International Journal of Physical Education, Sports and Health 2020; 7(5): 199-203

P-ISSN: 2394-1685
E-ISSN: 2394-1693
Impact Factor (ISRA): 5.38
IJPESH 2020; 7(5): 199-203

www.kheljournal.com
Received: 21-06-2020
Accepted: 07-08-2020

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The value of diagnostic ultrasound in the diagnosis of musculoskeletal disorders

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DOI: https://doi.org/10.22271/kheljournal.2020.v7.i5d.1849

Abstract
Diagnostic ultrasound is used to detect and evaluate the degree of inflammation of the synovial membrane in cases of suspected inflammatory arthritis. In cases of non-inflammatory aetiology, the ultrasound can identify problems related to soft tissue.
The purpose of this study was to investigate the success rate in the diagnosis of musculoskeletal disorders using ultrasound imaging and the confirmation rate of the ultrasound findings with other imaging methods, such as magnetic resonance imaging (MRI) and radiography (X-ray). The sample of the present study consisted of 120 patients who suffered from musculoskeletal disorders, and they visited the Orthopedic Outpatient Clinics of the General Panarkadikon Hospital in, Greece. All patients were examined by the orthopaedic doctor, who used an ultrasound device. After the ultrasound procedure, the doctor made a possible diagnosis, and then the patient underwent at least one more diagnostic process, and then both the outcomes were compared. An anonymous questionnaire was used to record the outcomes of the ultrasound per anatomic part and compare the results to the other diagnostic procedures. There were no statistically significant differences for gender and ultrasound confidence level (p=0.315), gender and MRI/X-ray confirmation level (p=0.966), age and ultrasound confidence level (p=0.374), age and MRI/X-ray confirmation level (p=0.081) and injuries type with MRI/X-ray confirmation level (p=0.070). The anatomical area was related to the ultrasound confidence level (p<0.001) and to the MRI/X-ray confirmation level (p= 0.017). The type of injuries was related to the ultrasound confidence level (p=0.026). The diagnosis was related to the ultrasound confidence level (p<0.001) and to the MRI/X-ray confirmation level (p < 0.001).
In conclusion, it seems that ultrasound is a fast imaging tool, which can provide very helpful information about the damaged tissue and permit an experienced doctor to make a safe diagnosis.

Keywords: Musculoskeletal disorders, diagnostic ultrasound, imaging methods, MRI

1. Introduction
According to the World Health Organization, musculoskeletal disorders are health problems of the locomotor apparatus, such as muscles, tendons, bone skeleton, cartilage, ligaments, and nerves. This definition includes any complaint, from minor transient discomfort to measurable and weak injuries [1]. Several diagnostic options have been described in the literature. They have been applied in clinical practice, with the most common being radiography (X-ray), magnetic resonance imaging (MRI) and computed tomography (CT). In recent years, the diagnostic ultrasound (US), a safer, more economical diagnostic option seems to be gaining ground. The first use of diagnostic ultrasound was in the diagnosis of musculoskeletal disorders for the differentiation of Baker cyst and thrombophlebitis, in 1972 [2]. A few years later, ultrasound was used to visualize arthritis and to evaluate treatment outcomes in patients with rheumatoid arthritis [3]. Gradually, the application of ultrasound has been extended to the diagnosis of other musculoskeletal disorders. Now, it tends to become one of the primary imaging methods for most musculoskeletal disorders. Diagnostic ultrasound can be used to image inflammatory and non-inflammatory musculoskeletal disorders. Mainly, it is used as a tool to detect and evaluate the degree of inflammation of the synovial membrane in cases of suspected inflammatory arthritis [4, 5]. In cases of non-inflammatory aetiology, the ultrasound can identify problems related to soft tissue.

Ultrasound (US) is a form of mechanical energy. Mechanical vibration at increasing frequencies is known as sound energy. Ultrasound transducers produce ultrasonic waves that have frequencies above the human hearing threshold (above 20KHz), but most transducers operate at much higher frequencies. It can also detect ultrasound reflections. As a medical diagnostic technique, high-frequency sound waves are used for real-time imaging inside the body without exposure to ionizing radiation [6-9]. Diagnostic ultrasound can be further subdivided into anatomical and functional ultrasound. Anatomical ultrasound provides images of internal organs or other structures. In contrast, functional ultrasound combines information such as the movement and velocity of tissue or blood, the softness or hardness of tissue, and other physical features with anatomical images that help physicians perceive changes or differences in operation within a structure - instrument [10].

2. Aim

The purpose of this study was to investigate the success rate in the diagnosis of various musculoskeletal disorders using ultrasound imaging and the confirmation rate of the ultrasound findings by other imaging methods, such as magnetic resonance imaging and radiography.

3. Material and Methods

3.1 Research Population

The sample of the present study consisted of 120 patients who suffered from musculoskeletal disorders, and they visited the Orthopedic Outpatient Clinics of the General Panarkadikon Hospital, in Tripoli, Greece, between November 2019 and June 2020. All patients underwent diagnostic ultrasound, followed by at least one more diagnostic procedure to confirm the diagnosis.

3.2 Research Tools

An anonymous questionnaire was used to examine the function of the ultrasound per anatomic part and compare the results with the other diagnostic options. The anonymous questionnaire was compiled by both the physician and the researcher. The first part of the questionnaire contained demographic characteristics, like gender and age. The second part had four sections, evaluating the anatomical area (head, upper limbs, chest, abdomen, back, waist, lower limbs), the type of musculoskeletal disorder, the aetiology and the diagnosis. In the end, there were the ultrasound outcomes and the confirmation or not by the other diagnostic modalities. All patients who visited the Outpatient Orthopedic Clinic were examined by the orthopaedic doctor, who used an EsaoteMylab 70 X-vision ultrasound and a direct sound transmitter at 12 MHz. After the diagnosis by ultrasound, each patient underwent at least one diagnostic modality (MRI or X-ray), and then the doctor compared the outcomes. Finally, the researcher marked the confidence level of the ultrasound procedure in each category with the following indications (No Diagnosis, Helpful, Almost Sure, Sure) and the confirmation level with the other diagnostic modalities with the following marks: Similar Outcomes, Confirmation, Better Image, More Outcomes, Diagnosis Set.

3.3 Statistical Analysis

The outcomes of the study were statistically analyzed using the IBM SPSS v.25 program. Initially, the researchers conducted a descriptive statistical analysis of the sample. Then, they performed a crosstabs correlation analysis to find out the correlations between the examined parameters.

3.4 Ethical Considerations

This study followed all fundamental ethical principles that govern the conduct of research such as full confidentiality regarding the patients' data, the safety of the material, and anonymity of the participants. Finally, the study protocol was in line with the Helsinki Declaration and was approved by the Ethical Committee of the University of Peloponnese (School of Health Sciences).

4. Results

120 patients (57 males and 63 females) with musculoskeletal disorders who visited the Orthopedic Outpatient Clinics of the General Panarkadikon Hospital, underwent an ultrasound, followed by at least one more diagnostic modality (MRI or X-ray). 18 patients were diagnosed with osteoarthritis, 19 patients with hydrarthrosis, 41 with tendinosis, 8 with ligament or cartilage injuries, 16 with bone fracture, 2 with trigger finger, 8 with Baker's cyst, 3 with Morton's neuroma, 1 with haematoma and 4 with carpal tunnel syndrome. Regarding the anatomical area, there were 46 patients with upper limbs disorders, 71 patients with lower limbs disorders and 3 patients with spine disorders. In terms of injuries, there were 26 patients with joint injuries, 17 patients with bone injuries and 77 patients with soft tissue injuries.

The results showed no statistically significant relation between gender and ultrasound confidence level (p=0.315). The same was observed for gender and MRI/X-ray confirmation level (p=0.966), age and ultrasound confidence level (p=0.374), age and MRI/X-ray confirmation level (p=0.081) and injuries type with MRI/ X-ray confirmation level (p=0.070).

The anatomical area was related to the ultrasound confidence level ($p<0.001$). Precisely, 44 out of 46 patients (95.65%) with upper limbs problems had almost-sure/sure diagnosis. Regarding patients with lower limbs problems, 62 out of 71 (87.32%) had almost-sure/sure diagnosis. In total, 96 out of 120 patients (80%) had an almost-sure or sure diagnosis for all examined anatomical areas. Patients with spine problems had not been diagnosed with ultrasound imaging. (Table 1).

Table 1: Crosstabs correlation of the anatomical area with the ultrasound confidence level

Anatomic Area - US Confidence Level	No Diagnosis	Helpful for the Diagnosis	Almost Certain Diagnosis	Certain Diagnosis	Total
Upper Limbs	0	2	9	35	46
Lower Limbs	2	7	21	41	71
Spine	1	2	0	0	3
Total	3	11	30	76	120

P-Value <0.001

The anatomical area was negatively related to the MRI/ X-ray confirmation level (p= 0.017). From the results obtained, only in 7 out of 46 (17.5%) patients with upper limbs problems and in 23 out of 71 (32.39%) patients with lower limbs problems the MRI/ X-ray gave better results. Overall, in 43 out of 120 patients (38.83%), the MRI/ X-ray provided better outcomes for all the examined anatomical areas. In contrast with the ultrasound confidence level, 3 out of 3 (100%) patients with

spine disorders had better results with the magnetic resonance imaging and radiography (Table 2).

Table 2: Crosstabs correlation of the anatomical area with the MRI/ X-ray confirmation level

Anatomic Area - MRI/ X-ray Confirmation Level	Similar Outcomes	Confirm	Better Image	More Outcomes	Diagnosis Set	Total
Upper Limbs	16	18	5	5	2	46
Lower Limbs	16	19	13	14	9	71
Spine	0	0	0	1	2	3
Total	32	37	18	20	13	120

P-Value=0.017

The type of injuries was related to the ultrasound confidence level (p=0.026). Precisely, 25 out of 26 (96.15%) patients with joint injuries, 11 out of 17 (64.7%) patients with bone injuries and 70 out of 77 (90.9%) patients with soft tissue injuries had almost-sure/sure diagnosis. In total, 106 out of 120 patients (88.33%) had a safe diagnosis for all examined type of injuries (Table 3).

Table 3: Crosstabs correlation of the injuries type with the ultrasound confidence level

Injuries - US Confidence Level	No Diagnosis	Helpful for the Diagnosis	Almost Certain Diagnosis	Certain Diagnosis	Total
Joint	0	1	5	20	26
Bone	2	4	3	8	17
Soft Tissue	1	6	22	48	77
Total	3	11	30	76	120

P - Value=0.026

The type of injuries was not related to the MRI/ X-ray confirmation level (p=0.070).

The diagnosis was related to the ultrasound confidence level ($p < 0.001$). Precisely, 17 out of 18 (94.44%) patients with osteoarthritis, 19 out of 19 (100%) patients with hydrarthrosis, 40 out of 41 (97.56%) patients with tendinosis, 5 out of 8 (62.5%) patients with ligament-cartilage injuries, 10 out of 16 (62.5%) patients with bone fractures, 2 out of 2 (100%) patients with trigger finger, 8 out of 8 (100%) patients with Baker's cyst and 4 out of 4 (100%) patients with carpal tunnel syndrome had almost certain/certain diagnosis. In total, 106 out of 120 (88.33%) patients with a diagnosis for all the examined cases had almost certain/certain diagnosis (Table 4).

Table 4: Crosstabs correlation of the diagnosis with the ultrasound confidence level

Diagnosis – US Confidence Level	No Diagnosis	Helpful for the Diagnosis	Almost certain Diagnosis	Certain Diagnosis	Total
Osteoarthritis	0	1	5	12	18
Hydrarthrosis	0	0	9	10	19
Tendinosis	0	1	7	33	41
Ligament-Cartilage	1	2	4	1	8
Fracture	2	4	3	7	16
Trigger Finger	0	0	0	2	2
Baker's Cyst	0	0	1	7	8
Morton's Neuroma	0	3	0	0	3
Haematoma	0	0	1	0	1
Carpal Tunnel	0	0	0	4	4
Total	3	11	30	76	120

P-Value <0.001

The diagnosis was negatively related to the MRI/ X-ray confirmation level ($p < 0.001$). In contrast with the ultrasound imaging, only 5 out of 18 (27.77%) had better results for osteoarthritis and 3 out of 19 (30%) for hydrarthrosis. Moreover, 8 out of 41 (19.51%) had better results for tendinosis, 6 out of 16 (37.5%) had better results for bone fractures, 1 out of 2 (50%) had better results for trigger finger and 3 out of 8 (37.5%) better results for Baker's cyst. However, 5 out of 8 (62.5%) patients with ligament-cartilage injuries had the same results with ultrasound. Overall, only 33 out of 120 (27.5%) had better outcomes for all the examined cases (Table 5).

Table 5: Crosstabs correlation of the diagnosis with the MRI/ X-ray confirmation level

Diagnosis - MRI/X-ray Confirmation Level	Similar Outcomes	Confirm	Better Image	More Outcomes	Diagnosis Set	Total
Osteoarthritis	8	3	2	4	1	18
Hydrarthrosis	3	9	4	3	0	19
Tendinosis	18	13	2	6	2	41
Ligament - Cartilage	1	2	1	2	2	8
Fracture	0	5	5	2	4	16
Trigger Finger	0	0	1	0	1	2
Baker's CYST	2	1	2	3	0	8
Morton's Neuroma	0	0	0	0	3	3
Haematoma	0	0	1	0	0	1
Carpal Tunnel	0	4	0	0	0	4
Total	32	37	18	20	13	120

P-Value <0.001

5. Discussion

The outcomes of the present study indicate that ultrasound imaging can show in most cases, precise diagnosis or very closed results with MRI and X-rays. Ultrasound images are created based on physical changes in tissue composition, in contrast with MRI images which are based on chemical changes in the structures. Ultrasound images achieve higher resolution images of superficial soft tissue anatomy than any other modality, including MRI [11, 12]. In cases of calcifications in soft tissue, and tendon tears, ultrasound gives earlier detection of these pathologies than MRI, x-rays or CT [13, 14]. Several studies have reported the benefits of diagnostic ultrasound in orthopaedics. In particular, diagnostic ultrasound seems to be the ideal tool, which can image needles and specific points that have been affected, in real time [15]. Ultrasound can also show tendon instability, which can cause severe musculoskeletal problems in the upper extremity [16] and the shoulder [17]. According to Borg *et al*., the use of ultrasound provides an excellent opportunity to educate the patients, and explain to them the aetiology of their condition [18]. Diagnostic ultrasound is considered the more advantageous method for the study of tendons, as it can determine the severity of the injury and depict the healing stages [19].

Ultrasound with low frequency allows diagnosis of extra-articular collections like haematomas, seromas [20, 21] and bursal inflammations of the hip region [22]. Moreover, ultrasound is the primary imaging modality when it comes to extra-articular pathologies of the hip region like fluid collections or joint degeneration [23, 24]. Ultrasound is also able to diagnose bone pathologies such as occult fractures, bone erosions [25, 26], arthritis and early diagnosis of arthritis [27]. In contrast to studies supporting the benefits of ultrasound, some studies have shown some limitations of this imaging modality. Specifically, in-depth structures are challenging to detect by diagnostic ultrasound. Unlike MRI, which has this capability, ultrasound has limited penetration into deeper structures, making it difficult to assess the deep body regions, morbidly obese patients and areas deep to the bone. It also does not have access to specific joints such as the 4th metacarpophalangeal joint. Ultrasound imaging of multiple joints requires the necessary time, resulting in a focused examination of a small number of active joints [28, 29]. Then, in this case, ultrasound should not be the first choice of imaging, and MRI is preferred. MRI has also proven to be a successful and well-established tool that provides an assessment of the full range of knee soft tissues [30, 31]. In the case of muscle injury, MRI may be useful in assessing patients in whom the clinical diagnosis is uncertain or when abnormalities are challenging to distinguish [32], and the development of MRI technology has enabled the immediate imaging of the joint that helps in diagnosis [33].

However, there are many concerns about the risks of MRI, and especially the majority of the risks are mainly related to claustrophobia caused by spending 45 minutes in a dark, closed tube. Some patients are not able to undergo MRI, especially those with a pacemaker or an intravascular stent. Additionally, patients who may have deposited metal debris on their soft tissues could potentially experience significant discomfort or have an injury associated with strong magnetic attraction [34-36].

Finally, a well-trained professional with appropriate, modern equipment, ultrasound examination is often the preferred first-line testing for patients with injuries in muscles, tendons and ligaments. However, in some instances, MRI is the best first-line testing, which is often required to solve problems in troubled patients.

6. Conclusions

The use of ultrasound as a diagnostic tool for the diagnosis of musculoskeletal disorders in many cases has given reliable results. However, the limited penetration of ultrasound into deeper structures leads the physician to use other imaging modalities. Therefore, further research and clinical trials may be needed to clarify in which disorders ultrasound imaging is the ideal diagnostic tool, without the need to use other diagnostic procedures. Eventually, it seems that ultrasound is a fast first-line technique in detecting abnormalities of all superficially located muscles and tendons. In contrast, MRI is a non-invasive way to assess bone, soft tissue, and joints in the more deeply located structures. Last but not least, the reliability of the ultrasound depends firstly on the experience of the health professional to make a safe and precise diagnosis.

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