Narrative Review

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Exploring Feasibility And Functionality of Rehabilitative Ultrasound in Nepal: A Narrative Review

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ABSTRACT

Introduction: Rehabilitative ultrasound imaging is a technique commonly used by physical therapists to evaluate the structure and function of muscles and surrounding soft tissues while a patient is moving or performing exercises. This review provides an overview of diagnostic sonography, specifically focusing on rehabilitative ultrasound imaging and point-of-care ultrasound in physiotherapy. The main objective of this review is to explore the feasibility and usability of integrating rehabilitative ultrasound imaging in the Nepalese physiotherapy context, this review also shows both the opportunities and challenges, especially given its current absence from physiotherapy sections in Nepal.

Observations: Real-time ultrasound imaging has proven to be a reliable method for assessing the thickness, morphology, function, and internal architecture of various muscles, including core muscles, supraspinatus, and rectus femoris, in both healthy individuals and those with musculoskeletal conditions. It can also assess force generation and muscle activity. Furthermore, ultrasound imaging serves as a valuable biofeedback tool for enhancing diaphragm activation, contractility, and muscle contraction to improve spinal stability. While its clinical and research potential is recognized globally, its application in less resource nations like Nepal remains largely unexplored.

Conclusions and Relevance: The conclusion of this review is that rehabilitative ultrasound imaging holds significant potential for clinical application in physiotherapy, particularly for assessing muscle characteristics and providing biofeedback to improve musculoskeletal function and spinal stability. It gives real time data and objective data on muscle morphology and function, makes it relevant clinically for guiding interventions and monitoring patient progress in conditions like low back pain and various musculoskeletal impairments. In Nepal, the integration of rehabilitative ultrasound imaging into physiotherapy practice and education is a worthwhile opportunity for the improvement of diagnostic potential, improving treatment effectiveness, and possibly increasing the scope of physiotherapy practice, as per international standards of healthcare. Surmounting the challenges of implementation and training will be at the core of harnessing these gains.

INTRODUCTION

Diagnostic sonography, or ultrasonography, is a non-invasive imaging technique that utilizes ultrasound waves to visualize various body structures, including tendons, muscles, joints, vessels, and internal organs, mainly to identify potential lesions or abnormalities.[1] In physiotherapy, rehabilitative ultrasound imaging (RUSI) is an application specially employed by physical therapists to assess morphology and functions of muscles and related soft tissues during patient movement or any form of exercise.[2] This falls under the broader spectrum of point-of-care ultrasound (POCUS) in physiotherapy, which aims to clarify clinical findings and enhance the effectiveness of interventions.[3] POCUS encompasses RUSI, diagnostic ultrasound imaging (DUSI), and interventional ultrasound imaging (IUSI), also includes a fourth category covering research applications.[3-5]

The clinical uses of ultrasound in physiotherapy is extensive and well-documented. Real-time ultrasound imaging (USI) has been established in many parts of world as a reliable method for measuring the thickness of core muscles, such as the transversus abdominis (TrAb), external oblique (EO), and internal oblique (IO), in both healthy individuals and those suffering from low back pain (LBP).[6] Studies have also shown good intra-rater reliability for diagnostic ultrasound

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imaging thickness measurements across various muscle groups by physical therapists.[7] Its application has expanded to areas like including the examination of numerous other muscles, including the supraspinatus and infraspinatus,[8] rectus femoris,[9] biceps brachii,[10] transversus abdominis (TrA) and internal oblique,[11] rectus abdominis,[12] cervical multifidus,[13] trapezius,[14] sartorius, and iliopsoas.[15] USI has also been used to investigate other aspects of muscle morphology and function, such as composition,[16-18] changes in internal architecture (pennation angles),[19-20] force generation,[9] and muscle activity (i.e., electrical activity recorded by electromyography [EMG]).[21-25] It has been shown that there is a link between decreased muscle size and various musculoskeletal impairments and pathologies,[26,27] which are significant contributors to global disability, pain, stiffness, mental distress, and reduced functionality.[28] Adding to that, ultrasound is increasingly utilized clinically and in research[29] as a biofeedback tool to improve diaphragm activation and contractility, as well as muscle contraction for enhanced spinal stability, in both healthy subjects[30] and in patients with LBP.[31]

Even though there are recognized benefits and recommendations for specialized training in its use by physical therapists, consistent with World Health Organization recommendations, the application of ultrasound in resource-scarce nations such as Nepal remains largely unexplored. This narrative review aims to comprehensively address the usability and feasibility of rehabilitative ultrasound within the Nepalese context. Mainly, it will highlight the opportunities that RUSI presents for advancing physiotherapy practice in Nepal and potentially expanding its scope, while also critically examining the challenges associated with its implementation, particularly given its current absence from Bachelor's and Master's level physiotherapy curriculum in the country. This study seeks to provide a foundational understanding for the practical and educational integration of Rehabilitative Ultrasound in Physiotherapy Schools of Nepal.

METHODS

A comprehensive literature search was conducted across two primary bibliographic databases: PubMed and Google Scholar. The search focused on literature related to Rehabilitative Ultrasound Imaging (RUSI), its applications, usability, and feasibility, particularly in the context of resource-scarce environments and physiotherapy education. Specific search terms used included "rehabilitative ultrasound imaging", "RUSI", "ultrasonography physiotherapy", "feasibility ultrasound physiotherapy" and combinations. No specific date range was applied for inclusion to ensure a broad coverage of relevant literature; however, priority was given to more recent and impactful studies.

The initial screening of search results involved reviewing titles and abstracts for relevance to RUSI, its clinical applications, educational aspects, and contextual challenges, especially in developing countries. Full-text articles deemed relevant were then retrieved and meticulously reviewed. The process of retrieving articles was mainly done by Mr. Binaya Kandel and the evaluation of the literature involved Mr. Shree Krishna Shilpakar reviewing the retrieved articles for their content and applicability to the review's scope. Concurrently, Mr. Shree Krishna Shilpakar engaged in communication with various stakeholders in the rehabilitation sector within Nepal to gather qualitative insights and perspectives on the feasibility and challenges of integrating RUSI.

Following the comprehensive literature review and stakeholder engagement, Mr. Shree Krishna Shilpakar prepared a preliminary manuscript. This draft was subsequently reviewed by Mr. Binaya Kandel and Dr. Padma Raj Adhikari, who provided critical feedback and insights. The manuscript underwent revisions based on this feedback, and the final version was collaboratively finalized by Mr. Binaya Kandel, Mr. Shree Krishna Shilpakar and Dr. Padma Raj Adhikari for submission.

THEMATIC ANALYSIS

Theme 1: Adoption at Nepal

The World Bank categorizes Nepal as a low-income country, with a gross national income per capita of $790 in which more than 25 percent of the population are living below the poverty line.[32] Due to limited access and financial limitations, Nepal faces healthcare challenges. One of the major barriers to health were poor geographical accessibility of people, according to the Nepal Health Sector Strategy 2015–2020.[33] Nepal has a large and growing unmet rehabilitation need. This implies that people do not receive the more specialized rehabilitative care they require and that there is a limited supply of specialized, longer-stay rehabilitation beds in Nepal.[34] However, Nepal attempts to improve its healthcare infrastructure and healthcare services ensuring equitable access to high-quality rehabilitation across various populations.

Theme 2: Perspective as Physiotherapist

Physiotherapists use a structured assessment pattern, including patient history, observation, and physical examination, to understand and address clinical conditions comprehensively. Physiotherapists gather detailed histories, observing movement patterns, and conducting thorough physical examinations, they diagnose issues and tailor personalized treatment plans to optimize outcomes for their patients.[35] Physiotherapists also make use of the universally accepted biopsychosocial model, considering biological, psychological, and social factors to properly assess and treat patients, promoting holistic well-being.

Rehabilitative ultrasound holds significant potential as a diagnostic and therapeutic tool in Nepal's healthcare, mainly in addressing musculoskeletal conditions. With its non-invasive nature and real-time imaging capabilities, ultrasound can help physiotherapists in accurately assessing soft tissue injuries, guiding towards interventions, and monitoring progress.[36] Furthermore, its affordability and portability enable it to be used even in environments with limited resources, improving diagnostic capabilities in isolated locations where cutting-edge imaging modalities might not be accesible.[32] However, careful consideration must be given to training to ensure accurate interpretation of ultrasound findings, as misdiagnosis or improper diagnosis use could lead to ineffective treatment or delays in appropriate care of patients.[37,38] Also the overemphasis on a biological component might be misled by neglecting other components such as psychological and social factors. To optimize the advantages of ultrasound and reduce potential risks such as burns, cavitation, and dependence in the Nepalese context, it is also necessary to address the availability of qualified personnel and sufficient infrastructure, such as a suitable workspace and equipment.

Theme 3: Perspective based on curriculum

A competency-based curriculum for rehabilitative ultrasound imaging (RUSI) is important for ensuring proficiency in this specialized area.[37,38] It creates clear learning objectives and benchmarks for skill acquisition, covering essential knowledge, safe scanning techniques, and accurate interpretation of ultrasound images. By emphasizing on achieving competency, practitioners are more prepared to perform out imaging and interventions, improving the standard of care provided to patients in rehabilitation settings.[37,38]

Theme 4: Perspective as an Administrator/Policy maker

When radiologists focus on diagnostic accuracy and physiotherapists focus on conservative approaches, conflicts may arise regarding the need for or interpretation of imaging findings for the treatment plan of a patient. A study by Manske et al showed 67% documented significant changes in physical therapy intervention strategies due to the RUSI.[39] Also, debates may arise regarding the appropriate utilization of resources like imaging technologies. Also, the number of rehabilitation personnel is 1/20,000 Nepalese people which is small considering the size of the population.[34] Due to the nation's weak economy, patients may also be burdened by the unnecessary imaging of structures for all musculoskeletal cases plus the price differences between private centers. However, inclusion of RUSI in national health insurance would make it easy and affordable to the patients. Overall collaboration, clear communication, and mutual respect for each profession's expertise are needed to mitigate potential disputes and ensure optimal patient care.

Feasibility of Implementing Rehabilitative Ultrasound Imaging in Nepal

The feasibility of implementing rehabilitative ultrasound imaging (RUSI) in Nepal is supported by several factors. With an increasing awareness of rehabilitation needs and the availability of trained healthcare professionals, there is an advantageous setting for integrating RUSI into clinical practice. Portability of Ultrasound makes RUSI more accessible, particularly in remote and underserved areas. Collaborations between government agencies, non-profit organizations, and academic institutions can facilitate purchase of the machines, training programs and research initiatives focused on RUSI. While there is very limited data on its effectiveness, research can be initiated to provide foundation for its implementation. Educating patients about the advantages of RUSI can improve adherence to rehabilitation programs, and acceptance and engagement are essential. Nepal can utilize RUSI to enhance musculoskeletal rehabilitation services and health outcomes for its people by removing hurdles and utilizing favorable conditions.

Facilitators to establish Rehabilitative Ultrasound Imaging in Nepal

In the Nepalese context, the functionality of rehabilitative ultrasound imaging (RUSI) holds significant assurance for addressing prevalent musculoskeletal conditions, including sports injuries, degenerative joint diseases, and those resulting from manual labor and agricultural activities. RUSI's real-time visualization capabilities enables healthcare providers to assess soft tissue structures, muscle function, and guide interventions such as therapeutic exercises and injections, enhancing diagnostic and therapeutic precision.[6,40-42] Also, RUSI can facilitate patient education by allowing individuals to visually understand their condition and track progress over time,[42] thus encouraging active participation in their rehabilitation journey and enhancing overall treatment outcomes. In spite of challenges such as equipment accessibility and training, the versatility and effectiveness of RUSI makes it a valuable tool in enhancing musculoskeletal rehabilitation practice in Nepal.

Challenges to Consider before establishment

Challenges surrounding the implementation of rehabilitative ultrasound imaging (RUSI) in Nepal have various factors, including limited availability of ultrasound machines, increased costs associated with equipment purchase and maintenance, and a shortage of trained personnel proficient in performing and interpreting RUSI examinations. Addressing these challenges will require collaborative efforts involving government agencies, non-profit organizations, academic institutions, and healthcare providers to invest in infrastructure development, training programs, and research initiatives targeted at demonstrating the clinical efficacy and cost-effectiveness of RUSI in Nepal. For implementation to be sustainable and successful, it is also crucial to account for logistical and cultural challenges, ensure fair access to RUSI services in a variety of geographical regions, and include RUSI into present healthcare systems.

CONCLUSIONS

In conclusion, rehabilitative ultrasound imaging shows significant promise as a valuable tool for enhancing musculoskeletal rehabilitation in Nepal. While challenges related to access, affordability, expertise, misuse and conflicts with the radiologists exist, combined efforts to overcome these barriers can help the way for the adoption and integration of RUSI into clinical practice. In the future, educational programs should be expanded to include training in rehabilitative ultrasound for physiotherapists, ensuring they are equipped with essential skills to provide advanced care. By utilizing the potential of RUSI, Nepal can improve the quality of care provided to individuals with musculoskeletal conditions, ultimately contributing to better health outcomes and enhanced quality of life for its population.

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Conflict of Interest: None.

REFERENCES

1. Carovac A, Smajlovic F, Junuzovic D. Application of ultrasound in medicine. Acta Inform Med. 2011 Sep;19(3):168-71. [PubMed | Full Text | DOI]
2. LaCross J, Proulx L, Kelli B, Humphrey J. Effect of rehabilitative ultrasound imaging (rusi) biofeedback on improving pelvic floor muscle function in individuals with stress urinary incontinence: a systematic review. J Womens Health Phys Therap. 2021 Oct-Dec;45(4):174-89. [Full Text]
3. Whittaker JL, Ellis R, Hodges PW, OSullivan C, Hides J, Fernandez-Carnero S, et al. Imaging with ultrasound in physical therapy: What is the PT's scope of practice? A competency-based educational model and training recommendations. Br J Sports Med. 2019 Dec;53(23):1447-53. [PubMed | Full Text | DOI]
4. Fernandez-Carnero S, Calvo-Lobo C, Garrido-Marin A, Arias-Buria JL. 2nd rehabilitative ultrasound imaging symposium in physical therapy, Madrid, Spain, 3–5 June 2016. British Journal of Sports Medicine. 2018;52(Suppl 2):A1-A4. [Full Text]
5. Hobson-Webb LD, Zwelling PJ, Pifer AN, Killelea CM, Faherty MS, Sell TC, et al. Point of care quantitative assessment of muscle health in older individuals: an investigation of quantitative muscle ultrasound and electrical impedance myography techniques. Geriatrics (Basel). 2018 Dec 16;3(4):92. [PubMed | Full Text | DOI]
6. Aboufazeli M, Afshar-Mohajer N. Within-day and between-day reliability of thickness measurements of abdominal muscles using ultrasound during abdominal hollowing and bracing maneuvers. J Bodyw Mov Ther. 2018 Jan;22(1):122-8. [PubMed | Full Text | DOI]
7. Overas CK, Myhrvold BL, Rosok G, Magnesen E. Musculoskeletal diagnostic ultrasound imaging for thickness measurement of four principal muscles of the cervical spine -a reliability and agreement study. Chiropr Man Therap. 2017 Jan 4;25:2. [PubMed | Full Text | DOI]
8. Juul-Kristensen B, Bojsen-Moller F, Holst E, Ekdahl C. Comparison of muscle sizes and moment arms of two rotator cuff muscles measured by ultrasonography and magnetic resonance imaging. Eur J Ultrasound. 2000 Jun;11(3):161-73.[PubMed | Full Text | DOI]
9. Delaney S, Worsley P, Warner M, Taylor M, Stokes M. Assessing contractile ability of the quadriceps muscle using ultrasound imaging. Muscle Nerve. 2010 Oct;42(4):530-8. [PubMed | Full Text | DOI]
10. Bemben MG. Use of diagnostic ultrasound for assessing muscle size. J Strength Cond Res. 2002 Feb;16(1):103-8. [PubMed | Full Text]

11. Hides J, Wilson S, Stanton W, McMahon S, Keto H, McMahon K, et al. An MRI investigation into the function of the transversus abdominis muscle during "drawing-in" of the abdominal wall. Spine (Phila Pa 1976). 2006 Mar 15;31(6):E175-E178. [PubMed | Full Text | DOI]
12. Coldron Y, Stokes MJ, Newham DJ, Cook K. Postpartum characteristics of rectus abdominis on ultrasound imaging. Man Ther. 2008 May;13(2):112-21. [PubMed | Full Text | DOI]
13. Lee JP, Tseng WY, Shau YW, Wang CL, Wang HK, Wang SF. Measurement of segmental cervical multifidus contraction by ultrasonography in asymptomatic adults. Man Ther. 2007 Aug;12(3):286-94. [PubMed | Full Text | DOI]
14. O'Sullivan C, Meaney J, Boyle G, Gormley J, Stokes M. The validity of Rehabilitative Ultrasound Imaging for measurement of trapezius muscle thickness. Man Ther. 2009 Oct;14(5):572-8. [PubMed | Full Text | DOI]
15. Mendis MD, Wilson SJ, Stanton W, Hides JA. Validity of real-time ultrasound imaging to measure anterior hip muscle size: a comparison with magnetic resonance imaging. J Orthop Sports Phys Ther. 2010 Sep;40(9):577-81. [PubMed | Full Text | DOI]
16. Langevin HM, Stevens-Tuttle D, Fox JR, Badger GJ, Bouffard NA, Krag MH, Wu J, Henry SM. Ultrasound evidence of altered lumbar connective tissue structure in human subjects with chronic low back pain. BMC Musculoskelet Disord. 2009 Dec 3;10:151. [PubMed | Full Text | DOI]
17. Sikdar S, Shah JP, Gebreab T, Yen RH, Gilliams E, Danoff J, et al. Novel applications of ultrasound technology to visualize and characterize myofascial trigger points and surrounding soft tissue. Arch Phys Med Rehabil. 2009 Nov;90(11):1829-38. [PubMed | Full Text | DOI]
18. Strobel K, Hodler J, Meyer DC, Pfirrmann CW, Pirkl C, Zanetti M. Fatty atrophy of supraspinatus and infraspinatus muscles: accuracy of US. Radiology. 2005 Nov;237(2):584-9. [PubMed | Full Text | DOI]
19. Lin YF, Lin JJ, Cheng CK, Lin DH, Jan MH. Association between sonographic morphology of vastus medialis obliquus and patellar alignment in patients with patellofemoral pain syndrome. J Orthop Sports Phys Ther. 2008 Apr;38(4):196-202. [PubMed | Full Text | DOI]
20. Zhou Y, Zheng YP. Estimation of muscle fiber orientation in ultrasound images using revoting hough transform (RVHT). Ultrasound Med Biol. 2008 Sep;34(9):1474-81. [PubMed | Full Text | DOI]
21. Brown SH, McGill SM. A comparison of ultrasound and electromyography measures of force and activation to examine the mechanics of abdominal wall contraction. Clin Biomech (Bristol). 2010 Feb;25(2):115-23. [PubMed | Full Text | DOI]
22. Hodges PW, Pengel LH, Herbert RD, Gandevia SC. Measurement of muscle contraction with ultrasound imaging. Muscle Nerve. 2003 Jun;27(6):682-92. [PubMed | Full Text | DOI]
23. John EK, Beith ID. Can activity within the external abdominal oblique be measured using real-time ultrasound imaging? Clin Biomech (Bristol). 2007 Nov;22(9):972-9. [PubMed | Full Text | DOI]
24. Kiesel KB, Uhl TL, Underwood FB, Rodd DW, Nitz AJ. Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. Man Ther. 2007 May;12(2):161-6. [PubMed | Full Text | DOI]
25. McMeeken JM, Beith ID, Newham DJ, Milligan P, Critchley DJ. The relationship between EMG and change in thickness of transversus abdominis. Clin Biomech (Bristol). 2004 May;19(4):337-42. [PubMed | Full Text | DOI]
26. Grimaldi A, Richardson C, Durbridge G, Donnelly W, Darnell R, Hides J. The association between degenerative hip joint pathology and size of the gluteus maximus and tensor fascia lata muscles. Man Ther. 2009 Dec;14(6):611-7. [PubMed | Full Text | DOI]
27. Hides J, Gilmore C, Stanton W, Bohlscheid E. Multifidus size and symmetry among chronic LBP and healthy asymptomatic subjects. Man Ther. 2008 Feb;13(1):43-9. [PubMed | Full Text | DOI]
28. Blyth FM, Briggs AM, Schneider CH, Hoy DG, March LM. The Global Burden of Musculoskeletal Pain-Where to From Here? Am J Public Health. 2019 Jan;109(1):35-40. [PubMed | Full Text | DOI]
29. Teyhen DS, Gill NW, Whittaker JL, Henry SM, Hides JA, Hodges P. Rehabilitative ultrasound imaging of the abdominal muscles. J Orthop Sports Phys Ther. 2007 Aug;37(8):450-66. [PubMed | Full Text | DOI]
30. Testa A, Soldati G, Giannuzzi R, Berardi S, Portale G, Gentiloni Silveri N. Ultrasound M-mode assessment of diaphragmatic kinetics by anterior transverse scanning in healthy subjects. Ultrasound Med Biol. 2011 Jan;37(1):44-52. [PubMed | Full Text | DOI]
31. Harper CJ, Shahgholi L, Cieslak K, Hellyer NJ, Strommen JA, Boon AJ. Variability in diaphragm motion during normal breathing, assessed with B-mode ultrasound. J Orthop Sports Phys Ther. 2013 Dec;43(12):927-31. [PubMed | Full Text | DOI]

32. The World Bank Group. Country profile: Nepal [Internet]. Kathmandu (NP): The World Bank Group; c2025 [cited 2025 Jun 25]. Available from: https://www.worldbank.org/en/country/nepal#:~:text=Nepal%20At%2DA%2DGlance,hydropower%20generation%20and%20paddy%20production. [Full Text]

33. Cao WR, Shakya P, Karmacharya B, Xu DR, Hao YT, Lai YS. Equity of geographical access to public health facilities in Nepal. BMJ Glob Health. 2021 Oct;6(10):e006786. [PubMed | Full Text | DOI]

34. Ministry of Health and Population, Government of Nepal. Situation Assessment of Rehabilitation in Nepal [Internet]. Kathmandu (NP): Ministry of Health and Population; 2022 [cited 2025 Jun 25]. Available from: https://edcd.gov.np/uploads/resource/639578fee6fc4.pdf [Full Text]

35. World Physiotherapy. Description of physical therapy: policy statement [Internet]. London (UK): World Physiotherapy; 2019 [cited 2025 Jun 25]. Available from: https://world.physio/sites/default/files/2020-07/PS-2019-Description-of-physical-therapy.pdf [Full Text]

36. Aboufazeli M, Afshar-Mohajer N. Within-day and between-day reliability of thickness measurements of abdominal muscles using ultrasound during abdominal hollowing and bracing maneuvers. J Bodyw Mov Ther. 2018 Jan;22(1):122-8. [PubMed | Full Text | DOI]

37. Training in diagnostic ultrasound: essentials, principles and standards. Report of a WHO Study Group. World Health Organ Tech Rep Ser. 1998;875:i-46; back cover. [PubMed | Full Text]

38. Whittaker JL, Teyhen DS, Elliott JM, Cook K, Langevin HM, Dahl HH, et al. Rehabilitative ultrasound imaging: understanding the technology and its applications. J Orthop Sports Phys Ther. 2007 Aug;37(8):434-49. [PubMed | Full Text | DOI]

39. Manske R, Podoll K, Markowski A, Watkins M, Hayward L, Maitland M. Physical therapists use of diagnostic ultrasound imaging in clinical practice: a review of case reports. Int J Sports Phys Ther. 2023 Feb 2;18(1):215-27. [PubMed | Full Text | DOI]

40. Hides J, Gilmore C, Stanton W, Bohlscheid E. Multifidus size and symmetry among chronic LBP and healthy asymptomatic subjects. Elsevier. 2008 Feb;13(1):43-9. [Full Text | DOI]

41. Grimaldi A, Richardson C, Durbridge G, Donnelly W, Darnell R, Hides J. The association between degenerative hip joint pathology and size of the gluteus maximus and tensor fascia lata muscles. Man Ther. 2009 Dec;14(6):611-7. [PubMed | Full Text | DOI]

42. Testa A, Soldati G, Giannuzzi R, Berardi S, Portale G, Gentiloni Silveri N. Ultrasound M-mode assessment of diaphragmatic kinetics by anterior transverse scanning in healthy subjects. Ultrasound Med Biol. 2011 Jan;37(1):44-52. [PubMed | Full Text | DOI]