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THE EFFECTIVENESS OF WHOLE BODY MAGNETIC RESONANCE IMAGING USED IN HEALTH SCREENING PROGRAMS IN EARLY STAGE CANCER DIAGNOSIS

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Abstract

Objective: We aim to present the findings and effectiveness of Whole Body Magnetic Resonance Imaging (WBMRI), which we use in the Health Screening Program (HSP) to diagnose cancer in early stage.

Methods: This retrospective study was conducted between January 2017-February 2023. 393 individuals, between the ages of 18 and 85, who underwent WBMRI for HSP purposes, were included. The mean age was 50.

Results: Malignancy suspicious lesions were observed in the head/neck region in 25 cases. Additional Magnetic Resonance (MRI) and Ultrasound (US) were performed. Mediastinal pathology was observed in 23 cases, and non-mediastinal thoracic pathologies were detected in 15. Therefore thorax Computed Tomography (CT), mammography, and breast US were performed. Benign lesions were observed in the liver in 44 cases, and US was performed. Malignancy-suspicious lesions in the liver were observed in 4, and dynamic abdominal MRI was performed. Cholelithiasis was observed in 16, and confirmed by US. The most common renal findings were; cysts and pelvicalyceal ectasia. Adrenal adenoma was observed in 5 cases. Two of the females had suspicion of gynecological malignancy. Massive diffuse concentric wall thickening was observed in the sigmoid colon, and colonoscopy was performed on one male. Musculoskeletal benign lesions were detected in 99 cases, and malignancy-suspicious lesions were detected in 35. Additional examinations such as US, CT, MRI, PET-CT, scintigraphy, and colonoscopy were performed on 172 cases. Malignancy was detected in 11 cases (2.8%).

Conclusion: WBMRI is a radiation-free, non-invasive, short-term examination method. WBMRI is beneficial in diagnosing early-stage cancer.

Keywords: *Health screening program, whole body magnetic resonance imaging, cancer screening.*

Introduction

Whole-Body Magnetic Resonance Imaging (WB-MRI), first introduced in the 1970s, was developed as an advanced imaging technique to detect diseases and possible cancer in multiple regions and organ systems in the body at an early stage.[1,2] With advances in MRI hardware and software, especially the development and addition of Diffusion-Weighted Magnetic Resonance Imaging (DW-MRI), WB-MRI has become an increasingly used method in today's health screening programs. DW-MRI was first developed by Takahara et al.[3] Since then, studies on the use and development of DW-MRI have increased, especially in oncological imaging. With technological advances, the DW WB-MRI concept has been developed and implemented in the clinic. DW WB-MRI enables the detection and characterization of oncological and non-oncological lesions in the body.[4] WB-MRI provides acceptable spatial resolution to detect focal lesions between 5 and 10 mm.[5]
In diffusion imaging, images are obtained based on the microscopic movement of water molecules depending on the tissue's cellular content. Uncontrolled proliferating cancer cells cause diffusion loss through increased signal in DW-MRI. However, physiological signal increases may be observed in some organs such as spleen, kidney, and spinal cord.[6] DW WB-MRI enables qualitative and quantitative evaluation of focal lesions through signal intensity evaluation and the creation of the Apparent Diffusion Coefficient (ADC) map.[7]
Although there are differences in the MRI sequences and protocols applied for image acquisition in WB-MRI, DW, fat-suppressed T2-weighted sequences, fat/water-suppressed T2-weighted sequences, and T1-weighted sequences are generally used. When an abnormal finding or mass is detected on imaging, the findings are more clearly characterized with specific radiological imaging for that area, aiming to distinguish benign from malignant, and deciding which patients should be followed and which patients should be biopsied. The whole body can be imaged in a single session. It can be applied alongside other health screening methods.[8] It provides the opportunity for early diagnosis and treatment in healthy people with a family history of cancer and genetic risk. It can also be used to evaluate the extent of the disease and response to treatment in patients diagnosed with cancer. The advantages of the examination are its high spatial resolution, the absence of ionizing radiation, and the absence of contrast material during the procedure. WB-MRI is contraindicated in those who carry metallic or electronic equipment incompatible with the magnetic field and those with claustrophobia.[8,9]
The aim of this study is to retrospectively evaluate a series of cases who underwent WB-MRI for health screening purposes. We aim to share our WB-MRI findings, present the advantages and disadvantages of the examination, determine its effectiveness in cancer diagnosis, and emphasize the importance of early diagnosis and treatment of cancer.

Methods

Images of 393 cases who underwent WB-MRI for the health screening program in our institution between January 2017 and February 2023 were retrospectively scanned. Demographic data of the cases from the hospital electronic record system and radiological images in the system, if any, and cases requiring further examination after WB-MRI were included in the study. WB-MRI was performed using a 1.5 Tesla MRI device (GE Signa Explorer). In imaging; Axial DW (b50-b800), Short T1-weighted Inversion Recovery (STIR) coronal slices, Liver Acquisition with Volume Acquisition (LAVA) fat and water-suppressed T2-weighted sequence coronal and sagittal slices, three-dimensional (3D) fast gradient echo (GRE) sequences used. The section thickness was 5 mm from the vertex of the cranial region to the distal thigh scanning was performed for the head-neck region, thorax, abdomen, and musculoskeletal system. The process took an average of 45-50 minutes. Patients held their breath for 20 seconds in each imaging to prevent respiratory artifacts in the thorax and abdomen sections. To evaluate the gallbladder and bladder, imaging was performed by fasting for 10 hours and ensuring that the bladder was full.
MR images were reviewed retrospectively by a single radiologist experienced in this field. The detected MRI findings are presented by classifying them as head-neck, thorax, intra-abdominal organs, and musculoskeletal system. Additionally, cases requiring further examination and suspicion of malignancy were identified and presented.

Statistical Analysis

All analyses were performed on SPSS version 21 (SPSS Inc., Chicago, IL, USA).

Results

The images of a total of 393 adult patients, 177 (45%) female and 216 (55%) male, who underwent WB-MRI for health screening purposes in our hospital's image archiving and communication system between January 2017 and February 2023, were retrospectively evaluated by a single radiologist. The age range of the cases was 18-85 years, the average age was 50.34 and the median age was 50.
In the head and neck region examination, no pathology was detected in 72 of the males and 81 of the females. In most of the remaining cases, minor findings that did not require additional examination were detected. Signs of sinusitis were observed in 69 males and 54 females, reactive lymph nodes were observed in 6 males and 10 females, and cervical reactive lymph nodes along with sinusitis were observed in 17 males and 6 females. Minor findings such as septal deviation were observed in 37 males and 16 females. Major findings are classified as findings requiring further radiological examination such as Ultrasonography (US), Computed Tomography (CT), and MRI. In male cases with major findings; An arachnoid cyst, an intracranial infarct area, and a postoperative encephalomalasic area were observed in 3 different cases. These patients underwent contrast-enhanced cranial MRI. Heterogeneous signal was observed in the parotid gland in 6 of them and US was performed. In 5 of them, nodules were detected in the thyroid gland and US was performed. Periventricular chronic ischemic changes were detected in 3 females. A possible meningioma was detected in one of them and a contrast-enhanced cranial MRI was performed (Figure 1). In 6 of them, a nodule was observed in the thyroid gland and US was performed.
No thorax pathology was detected in 156 females and 199 males. Pathology related to the thorax-mediastinum was detected in 11 females, and pathologies outside the thorax and mediastinum were detected in 10 females within the thoracic sections. Unilateral in one of them, bilateral atelectasis in one, cardiomegaly in one, mediastinal and hilar lymphadenopathy in one, hiatal hernia in one, pleural effusion and

accompanying atelectasis in one, right hemidiaphragm elevation in three, bilateral and unilateral lung parenchymal infiltration in one, and all of them underwent thorax CT. Breast cysts were observed in 7 females, and mammography and breast US were performed. Bilateral breast prosthesis was seen in one of them. Axillary lymph nodes were seen in 2 of them and US was performed. Thorax-mediastinum pathology was detected in 12 males. Cardiomegaly was observed in one of them, bilateral hilar lymph nodes in two, infiltration areas in both lung parenchyma in one, a lung nodule in one, right hemidiaphragm elevation in five, and left hemidiaphragm elevation in one, tortuous course in the ascending aorta in one, and evaluation with thorax CT was recommended. Non-thoracic-mediastinal pathology was detected in thoracic sections in 5 males. Retrosternal goiter was observed in one, bilateral axillary lymph nodes in three, unilateral axillary lymph nodes in one, and US was performed.

No liver pathology was detected in 130 males and 122 females. Hepatosteatosis and hepatomegaly were detected in 56 males and 37 females. Benign lesions were detected in the liver in 28 males and 16 females, and US was recommended to differentiate between solid and cystic lesions. Lesions suspicious for metastasis were observed in 2 males and 2 females, US, and dynamic liver MRI was performed. No gallbladder pathology was detected in 168 females and 209 men. Gallbladder stones were detected in 9 females and 7 males, and US was recommended. No pancreatic pathology was detected in any of the cases.

No kidney pathology was detected in 131 females and 139 males. Cystic lesions were observed in the kidneys of 25 females and 56 males. Pelvicalyceal ectasia was observed in 12 females and 13 males. Renal cyst and pelvicalyceal ectasia were observed together in 5 of the females. A cyst and a lesion compatible with angiomyolipoma in the other kidney were observed in one, angiomyolipoma was observed in one, pelvicalyceal ectasia and accompanying stones were observed in one, and atrophy in the native kidneys and a transplanted kidney were observed in another one. Cyst and pelvicalyceal ectasia were seen together in 5 males. Atrophy of the native kidneys and a transplanted kidney were observed in one male. Bilateral extrarenal pelvis was seen in two males. Further renal examination was not recommended for any of the cases.

No spleen pathology was detected in 166 females and 188 males. Splenomegaly was detected in 4 females, accessory spleen was detected in 5, spleen lesion was detected in 2, and US was performed. Splenomegaly in 14 males, accessory spleen in 10, and spleen lesion in 4 were observed, and US was performed.

No adrenal gland pathology was detected in 175 females, and 2 had adrenal adenoma. No adrenal gland pathology was detected in 211 males, 3 had adrenal adenoma, and 2 had adrenal fullness.

No gynecological pathology was detected in 129 females. Adnexal cyst was observed in 15, uterine myoma was observed in 10, and an adnexal cyst and uterine myoma were seen together in 2 females. Adnexal cysts and fluid in the pelvis were observed in 7, uterine myoma and fluid in the pelvis in 6, only fluid in the pelvis in 4, and cervical Nabothi Cysts were observed in one. Endometrial thickening was observed in one. Pelvic US was performed on these patients. In one of them, endometrial thickening and a hypointense lesion with irregular contours were observed in the endometrial cavity (Figure 2). Correlative US showed an increase in the endometrial double-layer wall thickness and a hypoechoic solid lesion with irregular contours in the endometrial canal, blood supply was seen in Doppler US. A gynecological examination and endometrial biopsy were performed. In one of the female cases, a right adnexal malignant mass, multiple LAP in the para-aortic area, intra-abdominal implants, liver metastasis, cervical, mediastinal, and hilar multiple LAP were observed (Figure 3,4). Positron Emission Tomography (PET)-CT was performed.

While no andrological pathology was detected in 205 males, an increase in prostate size was observed in 10, and a single testicle was observed in the scrotum in one.

No bladder pathology was detected in 211 males. Multiple bladder stones were detected in one, and US was performed. Bladder wall thickening in one, diverticula in the bladder in two males was detected. An increase in bladder anteroposterior diameter, trabeculation, and diverticular appearance in its contours was detected in one patient, and US was performed. No bladder pathology was detected in females.

Diffuse massive concentric wall thickening was observed at the rectosigmoid colon junction in one male without active complaints, and PET-CT was performed after the colonoscopy (Figure 5). Mesenteric panniculitis was observed in one male, and abdominal CT was performed. Infrarenal abdominal aortic aneurysm was detected in two males, and CT angiography was recommended.

Musculoskeletal system findings were divided into 3 classes: Those with no pathology, minor findings, and major findings requiring further CT/MRI. Mild findings were classified as mild gonarthrosis, coxarthrosis, scoliosis, tendinosis, bursitis findings, mild degenerative changes in the intervertebral discs/mild bulging appearance, mild bone marrow edema, and simple cystic degenerative changes in the humerus and femur. Findings requiring further examination were classified as mass lesions detected in the bones, significant bone marrow edema, intramedullary heterogeneous bone marrow signal, significant coxarthrosis, gonarthrosis, avascular necrosis, and significant herniation in the intervertebral discs (Figure 6,7). No pathological findings related to the musculoskeletal system were found in 119 females and 140 males. Mild findings were observed in 45 females, and findings requiring additional cross-sectional examination were observed in 13. In 2 of them, a bone lesion suspicious for metastasis was observed in the femur and humerus, and scintigraphy was performed. Mild findings were detected in 54 males, and findings requiring additional examination were detected in 22.

Further examination was recommended in 25 cases due to findings related to the head and neck, in 25 cases due to the findings associated with the thorax, in 87 cases due to findings related to the abdomen, and in 35 cases due to the findings associated with the musculoskeletal system. 172 cases underwent advanced examinations such as US, CT, MRI, colonoscopy, and PET-CT (Table 1).

In terms of malignancy, liver metastasis was detected in two of the females, endometrial cancer in one, ovarian malignancy in one, and bone metastasis (Table 2). One male had a lesion suspicious of an intracranial tumor, one had bilateral hilar lymphadenopathy, two had liver metastases, and one had rectosigmoid colon cancer (Table 3).

When divided by gender, no benign or malignant lesions were observed in 100 females and 122 males. Benign lesions were detected in 71 females and 89 males, and malignancy-suspicious lesions were detected in 6 females and 5 males (Table 4).

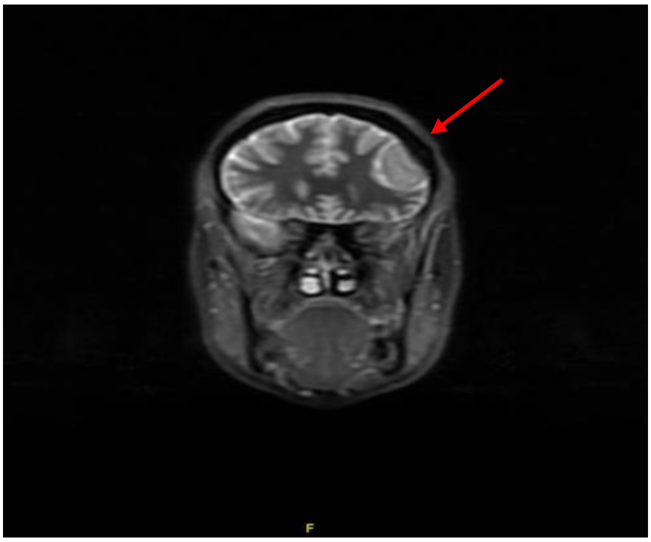

Figure 1. WB-MRI, T2-weighted sequence, is a smoothly contoured lesion in the left frontotemporal region in the cranial coronal section, primarily compatible with meningioma (red arrow).

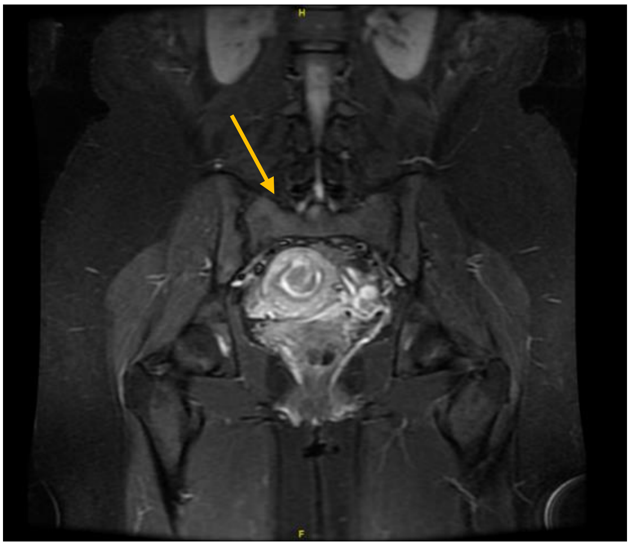

Figure 2. WB-MRI, fat-suppressed T2-weighted sequence pelvic coronal section, mass thickening with irregular contours in the endometrial cavity (yellow arrow).

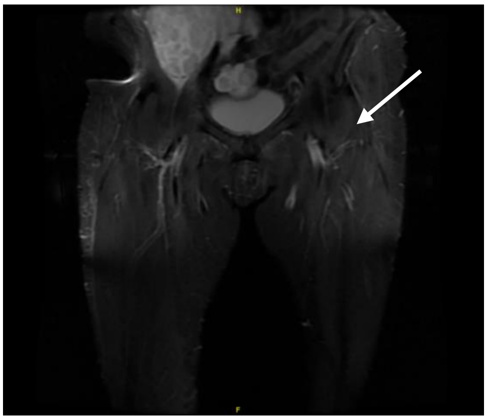

Figure 3. WB-MRI, fat-suppressed T2-weighted sequence, right adnexal mass with irregular borders and heterogeneous internal structure in pelvic coronal section (white arrow).

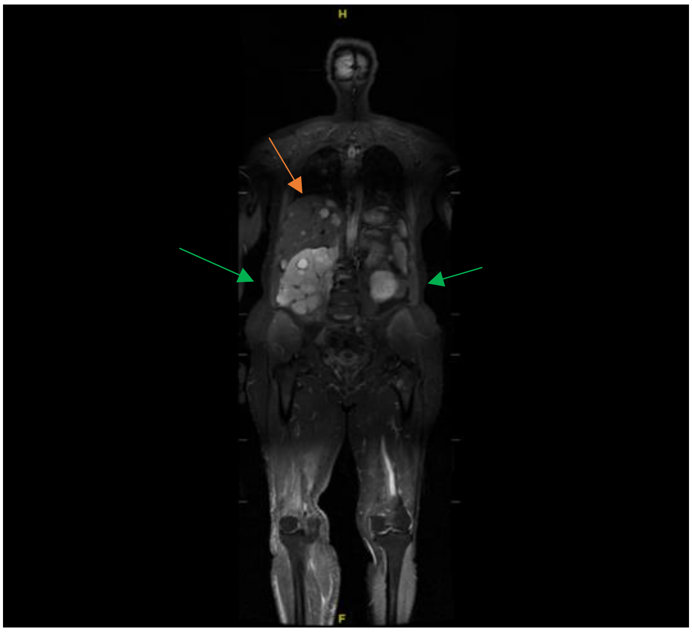

Figure 4. WB-MRI, fat-suppressed T2-weighted sequence coronal section, 4 metastases in the liver parenchyma (orange arrows), metastatic implants in the abdomen (green arrows).

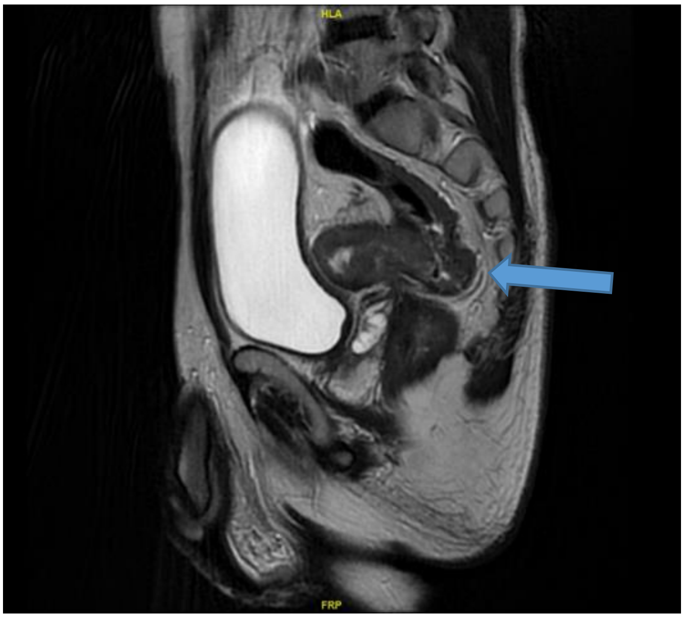

Figure 5. WB-MRI, pelvic T2-weighted sequence, irregular mass wall thickening in the rectosigmoid colon in the sagittal section (blue arrow).

Figure 6. WB-MRI, T2-weighted sequence, intramedullary mass at the level of the right femoral neck in the coronal section (yellow arrow).

Figure 7. WB-MRI, fat-suppressed T2-weighted sequence coronal section, intramedullary masses in the left femoral neck and right distal femur (red arrows).

Table 1. Number of cases recommended for further examination

Gender	Male	Female	n	(%)
Head-Neck	15	10	25	6.4
Thorax	15	10	25	6.4
Abdomen	52	35	87	22.1
Musculoskeletal	22	13	35	8.9
Total	104	68	172	43.8

Table 2. Location and number of malignancy-suspicious lesions detected in females

Location	Female (n)
Liver Metastasis	2
Bone Metastasis	2
Endometrial Mass	1
Adnexal Mass	1
Total	6

Table 3. Location and number of malignancy-suspicious lesions detected in females

Location	Male (n)
Intracranial Mass	1
Bilateral Hilar Lymphadenopathy	1
Liver Metastasis	2
Rectosigmoid Colon Tumor	1
Total	5

Table 4. Benign or malignancy-suspicious lesions according to gender

Gender	Female	Male	n	(%)
No lesion	100	122	222	56.5
Benign Lesion	71	89	160	40.7
Possible Malignancy	6	5	11	2.8
Total	177	216	393	100

Discussion

Today, various radiological imaging methods and laboratory tests are used in health screening programs for early-stage cancer screening. Standard radiological methods for the breast are mammography and breast US.[10,11] The most effective imaging methods in lung screening are chest radiography and thorax CT with low radiation doses.[12-14] The American Cancer Preventive Services Task Force recommends annual low-dose chest CT for health screening for people ages 55 to 80 with a history of smoking.[15] However, the ionizing radiation in CT can cause a significant increase in lifetime cancer risk. Therefore, there has been increased interest in WB-MRI.[16] WB-MRI is a method that provides a general scan of the thorax, abdomen, and musculoskeletal system, starting from the head and neck. Scanning is performed starting from the cranium vertex level to the thigh. Most lesions in the brain, spine, neck, paranasal sinuses, thyroid gland, abdominal solid parenchymal organs, adrenal glands, pelvis, testicles, and bones can be visualized. However, WB-MRI is suboptimal in mobile organs such as the cardiovascular system, lungs, joints, and colon.[17]

WB-MRI was insufficient in our study, especially in evaluating lung parenchymal diseases, and mediastinum. Detailed evaluation of the lung and mediastinum could not be made other than gross findings. In recent years, advances in MRI techniques, especially the 3D T1-weighted Gradient Echo (GRE) sequence, have helped to visualize pulmonary nodules more clearly.[18,19] However, thorax CT is still the most effective scanning for evaluating lung parenchyma and mediastinum. Since additional chest radiography and low-dose thorax CT in our health screening program detected possible lung and mediastinal pathologies, no additional MRI sequence was required.

With the developments in MRI technology, DWI WB-MRI has gained significant clinical value, especially in detecting primary and metastatic malignancies.20 Similar diagnostic rates were observed when DWI WB-MRI and PET-CT were compared in the detection of metastasis. It has been observed that DWI WB-MRI detects metastases to a greater extent in known cancer patients compared to PET-CT, especially thanks to the high spatial resolution in MRI devices of 3 Tesla and above.[20,21]

Pathologies such as inflammatory bowel diseases and abscesses may exhibit diffusion restriction, and increased signals that mimic malignant disease. Abscesses, in particular, can significantly impede water diffusion and cause low ADC values. Clinical signs and symptoms are often helpful in making the distinction. In addition, normal anatomical structures such as salivary glands, lymph nodes, spleen, spinal cord, ovaries, testes, red bone marrow, endometrium, intestinal wall, peripheral nerves, and neural ganglia have varying degrees of restriction of water diffusion on DWI-MRI examination. Therefore, disease processes arising from or involving these structures may be missed, leading to false-negative findings. Additionally, certain body areas are prone to imaging artifacts that can obscure lesions. These artifacts are seen in the neck base, lower mediastinum, left lobe of the liver, and lungs. Medical implants and orthopedic prostheses may cause magnetic susceptibility artifacts. For this reason, lesions adjacent to these areas may be missed on DWI. Lesions near metal implants may not be visible due to artifacts. In conclusion, although DWI WB-MRI is a good screening tool, more data is needed to confirm the diagnosis of various diseases and clinical situations.[22]

The most commonly used imaging for the evaluation of bone disease is technetium radionuclide bone scintigraphy (99m Tc-radiolabeled bone scintigraphy). However, lytic bone diseases may not cause an osteoblastic reaction and a false-negative result may occur in patients with active bone disease. Instead of 99m Tc-radiolabeled bone scintigraphy, 18-FDG-labeled PET/CT can also be performed. High diagnostic accuracy rates of WB-MRI have been demonstrated compared to bone scintigraphy, 18-FDG PET/CT for detecting bone metastases.[23-25] When scintigraphy findings were compared with WB-MRI findings in patients with bone metastases, it was seen that the areas missed by MRI were mostly in the rib and skull regions.[26] WB-MRI is effective in the early diagnosis of bone metastases in the lung, prostate, thyroid gland, malignant melanoma, breast cancer, and in evaluating the response to treatment.[27-29] In our study, bone metastasis suspicion was seen in 2 cases, and additional examinations were recommended to confirm the diagnosis.

When WB-MRI was compared with PET-CT in cancer patients, WB-MRI was found effective in detecting liver, bone, and lymph node metastases.[30,31] However, even if it detects lesions, especially in solid organ and lymph node metastases of breast cancer, it may not be specific for clear characterization.[32]

WB-MRI can also be an alternative to traditional multimodalities for cancer screening purposes.[33-35] Since it does not contain radiation, it can also be used as an alternative to PET-CT in cancer staging in children and pregnant women after the first trimester.[36-38]

With the developments in MRI technology, lesions can be detected quickly by scanning the whole body from head to neck, thanks to the high image quality T1-weighted, 3D GRE Sequence and DWI sequences applied in WB-MRI. Although this makes WB-MRI an important modality, it can not replace specialized MRI examinations and thorax CT, which provide more detailed evaluation of specific organ systems. In lesions detected by MRI, additional examinations such as US, CT, PET-CT, endoscopy, region-specific MRI, laboratory tests, and biopsies are required to confirm the diagnosis. It has been observed that incidentally detected findings in health screenings performed with WB-MRI in the healthy population impose a psychological burden on some cases. This can be considered a disadvantage of WB-MRI for health screening purposes.[39,40]

In conclusion, WB-MRI has been used for health screening purposes since its introduction. With new developments in radiological imaging techniques and artificial intelligence, WB-MRI has become an increasingly used modality, especially in oncological screening programs. As a result, WB-MRI can be used in health screening programs, as a cancer screening tool, and as an alternative to PET-CT in cancer staging in patients with known malignancies. Although WB-MRI cannot image every anatomical region in great detail, we believe that WB-MRI will find a place in cancer/health screening programs because it has no radiation damage, can be applied to healthy individuals, and is accessible today. The data in our study were obtained by performing WB-MRI examination on healthy individuals at their request for health screening, which constitutes the limitation of our study. Multicenter studies with larger cases may ensure the effective use of WB-MRI in early cancer screening.

Conflict of Interest

The authors have no conflicts of interest to disclose.

Compliance with Ethical Statement

The approval of this study in accordance with the ethical rules of the Declaration of Helsinki was approved by the ethics committee of Istanbul Okan University at the meeting numbered 169 on 18.10.2023 with decision number 15.

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Author Contributions

All authors contributed equally to the article.

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