	58 (92.1)	13 (86.7)	71 (91.0)	
Chronic disease number, n (%)				0.283
None	12 (19.0)	2 (13.3)	14 (17.9)	
1 to 2	21 (33.3)	6 (40.0)	27 (34.6)	
≥3	18 (28.6)	1 (6.7)	19 (24.4)	
Falls, n (%)				0.063
Yes	6 (9.5)	4 (26.7)	10 (12.8)	
No	55 (87.3)	10 (66.7)	65 (83.3)	
SARC-F, n (%)				0.818
<4	52 (82.5)	12 (80.0)	64 (82.1)	
≥4	11 (17.5)	3 (20.0)	14 (17.9)	
EWGSOP, n (%)				0.891
Sarcopenia (+)	26 (41.3)	6 (40.0)	32 (41.0)	
Sarcopenia (-)	37 (58.7)	9 (60.0)	46 (59.0)	

BMI: Body mass index, EWGSOP: The European working group on sarcopenia in older people.
Data were presented as mean ± standard deviation ($\bar{x}$ ± sd) or number (percentage).
p-values refer to comparison between the two groups by the Mann-Whitney U non-parametric test for quantitative variables, and by the chi-square test or Fisher's exact tests for qualitative variables (*p<0.05)

Regarding sarcopenia diagnosis, based on the EWGSOP criteria, 41.3% of females and 40.0% of males were identified as sarcopenic (p=0.891). The SARC-F score distribution showed no significant differences, with 82.5% of females and 80.0% of males scoring below 4, indicating a similar low-risk distribution (p=0.818).

Bioimpedance Analysis and Muscle Strength Variables by Sarcopenia Presence

Body composition and muscle strength data were analyzed based on SARC-F scores (Table 2). Among females, those with SARC-F scores ≥4 had significantly higher BMI (34.8±4.9 kg/m²) than those with scores <4 (30.8±5.1 kg/m²) (p=0.030). A similar trend was observed in the combined analysis of both genders (p=0.048). However, body fat percentage, fat-free mass, and MUAC did not show significant differences by SARC-F scores across genders.

Grip strength was slightly lower in females with SARC-F scores ≥4 (17.8±4.8 kg) compared to those with scores <4 (20.6±4.5 kg), though the difference was not statistically significant (p=0.088). Similarly, CC and fat-free mass indices did not vary significantly by SARC-F categories.

Nutritional, Physical Performance, and Balance Measures

Nutritional and physical performance measures also showed variability based on SARC-F scores (Table 3). The chair stand test was significantly associated with sarcopenia, as individuals with SARC-F scores ≥4 demonstrated higher scores in both the overall population (p=0.004) and the male subgroup (p=0.004). Similarly, balance test scores were significantly lower in those with SARC-F scores ≥4 (3.5±0.8) compared to those scoring <4 (3.9±0.5) (p=0.014).

The SPPB total score was significantly lower in the SARC-F ≥4 group (8.3±1.8) compared to the <4 group (12.6±2.3) (p=0.008). Nutritional scores, as measured by the MNA, did not differ significantly by SARC-F score in either gender or the overall sample.

Correlations Between SARC-F Scores and Clinical Parameters

Correlation analysis revealed significant associations between SARC-F scores and specific clinical parameters (Table 4). In females, higher SARC-F scores correlated negatively with

Table 2. The values of bioimpedance analysis and muscle strength variables according to the presence of sarcopenia

	Male			Female			Total		
	SARCF <4	SARCF ≥4	p	SARCF <4	SARCF ≥4	p	SARCF <4	SARCF ≥4	p
BMI (kg/m²)	28.2±6.1	29.6±4.1	0.633	30.8±5.1	34.8±4.9	**0.030**	30.3±5.3	33.7±5.1	**0.048***
Body fat (%)	27.2±9.7	27.3±3.8	0.840	36.9±5.8	39.6±3.4	0.145	35.1±7.6	36.9±6.2	0.387
Fat-free mass (kg)	55.3±9.3	65.3±1.2	0.136	45.1±6.1	46.7±5.9	0.478	47.1±7.9	50.7±9.5	0.264
Fat-free mass/weight (kg/m²)	20.1±2.7	21.5±2.0	0.448	19.3±2.4	20.3±2.6	0.227	19.4±2.4	20.5±2.4	0.119
Fat-free mass/BMI (m²)	2.0±0.3	2.2±0.3	0.448	1.5±0.2	1.4±0.2	0.078	1.6±0.3	1.5±0.4	0.342
MUAC (cm)	29.3±5.5	30.3±1.5	0.840	30.3±4.6	32.1±3.5	0.194	30.1±4.8	31.7±3.2	0.207
Calf circumference (cm)	37.3±3.9	38.3±3.2	0.734	37.3±4.7	37.7±3.8	0.612	37.3±4.7	37.8±3.6	0.582
Grip strength (kg)	33.5±7.9	37.7±6.9	0.448	20.6±4.5	17.8±4.8	0.088	23.2±7.3	22.1±9.8	0.348

BMI: Body mass index, MUAC: Mid-upper arm circumference.
Data were presented as mean ± standard deviation, ***p<0.05**

Table 3. The scores of nutrition, falls and physical performance, and balance tests according to the presence of sarcopenia in both female and male patients

	Male			Female			Total		
	SARCF <4	SARCF ≥4	p	SARCF <4	SARCF ≥4	p	SARCF <4	SARCF ≥4	p
MNA	24.3±2.5	27.8±7.5	0.633	24.5±2.9	23.8±2.3	0.380	24.4±2.8	24.6±4.0	0.569
PASE total score	69.5±28.2	40.6±25.3	0.088	69.5±29.0	75.0±37.9	0.935	69.5±28.6	67.6±37.6	0.522
4 m gait speed test (m/s)	0.8±0.4	0.7±0.05	1.000	0.6±0.2	0.6±0.2	0.638	0.7±0.3	0.6±0.2	0.694
Chair stand test	0.2±0.4	1.3±0.6	**0.004***	0.3±0.5	1.1±0.7	0.089	0.3±0.5	1.1±0.7	**0.004***
Balance test	4.0±0.0	3.3±1.2	0.448	3.8±0.5	3.6±0.8	0.068	3.9±0.5	3.5±0.8	**0.014***
SBBP total score	8.8±1.5	5.3±2.9	**0.018***	8.2±1.8	14.6±26.2	0.069	8.3±1.8	12.6±23.4	**0.008***
SARCF total score	1.2±1.0	4.7±1.2	**0.004***	1.5±1.2	5.3±1.3	**0.001***	1.4±1.2	5.1±1.2	**0.001***

MNA: Mini nutritional assessment, PASE: The physical activity scale for the elderly, SBBP: Short physical performance battery.
Data were presented as mean ± standard deviation, ***p<0.05**

grip strength (r=-0.424, p=0.001), balance test scores (r=-0.265, p=0.037), and chair stand test performance (r=-0.397, p=0.001). Body fat percentage and MUAC positively correlated with SARC-F scores (p=0.029).

Among males, significant negative correlations were observed between SARC-F scores and the SPPB total score (r=-0.522, p=0.046). However, other measures such as grip strength and body composition parameters did not demonstrate strong associations.

Logistic Regression Analysis of Sarcopenia Risk Factors

Logistic regression analysis identified key predictors of high SARC-F scores (≥4) (Table 5). Each unit increase in balance test score decreased the likelihood of scoring ≥4 on the SARC-F by approximately 60% [odds ratio (OR): 0.421, p=0.041]. Similarly, an improvement in chair stand test performance reduced this likelihood by 70% (OR: 0.326, p=0.008). In contrast, a one-unit increase in BMI was associated with a 13% higher likelihood of a high SARC-F score (OR: 1.134, p=0.041).

Discussion

This study evaluated the prevalence of sarcopenia in Turkish geriatric patients using the SARC-F questionnaire and examined its correlations with body composition, nutritional status, muscle strength, and physical performance. Our study demonstrates that the SARC-F can fulfill its primary purpose of screening for sarcopenia in Turkish older adults; however, it has limitations both in this context and in the detailed assessment of sarcopenia. The overall sarcopenia prevalence of 41.0% in our study population is consistent with previous reports in similar elderly cohorts, thereby highlighting the clinical significance of sarcopenia in aging demographics (8). According to the EWGSOP2 criteria reported in a meta-analysis (16), the prevalence of sarcopenia among individuals over the age of 60 ranges between 10% and 27%. Since our study included patients who presented to the PMR clinic for various reasons, unlike the general population, detecting higher rates seems plausible. According to the SARC-F, the prevalence of sarcopenia in our study was determined to be 17.9%. Although the SARC-F appears to provide a more accurate rate, it was insufficient to

Table 4. Correlation between nutrition and physical performance test scores, anthropometric measurements with SARC-F total score

	Male		Female	
	r	p	r	p
MNA	-0.306	0.267	-0.246	0.054
SBBP total score	-0.522	**0.046***	-0.319	**0.011***
PASE total score	-0.308	0.284	-0.157	0.224
4 m gait speed test	-0.172	0.557	-0.038	0.772
Chair stand test	-0.480	0.070	-0.397	**0.001***
Balance test	-0.443	0.098	-0.265	**0.037***
Body fat (%)	0.084	0.766	0.278	**0.029***
Fat-free mass (kg)	0.258	0.354	0.109	0.400
Fat-free mass/weight (kg/m^2)	-0.037	0.897	0.206	0.109
Fat-free mass/BMI (m^2)	0.164	0.558	-0.281	**0.027***
MUAC (cm)	-0.181	0.519	0.280	**0.029***
Calf circumference (cm)	-0.151	0.591	0.244	0.058
Grip strength (kg)	-0.146	0.603	-0.424	**0.001***

MNA: Mini nutritional assessment, SBBP: Short physical performance battery, PASE: The physical activity scale for the elderly, BMI: Body mass index, MUAC: Mid-upper arm circumference, r: correlation coefficient, **(*p<0.05)**

Table 5. Logistic regression analysis

Variables	SARC-F total score						
	≥4				<4 (reference)		
	B	OR	%95 CI	p	OR	%95 CI	p
Balance score	-0.864	0.421	0.18-0.97	**0.041***	1	-	-
Chair stand test	-1.122	0.326	0.14-0.75	**0.008***	1	-	-
BMI (kg/m^2)	0.126	1.134	1.01-1.28	**0.041***	1	-	-

Hosmer and Lemeshow (p) >0.05 (all models), OR: Odds ratio, CI: Confidence interval, BMI: Body mass index

predict the prevalence of sarcopenia determined according to the EWGSOP2 criteria, which offer a more comprehensive assessment. At the time of our study, the EWGSOP2 criteria had not yet been published, and because SARC-F was developed prior to that update, we compared it against the original 2010 EWGSOP criteria. We believe that SARC-F, introduced in 2013, should be evaluated according to the 2010 standards rather than the 2019 revision. Nonetheless, our findings suggest that SARC-F may still have certain limitations (8,11,35).

The SARC-F questionnaire demonstrated significant associations with several physical performance measures, particularly balance and the chair sit-to-stand test. These findings reinforce the utility of SARC-F as an initial screening tool that captures aspects of functional impairment associated with sarcopenia. However, the absence of strong correlations with certain parameters such as grip strength and specific body composition measures suggests that SARC-F alone may not fully capture the complexity of sarcopenia. This is in line with previous studies (36) which indicate that while SARC-F is effective in screening for mobility limitations, a comprehensive evaluation requires additional assessments.

In this study, the negative correlation between SARC-F scores and handgrip strength scores, particularly in women, emphasizes the role of muscle strength in the diagnosis of sarcopenia (11,37). The absence of significant changes in fat-free mass or nutritional assessment scores (e.g., MNA), which are critical aspects of sarcopenia, raises questions about whether the SARC-F accurately measures sarcopenia. Moreover, muscle mass and strength between modest association in comparison to specific standards like the EWGSOP supports earlier concerns that the SARC-F may lack the sensitivity required for a precise diagnosis (38). Contrary to findings in the literature, parameters such as calf circumference, handgrip strength, and muscle mass did not differ significantly between the groups classified according to SARC-F. This outcome may be attributed to the unpredictable characteristics of the study population and the small sample size, particularly among male participants.

An important finding of this study, that participants with a SARC-F score of 4 and above exhibited impaired physical performance, supports previous findings that the SARC-F does not directly measure muscle mass but instead evaluates functional parameters (37). Also, these findings support the recommendations of the EWGSOP to apply more sensitive diagnostic methods (e.g. grip strength measurements or bioimpedance analysis) after the use of SARC-F as a first-stage screening tool (27,39). On the other hand, the association between high SARC-F scores and high BMI highlights the importance of body composition in the diagnosis of sarcopenia. The results suggest that individuals with high BMI are more likely to have higher SARC-F scores due to the confounding effects of obesity. This finding is consistent with previous research suggesting that obesity obscures muscle wasting, complicating the diagnosis of sarcopenia (40). For this reason, recent studies have proposed the use of methods such as ultrasonography to detect sarcopenia and sarcopenic obesity or to assess body composition (41,42).

Our logistic regression analysis further revealed that each unit improvement in balance and chair stand performance significantly reduced the odds of a high SARC-F score, whereas an increase in BMI was associated with an elevated risk. These results suggest that impaired balance and reduced lower extremity strength are key determinants of functional decline in sarcopenia, and they underscore the interplay between obesity and muscle function in this population.

Study Limitations

Despite the strengths of our study, including the comprehensive assessment of both physical performance and nutritional status, several limitations must be acknowledged. The cross-sectional design limits the ability to draw causal inferences, and the study's single-center nature may affect the generalizability of the findings. We consider the fact that our study was not conducted on community-based elderly as a distinguishing feature rather than a limitation, and we believe it contributes to the literature. However, we would like to emphasize the need for larger studies on patients aged 60 and over who apply to rehabilitation clinics, as the small sample size may have influenced some parameters. Our study includes patients over the age of 60 who presented to the PMR outpatient clinic with various complaints. Individuals over the age of 60 who present to the PMR outpatient clinic appear to be more prone to sarcopenia, and the findings of our study support this observation. The fact that we evaluated individuals aged over 60 rather than over 65 demonstrates an earlier stage of impact in this population, which constitutes a significant strength of our study. Furthermore, another notable strength of our research is the comprehensive and multidimensional evaluation of the individuals included in the study.

Conclusion

Sarcopenia is a condition that should be addressed multidimensionally, such as muscle strength, physical function, and nutrition. Although the SARC-F questionnaire is a practical and cost-effective screening tool for sarcopenia in elderly Turkish patients, its diagnostic accuracy is limited when used in isolation. Integrating the SARC-F with objective measures of muscle mass and strength may provide a more robust framework for early diagnosis and management of sarcopenia in clinical practice.

Ethics

Ethics Committee Approval: The study was approved by the Ethical Committee of Hacettepe University (approval no: GO 18/294-07, date: 20.03.2018).

Informed Consent: Consent was obtained from all participants, and all evaluations were conducted by competent physicians and dietitians in their respective fields.

Footnotes

Authorship Contributions

Surgical and Medical Practices: Y.D., Concept: Y.D., P.B., P.B., Y.G.K., Design: Y.D., P.B., P.B., Y.G.K., Data Collection or Processing: Y.D.,

S.Ö., N.K.H., S.K., Analysis or Interpretation: Y.D., P.B., P.B., S.Ö., N.K.H., S.K., Y.G.K., Literature Search: Y.D., P.B., S.Ö., Writing: Y.D., P.B., S.Ö.

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Case Report / Olgu Sunumu

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A Rare Hypersensitivity Reaction with Golimumab: Recurrent Fever After Each Injection

Golimumab İlişkili Nadir Bir Hipersensitivite Reaksiyonu: Her Enjeksiyon Sonrası Tekrarlayan Ateş

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Abstract

Ankylosing spondylitis (AS) is a chronic inflammatory disease treated with non-steroidal anti-inflammatory drugs (NSAIDs) and, in refractory cases, biologic agents such as tumor necrosis factor inhibitors (TNF-Is). While TNF-Is are generally well tolerated, rare hypersensitivity reactions may occur. We present a 31-year-old female diagnosed with AS, previously unresponsive to NSAIDs, who achieved remission with golimumab (50 mg/month) for six years. However, during the coronavirus disease-2019 pandemic, she began experiencing recurrent fever, fatigue, and elevated C-reactive protein levels 2-3 days post-injection. Extensive investigations, including antinuclear antibody, extractable nuclear antigen, antineutrophil cytoplasmic antibodies, and infectious serologies, were unremarkable. The symptoms resolved spontaneously within a week. Given the exclusion of infectious or autoimmune etiologies, a hypersensitivity reaction to golimumab was suspected. Treatment was switched to secukinumab, resulting in symptom resolution without further complications. Hypersensitivity reactions to TNF-Is, particularly fever, are rare but important adverse events. While similar reactions have been reported with infliximab, this is the first documented case associated with golimumab. Clinicians should be aware of this potential side effect to ensure prompt diagnosis and management. This case underscores the importance of vigilant monitoring for atypical adverse events during long-term biologic therapy in AS patients. Further research is needed to elucidate the pathophysiology and risk factors for hypersensitivity to TNF-Is.

Keywords: Ankylosing spondylitis, golimumab, TNF-inhibitors, hypersensitivity, fever

Öz

Ankilozan spondilit (AS), steroid olmayan anti-enflamatuvar ilaçlar (SOAİ) ve dirençli olgularda tümör nekroz faktörü inhibitörleri (TNF-İ) gibi biyolojik ajanlarla tedavi edilen kronik enflamatuvar bir hastalıktır. TNF-İ'ler genellikle iyi tolere edilmekle birlikte, nadir olarak aşırı duyarlılık reaksiyonları görülebilir. Bu makalede, SOAİ'lere yanıt vermeyen ve altı yıl boyunca aylık 50 mg golimumab ile remisyona ulaşan 31 yaşındaki AS tanılı bir kadın hasta sunulmaktadır. Ancak, koronavirüs hastalığı-2019 pandemisi sırasında, enjeksiyondan 2-3 gün sonra tekrarlayan ateş, yorgunluk ve yükselmiş C-reaktif protein düzeyleri yaşamaya başlamıştır. Antinükleer antikor, ekstrakte edilebilir nükleer antijen, antinötrofil sitoplazmik antikor ve enfeksiyöz serolojiler dahil kapsamlı incelemelerde herhangi bir anormallik saptanmamıştır. Belirtiler genellikle bir hafta içinde kendiliğinden düzelmiştir. Enfeksiyöz veya otoimmün nedenlerin dışlanmasıyla, golimumaba karşı gelişen bir aşırı duyarlılık reaksiyonundan şüphelenilmiştir. Tedavi secukinumaba geçilmiş ve hasta, semptomlarda tam düzelme sağlamıştır. TNF-İ'lere bağlı aşırı duyarlılık reaksiyonları, özellikle ateş, nadir ancak önemli olumsuz olaylardır. İnfliksimaba benzer reaksiyonlar bildirilmiş olsa da, golimumab ile ilişkili ilk olgu bu çalışmada sunulmaktadır. Klinik hekimlerin bu olası yan etkiyi tanıyabilmesi için farkındalık geliştirmesi gereklidir. Bu olgu, AS hastalarında uzun süreli biyolojik tedavi sırasında atipik advers olayların dikkatle izlenmesinin önemini vurgulamaktadır. TNF-İ'lere karşı aşırı duyarlılığın patofizyolojisini ve risk faktörlerini aydınlatmak için daha fazla araştırmaya ihtiyaç vardır.

Anahtar kelimeler: Ankilozan spondilit, golimumab, TNF inhibitörleri, hipersensitivite, ateş

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Introduction

Ankylosing spondylitis (AS) is the prototypical condition within the spondyloarthritis spectrum, characterized by inflammatory low back pain and sacroiliac joint involvement, with or without peripheral arthritis, enthesitis, and extra-articular manifestations (1). Early initiation of treatment is critical to prevent skeletal deformities and physical disability (2). First-line pharmacological management typically involves the regular use of non-steroidal anti-inflammatory drugs (NSAIDs). When NSAIDs fail to provide adequate symptom control, biologic agents, such as tumor necrosis factor inhibitors (TNF-Is) or interleukin-17 inhibitors, are recommended (3,4). Patients undergoing treatment require close monitoring for drug efficacy, disease activity, and potential adverse effects. Here, we present a case of a patient who developed recurrent fever and elevated acute-phase reactants following the administration of golimumab.

Case Report

A thirty one-year-old female patient, who was diagnosed with AS at an external center 5 years ago, presented to our clinic due to increased pain. Upon admission, the patient reported that she had discontinued her medications two years prior. She had previously used various NSAIDs but noted that her symptoms had not resolved completely. On the initial examination, the cervical and lumbar range of motion was restricted and painful, and bilateral Mennel's test was positive on the sacroiliac joint assessment. Tenderness was noted over the left spina iliaca anterior superior, left iliac crest, and left achilles tendon insertion. Disease activity and functional status were evaluated using the Bath ankylosing spondylitis disease activity index (BASDAI; score: 9) and the Bath ankylosing spondylitis functional index (score: 8).

The patient had no comorbidities. Blood tests showed normal liver and kidney function but elevated inflammatory markers, with a C-reactive protein (CRP) level of 1.77 mg/dL and an erythrocyte sedimentation rate of 36 mm/hour. The human leukocyte antigen (HLA) typing was positive for HLA B27 and previous sacroiliac magnetic resonance imaging findings confirmed sacroiliitis. Initial treatment included regular NSAID therapy combined with a proton pump inhibitor, which was maintained for two years. However, her pain persisted, with a BASDAI score of 6.8. Consequently, TNF-I therapy was initiated, and golimumab 50 mg/month was prescribed, leading to the discontinuation of NSAIDs.

The patient demonstrated significant improvement, achieving sustained remission and becoming pain-free on golimumab therapy for six years until 2021. However, during the coronavirus disease-2019 pandemic, she missed follow-up visits for one year but continued golimumab as prescribed. Over the past five months, she experienced intermittent fever, fatigue, flu-like symptoms, and elevated CRP levels (up to 12 mg/dL) two to three days following each golimumab administration. During her clinic visit, four days after her most recent golimumab dose, her temperature was 38 °C, and CRP was elevated at 4 mg/dL. No dermatological findings or other systemic symptoms were observed.

Extensive laboratory investigations, including antinuclear antibody, anti-double stranded DNA, extractable nuclear antigen, antineutrophil cytoplasmic antibodies, complement levels, rheumatoid factor, anti-cyclic citrullinated peptide, and *Brucella* tube agglutination tests, revealed no abnormalities. Internal medicine and infectious diseases consultations excluded systemic causes of fever, elevated CRP, and flu-like symptoms. Based on the clinical presentation and the exclusion of alternative diagnoses, the reaction was attributed to hypersensitivity to golimumab. Treatment was then transitioned to secukinumab, which the patient has been receiving for eight months without adverse effects. A written informed consent was obtained from the patient.

Discussion and Conclusion

Golimumab is effective in inducing and maintaining remission in patients with AS and has a long-term safety profile comparable to other TNF-Is (5). Common side effects include headache, injection site reactions (for subcutaneous administration), infusion reactions (for intravenous administration), rash, anemia, upper respiratory tract infections, cough, pharyngitis, diarrhea, nausea, and abdominal pain, occurring in over 10% of patients treated with golimumab. Other common side effects, observed in approximately 2-5% of patients, include sinusitis, bronchitis, viral infections, mild transaminase elevations, hypertension, dizziness, paresthesia, and pyrexia (6). Severe adverse events, such as life-threatening fungal or bacterial infections, heart failure, worsening or new-onset demyelinating disorders, hepatitis or tuberculosis reactivation, and lupus-like syndrome, occur less frequently. Acute infusion or injection reactions typically arise during drug administration and can vary in severity, ranging from a simple rash to anaphylaxis (7).

Drug fever, a type III hypersensitivity reaction, can be induced by various medications (8). It is a similar entity to serum sickness. Drug fever is identified as a febrile response that starts after drug administration, and resolves within 72 hours after drug possession, no other cause is identified and no recurrence of fever within 72 hours after the fever subsides. CRP elevation can accompany drug fever reactions, as observed in our case.

This case highlights a hypersensitivity reaction, manifesting as fever and elevated acute-phase reactants, which resolved spontaneously within one week after each golimumab injection. This reaction occurred despite the patient tolerating golimumab without issues for six years. The absence of abnormalities in anti-nuclear antibodies, complement levels, and other relevant investigations excluded drug-induced lupus, vasculitis, and serum sickness-like reactions. Consultations from internal medicine and infectious diseases identified no alternative diagnoses, further confirming the hypersensitivity-related nature of the response.

A literature review identified two similar hypersensitivity cases associated with TNF-Is, both involving infliximab. The first case

described a sixty one-year-old woman with ulcerative colitis who developed a fever of 38.3 °C nine days after her second infliximab dose. Anti-dsDNA and anti-histone antibody tests were negative, and no infectious etiology was identified. Her fever resolved spontaneously after 25 days (9). The second case involved a sixty five-year-old woman with rheumatoid arthritis, who experienced a high fever with rigors lasting 13 days after her second infliximab infusion. This episode was attributed to delayed hypersensitivity (10).

To our knowledge, this is the first reported case of a hypersensitivity reaction to golimumab presenting as a recurrent fever. This report aims to raise awareness among clinicians about this adverse effect.

Ethics

Informed Consent: A written informed consent was obtained from the patient.

Footnotes

Authorship Contributions

Surgical and Medical Practices: B.G., N.M., D.G.K., M.Ö., Concept: B.G., N.M., D.G.K., M.Ö., Design: B.G., N.M., D.G.K., M.Ö., Data Collection or Processing: B.G., N.M., D.G.K., M.Ö., Analysis or Interpretation: B.G., N.M., D.G.K., M.Ö., Literature Search: B.G., N.M., D.G.K., M.Ö., Writing: B.G., N.M., D.G.K., M.Ö.

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Ülseratif Kolitli Bir Olguda Üç Farklı Tutulum: Bilateral Femur Başı Avasküler Nekrozu, Spondilodiskit ve Spondiloartropati

Three Different Involvements in a Case of Ulcerative Colitis: Bilateral Femoral Head Avascular Necrosis, Spondylodiscitis and Spondyloarthropathy

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Öz

Avasküler nekroz (AVN), kemik dokusunun yetersiz kanlanması sonucu gelişen ciddi bir durumdur. Bu durum genellikle travma, uzun süreli steroid kullanımı veya sistemik hastalıklarla ilişkilidir. Spondilodiskit, omurga diskleri ve vertebra cisimlerini etkileyen ciddi bir enfeksiyon olup genellikle bakteriyel kaynaklıdır. Spondilodiskit ve AVN'nin birlikteliği nadir görülür. Bu olgu sunumunda, ülseratif kolit tanısı olan 53 yaşındaki kadın hastada bilateral femur başı AVN'yi ve spondilodiskit birlikteliği ele alınmıştır. Bu olgu, kronik inflamatuvar hastalığı olan, uzun süreli kortikosteroid tedavisi gören hastalarda AVN ve spondilodiskit gelişme riskinin vurgulanmasını amaçlamaktadır.
Anahtar kelimeler: Avasküler nekroz, spondilodiskit, inflamasyon, kortikosteroid, osteoimmünoloji, spondiloartropati

Abstract

Avascular necrosis (AVN) is a serious condition that develops as a result of inadequate blood supply to bone tissue. This condition is usually associated with trauma, long-term steroid use, or systemic diseases. Spondylodiscitis is a serious infection affecting the spinal discs and vertebral bodies and is usually of bacterial origin. The association of spondylodiscitis and avascular necrosis is rare. In this case report, bilateral femoral head avascular necrosis and spondylodiscitis coexistence in a 53-year-old female patient diagnosed with ulcerative colitis is discussed. This case aims to emphasize the risk of developing AVN and spondylodiscitis in patients with chronic inflammatory disease who receive long-term corticosteroid treatment.
Keywords: Avascular necrosis, spondylodiscitis, inflammation, corticosteroid, osteoimmunology, spondyloarthropathy

Giriş

Avasküler nekroz (AVN), kemik vasküleritesinin bozulması sonucu osteosit ve yağ hücrelerinin ölmesine yol açan kemik yıkımını ifade eder. AVN, travma, uzun süreli kortikosteroid kullanımı, alkolizm, orak hücre anemisi, otoimmün hastalıklar, hiperlipidemi, kemoterapi ve radyoterapi gibi durumlarla tetiklenebilir. AVN'nin patogenezi tam olarak anlaşılamamış olsa da vasküler bozulma, adiposit disfonksiyonu ve intraosseöz basınç artışının bu süreçte önemli rol oynadığı düşünülmektedir. AVN en sık femur başında görülür ancak vücudun farklı bölgelerinde de etkileyebilir. Bu da mekanik olarak engellenen subkondral kemiğin çökmesine ve sekonder osteoartrite neden olabilir (1-3). Osteonekroza bağlı olarak nekrotik kemiği ve intramedüller dokuyu ortadan kaldırmaya yönelik inflamatuvar bir yanıt başlar. Bu süreç doku rejenerasyonunu bozabilir. Osteonekrozun tetikleyici faktörünün devam etmesi kronik inflamasyona ve kemik onarımının bozulmasına yol açar (4,5). Uzun süreli veya yüksek dozda kortikosteroid kullanımı osteonekroz için önemli bir risk faktörüdür. Steroidlerin, lipit metabolizmasını etkileyerek damar yapısında mikroemboliler ve dolaşım bozukluklarına neden olduğu düşünülmektedir (3,6). Literatürde, prednizon dozunun 20 mg/gün'ün üzerinde olması veya kümülatif dozun 12 gramı aşması AVN riskini artırdığı gösterilmiştir (6,7). Shibatani ve ark. (8), steroid kullanımının ilk 8 haftasında günlük doz ile osteonekroz riski arasında istatistiksel olarak anlamlı bir ilişki olduğunu belirtirken; Koo ve ark. (9) günlük yüksek steroid dozlarının, kümülatif dozdan daha önemli bir risk faktörü olduğunu vurgulamıştır.

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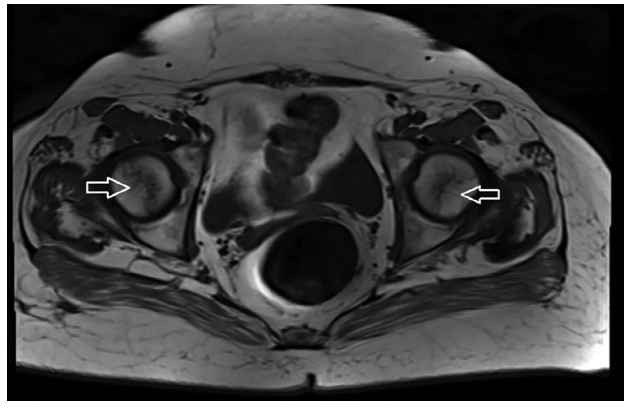
Spondilodiskit, intervertebral diskler ve bitişik vertebral cisimlerde meydana gelen enfeksiyöz inflamasyondur. Özellikle vertebral spondilodiskit, vertebra cisimlerini ve diskleri etkileyen nadir ancak ciddi bir omurga enfeksiyonudur. En sık etkenler arasında *Staphylococcus aureus* ve *Mycobacterium tuberculosis* yer almaktadır. Bu durum genellikle yaşlı bireylerde veya immün sistemi zayıflamış kişilerde görülür ve sıklıkla sırt ağrısı, ateş ve nörolojik belirtilerle kendini gösterir. Tanı için eritrosit sedimantasyon hızı (ESR) ve C-reaktif protein (CRP) testleri önemli laboratuvar göstergeleridir. Manyetik rezonans görüntüleme (MRG), spondilodiskit tanısında kritik öneme sahiptir ve enfeksiyonun yayılımı ile ciddiyetini belirlemede kullanılır. Tedavi genellikle uzun süreli antibiyotik tedavisi ve bazı durumlarda cerrahi müdahale gerektirir (10). AVN ve spondilodiskit, kronik inflamatuvar hastalığı olan hastalarda nadiren birlikte görülen ciddi komplikasyonlardır. Uzun süreli kortikosteroid ve immünosupresif tedavi kullanımı bu komplikasyonların gelişme riskini artırır. Bu olgu sunumunda, ülseratif kolit tanısı olan hastada bilateral femur başı AVN'yi ve spondilodiskit birlikteliği sonrasında gelişen spondiloartropati ele alınmıştır.

Olgu Sunumu

2004 yılından beri ülseratif kolit tanısı olan 53 yaşında kadın hasta bel ve sağ kalça ağrısı şikayetleri ile polikliniğimize başvurdu. Hasta öyküsünde bu yakınmasının yaklaşık 2 ay önce başladığını, sürekli olduğunu, gece uykudan uyandırdığını belirtti. Tekstil işçisi olarak çalışan hastanın herhangi bir travma öyküsü ve soygeçmişinde özellik yoktu. Özgeçmişinde hipotroidi, anksiyete bozukluğu ve ülseratif kolit mevcuttu. Sigara ve alkol kullanımı yoktu. Hastanın başvurusunda 75 mcg/gün levotiroksin sodyum, 50 mg/gün ketiapin, 2000 mg/gün sulfasalazin, 1x1/gün mesalazin lavman, 20 mg/gün prednizolon ve 150 mg/gün azatioprin kullandığı öğrenildi. 2018 yılına kadar mesalazin ve sülfasalazin tedavisi ile düzenli takip edilen hastanın daha sonra medikal tedavisini aralıklı kullandığı ve takiplerinin olmadığı görüldü. 2023 yılında karın ağrısı ve kanlı ishal şikayetleri olan hastaya ülseratif kolit atağı nedeniyle 20 mg/gün prednizolon ve azatioprin 50 mg/gün başlanmıştı. Hastanın prednizolon dozu sabah 32 mg, akşam 16 mg olarak düzenlenmiş; azatioprin dozu 150 mg/gün'e çıkarılmıştı. Prednizolon tedavisinin 3. ayında prednizolon 20 mg'a düşürülmüş olup, bu süreçte hastaya adalimumab tedavisinin başlandığı ancak devam etmediği görüldü. Hastanın genel sistem muayenesi normaldi. Kas iskelet sistemi muayenesinde kas gücü bilaterel alt ve üst ekstremitede 5/5 idi. Bilateral kalça eklem hareketleri ağrılıydı. Eklemlerinde artrit ile uyumlu bulgu yoktu. Başvuru esnasında hastanın düzenli olarak kullandığı ilaçlar azatioprin 150 mg/gün, 1200 mg/gün kalsiyum +880 IU/gün vitamin D3, rabeprazol 1x1/gün ve prednizolon 4 mg/gündü. Hastanın mevcut şikayetlerine yönelik yapılan laboratuvar tetkiklerinde CRP: 2,59 mg/L (0-0,5 mg/L), ESR: 6 mm/saat (0-25 mm/saat), romatoid faktör düzeyi 10,84 IU/mL, antisiklik sitrulin peptid (<7 U/mL), ENA profili (antiSM-RNP), hepatit markerları ve *Brusella* negatifti. Spondiloartropati ve AVN ön tanıları ile kalça, sakroiliak eklem ve lomber MRG yapıldı. Kontrastlı sakroiliak MRG incelemesinde sakroileit bulgusu saptanmadı. Lomber MRG incelemesinde L3-L4 intervetrebral diskinde ve L4-L5 intervertebral diskinde diffüz bulging zemininde geniş tabanlı santral posterior minimal protrüzyon izlendi. Kontrastlı kalça MRG incelemesinde bilateral femur baş kesiminde T1AG'de jeografik sınırları hipointens hatlar olup AVN olarak tespit edildi (Şekil 1). Bilateral femur başı AVN'yi tanısı ile ortopedi bölümüne yönlendirilen hastanın konservatif takip edilmesi planlandı. Sık aralıklarla takip edilen hastaya ağrı palyasyonu, yatak istirahati, prednol 4 mg/gün dozunun kesilmesi, azatioprin 150 mg/gün devam edilmesi önerildi. Hastanın kemik mineral yoğunluğu ölçümünde L1-L4 vertebra T-skoru-2,0 ve sol femur boyun T-skoru-1,9 olması nedeniyle ibandronik asit 3 mg intravenöz tedavi başlandı, daha önce başlanan kalsiyum karbonat ve kolekalsiferol tedavisine devam edildi. Polikliniğimizde takip edilen hastanın, yaklaşık 20 gün sonra bel ve kalça ağrısının devam etmesi, sağ alt ekstremitede güçsüzlük ve yürüme güçlüğü şikayetlerinin gelişmesi üzerine kontrastlı lomber MRG incelemesi planlandı. L1, L2 vertebra komşu end platelerinde düzensizlikler, vertebra korpuslarında T1AG ve T2AG'de hipointens sinyal değişiklikleri, intervertebral disk mesafesinde sağ yarımında hafif intensite artışı izlendi. Vertebra korpuslarında ve komşu end platelerinde yoğun kontrast tutulumu, disk komşuluğundan başlayıp paravertebral yumuşak dokulara ve sağda psoas kasına uzanım gösteren spondilodiskit lehine bulgular izlendi (Şekil 2). Hastanın laboratuvar tetkiklerinde CRP: 4,75 mg/L, ESR: 103 mm/saat idi. Kemik doku kültüründe ve mikobakteri kültüründe üreme saptanmaması, mikobakteri polimeraz zincir reaksiyon testi negatif olması üzerine hastaya spondilodiskit tanısıyla moksifloksasin 400 mg 1x1/gün, sodyum fusidat 500 mg 3x1/gün olarak medikal tedavisi başlandı. Üç ay sonra yapılan kontrol kontrastlı lomber MRG incelemesinde L1-L2 vertebraların komşu end platelerindeki T1AG ve T2AG'de hipointens sinyal değişiklikleri ve intervertebral disk mesafesinde sağ yarımındaki hafif intensite artışı önceki incelemeye kıyasla hafif gerilemiş;



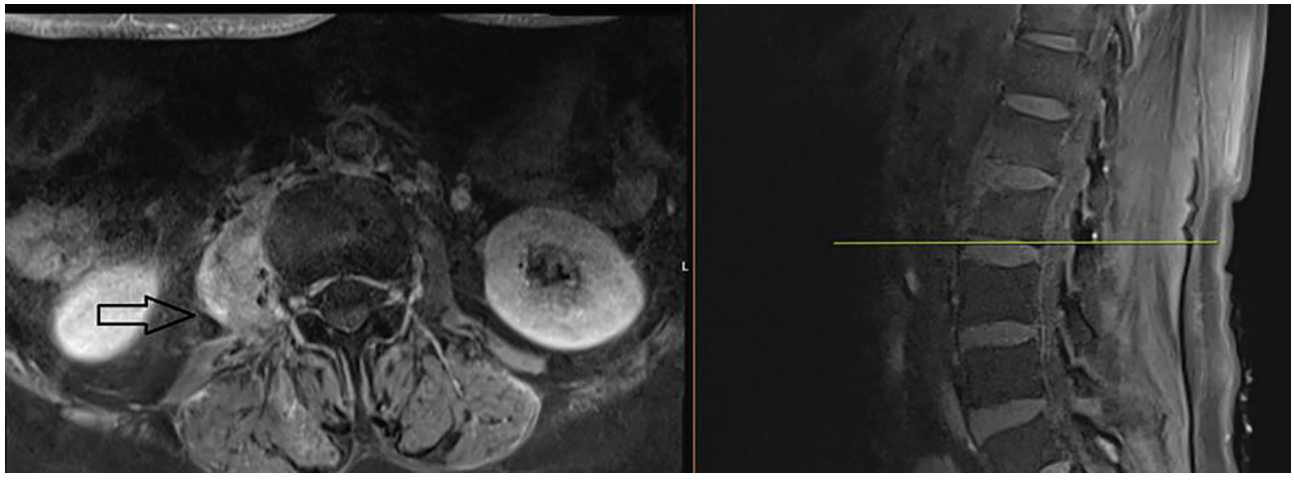
Şekil 1. Bilateral kalça MRG (bilateral femur baş kesiminde T1 ağırlıklı sekanslarda jeografik sınırlı hipointens hatlar izlendi ve avasküler nekroz tespit edildi)

MRG: Manyetik rezonans görüntüleme

kontrast görüntülerde L1-L2 vertebra korpuslarındaki kontrast tutan alan genişliği ve kontrast tutulumu güncel incelemede minimal azalmakla birlikte devam etmiş olarak görüldü (Şekil 3). Hastanın polikliğimizdeki takiplerinde ilk başvurudan yaklaşık 5 ay sonra yaygın eklem ağrısı, el-bilek eklemlerinde şişlik, hassasiyet ve sabah tutukluğu şikayetleri başladı. Fizik muayenesinde sağ 3. parmak PIF ekleminde artrit, el-el bilek eklemlerinde hassasiyet görüldü. Hastanın medikal tedavisine kolşisin 1 mg/gün ve selekoksib 200 mg 1x1/gün eklendi. Antibiyotik tedavisi 6 aya tamamlanan hastanın laboratuvar tetkiklerinde CRP: 0,08 mg/L, ESH: 13 mm/saat olarak izlendi. Hastaya ülseratif kolit ve spondiloartraopati tanılarıyla Upadacitinib 30 mg/gün başlandı. Bir ay sonraki kontrolünde akut faz reaktanlarının da negatif olduğu görüldü. İlk başvurudan yaklaşık 10 ay sonra yapılan lomber MRG'de L1-L2 vertebra karşılıklı end platelerde anterior yarıda hafif kontrastlanma olup önceki incelemeye göreye vertebra korpuslarındaki kontrast tutulumunda tümüyle regresyon ve end platede kontraslanmada belirgin azalma izlendi (Şekil 4). Artrit, inflamatuvar bel ve kalça ağrısı olmayan hastanın romatolojik takip ve tedavisi devam etmektedir.

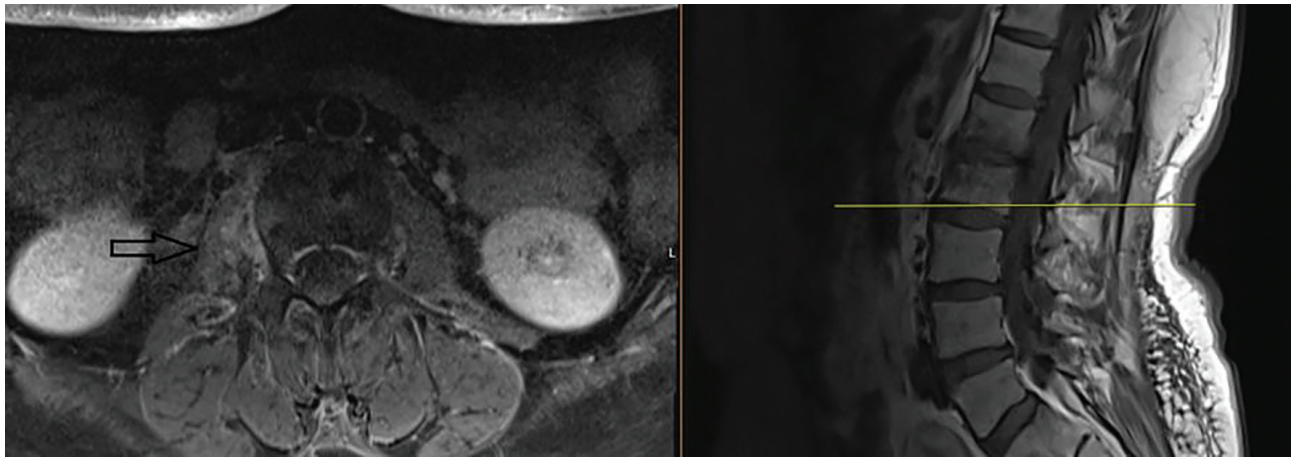
Tartışma

Spondilodiskit, omurga diskleri ve vertebral cisimlerin enfeksiyonuyla karakterize edilen ciddi bir klinik durumdur. Literatürde spondilodiskit için farklı etiyolojik ajanlar ve risk faktörleri bildirilmiştir. Ancak, spondilodiskit ve AVN'nin birlikte görüldüğü olguların sayısı oldukça nadirdir ve bildiğimiz kadarıyla literatürde, bu iki durumu birlikte ele alan spesifik bir olguya rastlanmamıştır. Olgumuzda, femur başı AVN gelişimini takiben



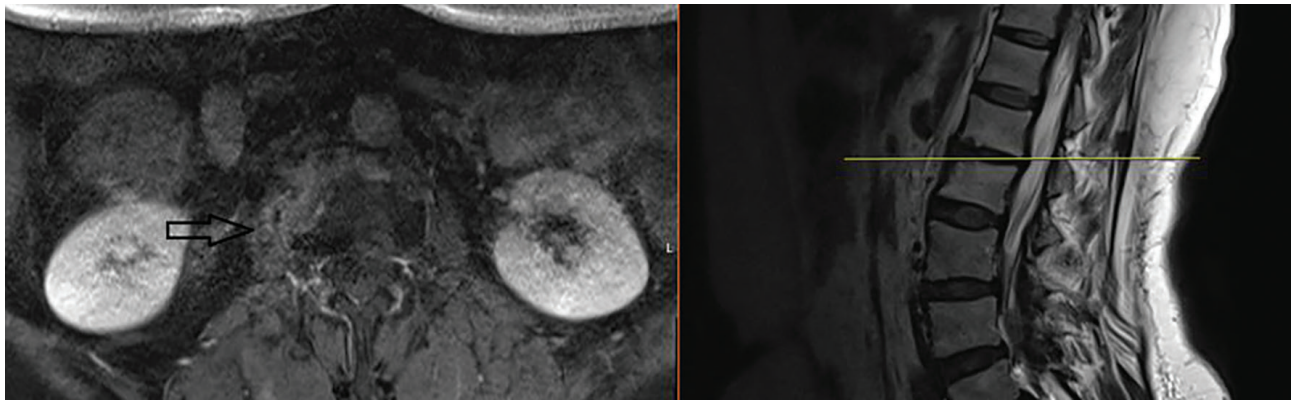
Şekil 2. Kontrastlı lomber MRG'de L1-L2 vertebra komşu end platelerinde düzensizlikler, L1-L2 vertebra korpuslarında T1 ağırlıklı sekaslarda hipointens sinyal değişiklikleri mevcuttu. T1 ağırlıklı postkontrast serilerde L1-L2 vertebra korpuslarında, paravertebral yumuşak dokularda ve sağda psoas kasına uzanım gösteren spondilodiskit lehine bulgular izlendi

MRG: Manyetik rezonans görüntüleme



Şekil 3. Kontrastlı lomber MRG incelemesinde T1 ağırlıklı sekaslarda L1-L2 vertebraların komşu end platelerindeki hipointens sinyal değişiklikleri ve intervertebral disk mesafesinde sağ yarımındaki hafif intensite artışı 3 ay önce yapılan incelemeye kıyasla hafif gerilemiş olup devam etmektedir. T1 ağırlıklı postkontrast serilerde L1-L2 vertebra korpuslarındaki kontrast tutan alan genişliği ve kontrast tutulumu minimal azalmış olup devam etmektedir

MRG: Manyetik rezonans görüntüleme



Şekil 4. Kontrastlı lomber MRG incelemesinde T1 ağırlıklı sekaslarda L1 ve L2 vertebra karşılıklı end platelerde anterior yarıda hafif kontrastlanma mevcuttu. Üç ay önce yapılan incelemeye göre vertebra korpuslarındaki kontrast tutulumda tümüyle regresyon ve end platede kontrastlanmada belirgin azalma mevcuttu

MRG: Manyetik rezonans görüntüleme

spondilodiskit gelişmiş; takiplerde spondiloartropati gelişimi ve tedavi süreci vurgulanmıştır.

Spondilodiskit, romatizmal, enfeksiyöz ve dejeneratif hastalıklarla ilişkili olarak gelişebilen; insidansını artıran risk faktörleri arasında diabetes mellitus, immünosupresyon, uyuşturucu kullanımı öyküsü ve HIV'nin bulunduğu ciddi bir enfeksiyondur. Spondilodiskit, geniş bir klinik spektruma sahip olup, birçok klinik durumu taklit edebildiği için yanlış tanı ve tedavi sonucu geri döndürülemez deformiteler gelişebilir. Genellikle bakteriyel kaynaklıdır ve erken teşhis ile uygun tedavi gerektirir. Enfeksiyon, hematojen yayılım yoluyla monobakteriyel enfeksiyon olarak ortaya çıkabilir. Spondilodiskitte Avrupa'daki olguların %50'sinden fazlasından sorumlu olan patojen *Staphylococcus aureus*'dur, bunu ise *Escherichia coli* gibi Gram-negatif patojenler (%11-25) takip eder. Dünya genelinde granülomatöz spondilodiskitin en sık nedeni *Mycobacterium tuberculosis*'tir. Bruselloz, Akdeniz ülkeleri ve Orta Doğu'da önemli bir diğer nedenidir (10-13).

Osteonekroz gelişimi sırasında, nekrotik kemik dokusu kontrolsüz inflamasyona yol açarak kronik bir inflamatuvar mikroçevre yaratır. Bu durum kemik rejenerasyonunu ve onarımını engeller. Osteonekrozun patogenezinde bağışıklık hücrelerinin ve inflamatuvar yanıtlarının düzenlenmesinin önemi, osteonekrozun patofizyolojik mekanizmasını ve immünolojik yanıtın rolünü ortaya koymaktadır. İmmün sistemin osteonekrozun gelişimi ve şiddeti üzerindeki karmaşık etkileri literatürde bildirilmiştir (5,11,14). Spondilodiskit, özellikle enfeksiyonun tetiklediği inflamatuvar süreçler nedeniyle dolaşım sistemini olumsuz etkileyerek osteonekroz gelişimine zemin hazırlayabilir. Enfeksiyona bağlı inflamasyon sırasında aşırı miktarda reaktif oksijen radikalleri üretilir. Bu durum çevredeki normal dokulara zarar veren proteazların aktive olmasına neden olur. Sürekli yüksek inflamasyon seviyeleri, osteogenik yanıtı bozarak kemik rejenerasyonunu olumsuz yönde etkiler. Kemik hasarının erken evresinde, tümör nekroz faktörü-α ve interlökin-6 gibi inflamatuvar sitokinler osteoblastların öncü hücrelerini harekete geçirerek rejenerasyonu destekleyen sinyaller oluşturur. Ancak bu sitokinlerin kronik olarak yüksek seviyelerde bulunması osteogenezi engelleyip kemik dokusunda daha fazla hasara yol açabilir. Aşırı inflamasyon, osteoklast farklılaşmasını ve aktivasyonunu uyararak inflamatuvar osteolize neden olur. İnflamatuvar yanıtın yetersiz olduğu durumlarda ise lokal ölü hücre ve kemik artıkları mikroçevrede birikerek hasar ilişkili moleküler paternlerin kalıcı hale gelmesine yol açar. Bu iki durum inflamasyonun kronikleşmesine neden olur ve sonuçta kemik rejenerasyonunu engelleyip osteonekrozu tetikler (14).

Spondilodiskit bağlamında enfeksiyon kaynaklı inflamasyonun bu mekanizmalar aracılığıyla osteonekroz riskini artırdığı düşünülmektedir. Ayrıca artan kronik inflamasyonun, osteonekroz gelişen alandaki lokal bağışıklık fonksiyonlarına zarar verdiği bildirilmiştir. Olgumuzda, ülseratif kolit nedeniyle uzun süre immünosupresan ilaç kullanımı öyküsü bulunmaktaydı. Spondilodiskitin AVN'yi takiben gelişmesi, bu iki durumun patofizyolojik süreçlerinin birbiriyle nasıl etkileşime girebileceği konusunda yeni sorular ortaya çıkarmaktadır. İmmün sistem fonksiyonlarındaki bu değişiklikler, spondilodiskit gelişimini kolaylaştırabileceği gibi mevcut enfeksiyöz etkenlerin daha geniş bir alana yayılmasına neden olarak spondilodiskite neden olabilir. İki patolojik sürecin birbirini takip ederek gelişmiş olması, femur başındaki AVN'nin inflamatuvar süreçleri tetikleyerek genel vücut savunma mekanizmalarını zayıflatmış olabileceğini ve böylece spondilodiskit gelişimine zemin hazırlamış olabileceğini düşündürmektedir. Patofizyolojik mekanizmalar göz önüne alındığında, bu süreçlerin birbirini karşılıklı olarak besleyebileceği ve bunun bir kısır döngü oluşturabileceği ihtimali öne çıkmaktadır. Bu nedenle, inflamasyon ve nekrozun bir arada bulunması enfeksiyonun seyrini olumsuz etkileyebilir ve tedavi sürecini karmaşıklaştırabilir. Hem osteonekrozun spondilodiskiti artırması hem de spondilodiskitin osteonekrozu kötüleştirmesi tedavi sürecini oldukça uzun ve zorlu hale getirebilir. Mevcut olgumuzda da yaklaşık altı ay süren tedavi süreci bu durumu desteklemektedir.

Spondilodiskit gelişimine zemin hazırlayan faktörlerden biri de romatizmal hastalıklardır. Romatoloji pratiğinde, spondilodiskitin en önemli nedeni ankilozan spondilittir. Spondilodiskit, ankilozan

spondilitin nadir görülen bir komplikasyonudur. İlk olarak 1937'de Andersson (15) tarafından tanımlanmış ve yaygınlığının %1-10 arasında olduğu bildirilmiştir. Genellikle akut bir başlangıcı vardır ve ağrı özellikleri daha önce tanımlananların aksine, hareketle kötüleşir ve dinlenmeyle düzelir (15,16). Olgumuzda, ilk başvuru anında ve takiplerde aksiyal spondiloartriti gösteren klinik ve görüntüleme bulguları yoktu. Ancak hastanın poliklinik takiplerinde periferik eklem tutulumu gelişmişti.

Sonuç

Bilateral femur başı AVN'yi ve spondilodiskitin birlikte görülmesi nadir bir durumdur. Bu iki ciddi durumun birbirini nasıl etkilediği tam olarak anlaşılamamıştır. Bu olgu, klinisyenlerin iki durumun birlikte bulunduğu hastalarda daha dikkatli olmaları gerektiğini ve her iki patolojiyi de tedavi planlarına dahil etmeleri gerektiğini göstermiştir. AVN ve spondilodiskit gelişen, uzun süre immünsupresan tedavi alan olgumuzda multifaktöriyel etiyoloji olduğu ihtimali yüksektir. Kronik kortikosteroid kullanımı, immünosupresif tedavi ve altta yatan inflamatuvar durum patogeneze katkıda bulunmuştur. Ülseratif kolit tanılı hastada gelişen ve dizabiliteye neden olabilecek bu iki ciddi durumu takiben gelişen periferik eklem tutulumu kronik inflamatuvar hastalığı olan ve uzun süreli kortikosteroid tedavisi gören hastalarda dikkatli izlem ve erken müdahalenin önemini göstermiştir.

Etik

Hasta Onayı: Olgu raporunun ve eşlik eden görsellerin yayınlanması için yazılı bilgilendirilmiş onam alındı.

Dipnot

Yazarlık Katkıları

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Beyond Greater Trochanteric Pain Syndrome: The Role of Tensor Fascia Latae Myofascial Pain in Lateral Hip Pain

Büyük Trokanterik Ağrı Sendromunun Ötesinde: Lateral Kalça Ağrısında Tensor Fasya Lata Miyofasiyal Ağrısının Rolü

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Keywords: Greater trochanteric pain syndrome, lateral hip pain, myofascial pain, tensor fascia lata, trigger point

Anahtar kelimeler: Büyük trokanterik ağrı sendromu, lateral kalça ağrısı, miyofasiyal ağrı, tensor fasya lata, tetik nokta

Dear Editor,

Lateral hip pain, characterized by discomfort around the greater trochanter, has traditionally been attributed to trochanteric bursitis. However, advances in imaging techniques have revealed that the prevalence of true trochanteric bursitis is lower than previously thought. Given the complexity of lateral hip pain, trochanteric bursitis alone does not fully account for the spectrum of symptoms. Conditions such as snapping hip syndrome, abductor tendon tears, and dysfunction of the surrounding musculature are now collectively referred to as greater trochanteric pain syndrome (GTPS) (1-3).

Dysfunction, overuse injuries, and tears of key stabilizing muscles, particularly the gluteus medius and minimus, are primary contributors to GTPS. Other potential causes of lateral hip pain include joint-related disorders, iliotibial band syndrome, meralgia paresthetica, lumbar spine pathologies, and myofascial pain syndromes, although these are less frequently diagnosed.

Although less frequently reported in the literature, myofascial disorders of the tensor fascia latae (TFL) muscle represent another overlooked cause of lateral hip pain, distinct from GTPS. The TFL muscle, located on the anterolateral aspect of the hip, functions synergistically with the gluteal muscles to facilitate hip abduction, flexion, and internal rotation. Originating from the anterior superior iliac spine, the TFL inserts into the fascia lata and distally transitions into the iliotibial band, playing a crucial role in stabilizing the pelvis during gait and maintaining tension in the fascia lata (1-4). Given its anatomical positioning and functional connections, myofascial pain originating from the TFL muscle may present as referred pain, radiating from the anterolateral aspect of the hip to the lateral thigh and sometimes extending to the knee (Figure 1a). This pain pattern can mimic other common causes of lateral hip and knee pain, often leading to misdiagnosis.

The diagnosis of TFL myofascial pain hinges on the identification of hyperirritable nodules within the muscle, eliciting referred pain patterns upon palpation. A hallmark feature is the local twitch response triggered by direct pressure or needling. Clinically, TFL myofascial pain may result in restricted joint range of motion and muscle weakness despite the absence of visible atrophy. This diagnostic overlap with other hip pathologies underscores the importance of a thorough physical examination. A meticulous physical examination, emphasizing palpation to localize tenderness and identify trigger points, is essential for accurate diagnosis. The flat palpation technique is particularly effective in detecting trigger points within the TFL muscle (2-5).

Management of TFL myofascial pain involves a multimodal approach, including stretching and strengthening exercises, posture correction, and pharmacological interventions such

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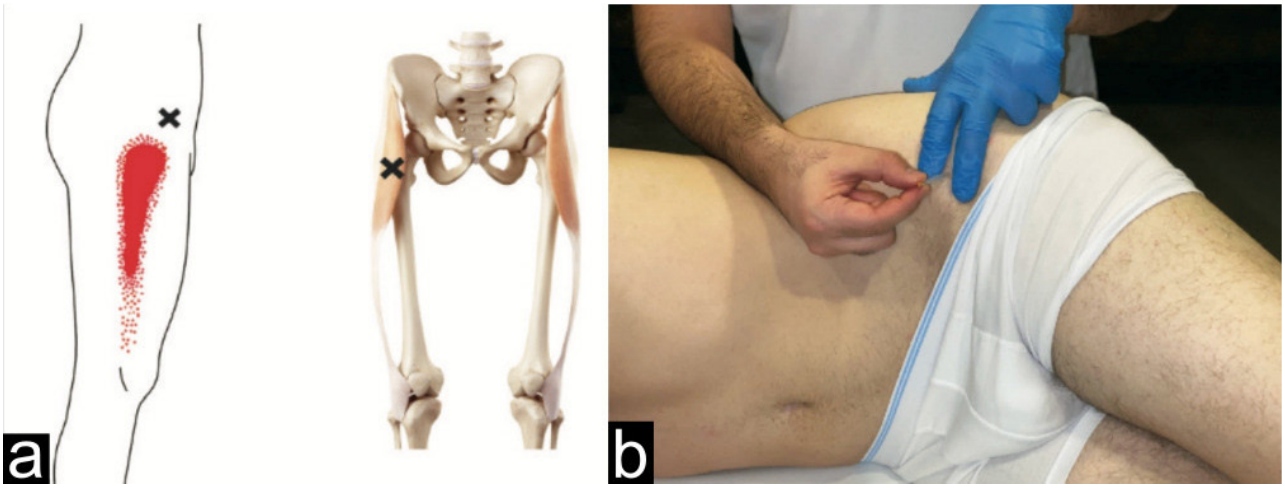

Figure 1. (a) Referred pain distribution associated with the tensor fascia latae (TFL) muscle trigger point, illustrating the radiation from the anterolateral hip to the lateral knee. (b) Illustration of the dry needling technique for TFL trigger points, employing flat palpation and perpendicular needle insertion at the identified site

as tricyclic antidepressants and muscle relaxants. Additionally, thermal agents (hot and cold therapy) and targeted trigger point injections are commonly employed to alleviate symptoms and restore functional mobility (5). Dry needling, a highly effective technique for deactivating trigger points, is frequently utilized in the management of TFL myofascial pain. The procedure is performed with the patient in a supine position, the hip and knee slightly flexed to optimize muscle accessibility. Using the flat palpation method, an acupuncture needle (0.30×30 mm) is inserted perpendicularly from ventral to dorsal into the identified trigger point (Figure 1b). This approach has shown promising results in relieving pain and improving mobility.

Lateral hip pain is a multifactorial condition requiring a comprehensive diagnostic framework. While GTPS is commonly diagnosed, the potential involvement of the TFL muscle in myofascial pain syndromes is underexplored. Unlike gluteal tendinopathies or bursitis, TFL myofascial pain has distinct characteristics, including its referred pain pattern and response to specific interventions like dry needling.

Identifying TFL as a potential source of pain broadens the scope of differential diagnosis for lateral hip pain. This is particularly relevant when conventional treatments for GTPS or hip osteoarthritis fail to alleviate symptoms. The referred pain distribution to the lateral thigh and knee may mislead clinicians toward diagnoses such as iliotibial band syndrome or lateral meniscus pathology, underscoring the need for a detailed physical examination focused on myofascial trigger points (2,5).

Dry needling has emerged as an effective intervention for deactivating TFL trigger points. Its mechanism involves disrupting the dysfunctional motor endplates and improving local blood flow, which helps reduce sensitization and restore muscle function. When combined with postural training, stretching, and strengthening exercises, it provides a comprehensive strategy for managing TFL-related myofascial pain. Additionally, the minimally invasive nature of dry needling makes it a practical choice for patients unresponsive to pharmacological or conservative measures (5,6).

There is a need for high-quality studies investigating the prevalence of TFL myofascial pain and its contribution to lateral hip pain syndromes. Moreover, randomized controlled trials comparing dry needling with other modalities, such as ultrasound-guided injections or physiotherapy, could establish clearer guidelines for treatment.

Myofascial pain of the TFL, although a less common etiology, should be recognized as an important differential diagnosis in lateral hip pain. The muscle's unique referred pain pattern and anatomical positioning often result in diagnostic challenges. By incorporating targeted interventions such as dry needling, clinicians can offer effective relief for patients with refractory lateral hip pain. Future research focusing on diagnostic precision and comparative treatment efficacy will further enhance our understanding of this underappreciated condition.

Footnotes

Authorship Contributions

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

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Not Every Popliteal Swelling is a Baker's Cyst

Her Popliteal Şişlik Baker Kisti Değildir

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Keywords: Popliteal region, Baker's cyst, desmoid-type fibromatosis
Anahtar kelimeler: Popliteal bölge, Baker kisti, desmoid tip fibromatozis

Dear Editor,

We present the case of a 45-year-old male patient who presented to our outpatient clinic with a complaint of swelling behind his right knee, which he had noticed for the past 2-3 months. Prior to this consultation, the patient had visited an orthopedic clinic where, without further investigation, the swelling was diagnosed as a Baker's cyst. He was informed that the cyst could recur if removed, but given the minimal discomfort, no further recommendations were provided.

Subsequent ultrasonography (US) by another physician revealed a dense hypoechoic lesion, approximately 4-cm in diameter, located in the left popliteal fossa. The lesion was initially suspected to be a complicated Baker's cyst or an abscess. The patient returned to our clinic on the same day (March 2022) with this US report. His medical history was otherwise unremarkable, with no systemic diseases or traumatic events. Notably, there was no clinical history suggesting a Baker's cyst at his age, particularly one of such size.

The patient's primary complaint was localized swelling, which caused difficulty squatting. He was otherwise able to perform daily activities without issue. On physical examination, the patient ambulated normally with no signs of antalgia. A large, firm swelling was palpated on the lateral aspect of the left calf (Figure 1), with a noticeable increase in calf diameter by 2-cm. The knee and hip joint range of motion were both normal and pain-free.

Plain radiographs were unremarkable, and a follow-up US revealed a heterogeneous, hypoechoic mass with lobulated contours, measuring approximately 4 cm in diameter. Color Doppler imaging showed evidence of vascular flow. Magnetic resonance imaging (MRI) performed the following day (Figure 2) revealed grade II meniscopathy of the medial meniscus posterior horn and a linear hypointense extension in the subchondral region of the tibial plateau, suggestive of a subchondral insufficiency fracture. A mass (56×90×102 mm) was identified in the lateral popliteal region with heterogeneous T1 hypointensity and T2 hyperintensity, which demonstrated signal voids, likely representing vascular structures, and exhibited intense, heterogeneous contrast enhancement with external compression of adjacent muscles and vasculature. Differential diagnoses included peripheral nerve sheath tumors and soft tissue sarcomas.

The patient was referred to orthopedic surgery, where biopsy results confirmed the diagnosis of desmoid fibromatosis. Despite its locally aggressive nature, no chemotherapy or radiotherapy was initiated, and the patient was closely monitored. A second surgical intervention was performed in August 2023.

Follow-up MRI in May 2024 identified two new lesions: One measuring 24 mm in diameter near the biceps femoris muscle in the popliteal region and another 18×13 mm lesion beneath the skin in the popliteal fossa posteriorly. These findings raised concerns for recurrence, and the patient continues to be monitored by his orthopedic team.

While Baker's cyst is the most common cause of popliteal masses in adults, other potential etiologies, including hematomas, adipose tissue proliferation, extra-articular ganglion cysts, popliteal artery aneurysms, thrombosed varicose veins, gouty tophi, and both benign and malignant soft tissue tumors, should be considered in the differential diagnosis (1-4). A Baker's cyst, characterized by a fluid-filled cystic formation within the bursa between the medial head of the gastrocnemius and semimembranosus tendons, is typically located medially within the popliteal fossa. It commonly arises in conjunction with conditions associated with increased intra-articular fluid, such as osteoarthritis, inflammatory rheumatic diseases, and trauma, although it can also occur idiopathically. US is a valuable tool for

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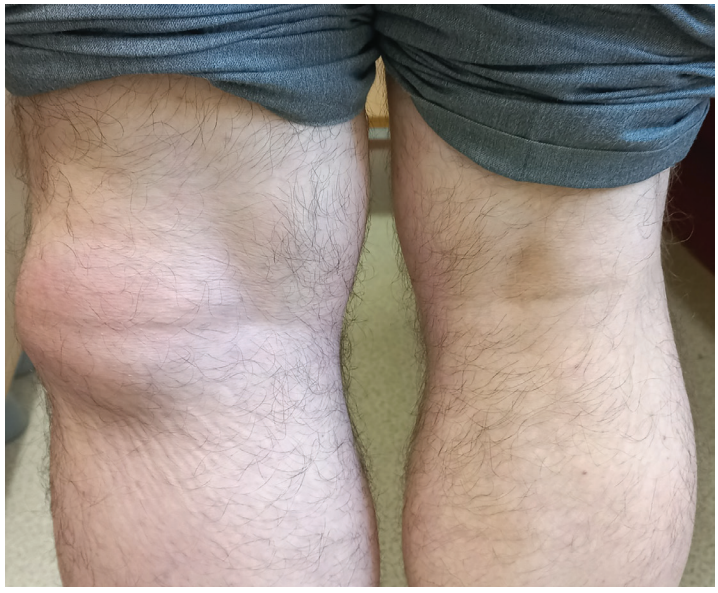

Figure 1. There is a significant swelling in the lateral aspect of the left popliteal region

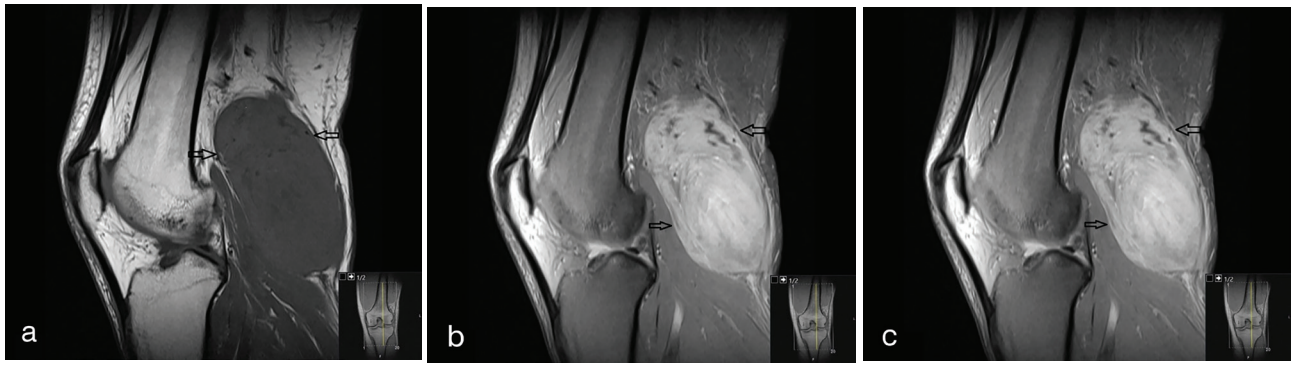

Figure 2. a) A 45-year-old male patient with a T1 hypointense mass with regular lobulated contours located within the biceps femoris muscle in the distal thigh (open black arrows). b) The same mass shows heterogeneous hyperintense signal characteristics on sagittal proton density-weighted imaging (open black arrows). c) The mass shows heterogeneous intense contrast enhancement on coronal T1-weighted images obtained following contrast medium administration (open black arrows)

evaluating knee and popliteal masses, enabling differentiation between cystic and solid lesions (5). However, diagnostic accuracy is highly operator-dependent, and, as seen in this case, a solid mass may be misinterpreted as a Baker's cyst on initial examination.

Desmoid-type fibromatosis is a locally aggressive fibroblastic neoplasm arising from deep soft tissues. Although it lacks metastatic potential, it exhibits infiltrative growth, a high tendency for local recurrence, and, in some cases, spontaneous regression (6,7). In this case, despite the initial suspicion of a Baker's cyst, the presence of a large mass in an adult without a history of significant trauma or inflammatory disease warranted further investigation. The lateral location of the mass, which is atypical for a Baker's cyst, further supported the need for a broader differential diagnosis.

In conclusion, while Baker's cysts remain the most common cause of popliteal masses in adults, other potential causes, particularly benign and malignant soft tissue tumors, must also be considered. A thorough clinical history, physical examination, and imaging studies such as US and MRI, complemented by radiography, are essential for accurate diagnosis and appropriate management.

Footnotes

Authorship Contributions

Concept: S.Ç., O.D., A.Y., Design: S.Ç., O.D., A.Y., Data Collection or Processing: S.Ç., O.D., A.Y., Analysis or Interpretation: S.Ç., O.D., A.Y., Literature Search: S.Ç., O.D., A.Y., Writing: S.Ç., O.D., A.Y.

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