REVIEW ARTICLE

Different Measurement Methods of Heel Pad Thickness and their Clinical Implications: A Narrative Review

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Abstract

Introduction: The heel pad has an important role in pain-free locomotion due to its shock-attenuation function. Various diagnostic techniques are available to measure heel pad thickness. However, each measurement method makes a different clinical impact on heel pad thickness.

Aim of the study: The current study will be aimed to evaluate the clinical impact of different measurement methods on heel pad thickness.

Methodology: The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines will be used for conducting this systematic review and meta-analysis. Literature searches will be carried out on the following databases, such as Cochrane, Google Scholar, PubMed, EMBASE, and Medline databases with the appropriate key terms. Relevant articles will be chosen for full-text screening after the application of the eligibility criteria. Meta-analysis will be performed using Review Manager 5.3 software.

Observations and analysis: The current systematic review and meta-analysis will include all the published studies regarding the impact of different measurement methods on heel pad thickness. Finally, the review will summarize and analyze the results of the included studies to find out the most frequently used measurement methods and their clinical impact.

Discussion: Increased heel pad thickness, commonly known as the heel pad sign, is characterized by an increase in the soft tissue thickness of the heel pad on lateral ankle radiographs in a variety of circumstances (Rogers et al., 2022; Morales-Orcajo et al., 2018). Studies on heel pad thickness using nonweight-bearing radiographs have indicated atrophy of the heel pad in elderly, sedentary subjects, while a recent study has demonstrated that ultrasonic heel pad thickness was significantly greater in patients suffering from unilateral displaced intra-articular fractures of the calcaneum at 21–35 months after injury (Lin et al., 2022; Taş, 2018).

Conclusion: Different methods like photography, radiography, ultrasonography, and magnetic resonance imaging (MRI) have been used for the measurement of thickness of heel pad. However, ultrasonography and radiographic methods have found the maximum use in clinical applications for individuals with or without health issues. Hence, although the most widely used method is ultrasound due to its safety and efficacy, this is dependent on the requirement and availability of the choice of these methods which may vary.

Keywords: Complications, Diagnosis, Heel pad thickness, Magnetic resonance imaging, Ultrasonography.

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Introduction

The heel is a fat layer beneath the calcaneus that protects the foot's underlying bones. It also serves as a shock absorber, minimizing the impact of moving, sprinting, leaping, or falling from a high altitude. It consists of spiral microchambers composed of unsaturated fat surrounded by whorls of fibroelastic tissue attached to both the dermis and the calcaneus.[1] Since the heels are one of the portions of the foot that come into contact with the ground during daily activities, they must be anatomically and physiologically sound to provide the necessary support, balance, and mobility. Because of the forces that the heel is subjected to while walking, jogging, hopping, and landing, as well as the pull from multiple ligaments and muscles, it is critical to evaluate the heel pad in diabetic patients. This group of individuals is prone to ulcers (especially on the toes) and microtears on the plantar surface of their foot. Many degenerative processes can produce major changes in the histomorphology of the foot pad, including aging, diabetes mellitus, deformities, rheumatoid arthritis, dysvascula of the foot, plantar heel discomfort, and trauma. Histology may also be referred to as microscopic anatomy, which involves the study of microscopic anatomy of the cells and tissues, whereas anatomy deals with the structure of organs. Incrassation of septa, disorganization of septa due to collagen bundles and elastin strand breakage, and relative shrinkage of adipocytes are among the histomorphological alterations. As a result of these changes, the biomechanical characteristics of the septa would be altered further, resulting in increased stiffness (specifically elasticity) of the septa, decreased damping ability, and greater tissue sensitivity to damage. As a result, identifying the mechanical characteristics of every patient's heel fat pad is crucial for early detection and treatment of pathological problems.[2]

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The thickness of the heel pad is determined by the patient's clinical assessment. Diagnostic imaging techniques like ultrasonography and MRI may be necessary in the event of refractory individuals. Both imaging modalities show increased thickness in the plantar fascia and tissue abnormalities in the presence of heel pad thickness. Ultrasonography can be performed to rule out soft tissue disease in the heel. It is less intrusive and less costly than an MRI. Plantar fasciitis can be diagnosed with ultrasonography findings such as proximal plantar fascia thickness of more than 4 mm and regions of hypoechogenicity.[3,4] Various clinical complications were found to be positively associated with the heel pad thickness, which include acromegaly, diabetes, obesity, and plantar fasciitis.[5,6] With these backgrounds, the current review aimed to evaluate the different measurement methods used in the diagnosis and assessment of the thickness of the heel pad along with their clinical implications.

Factors that influence the Thickness of a Heel Pad

Weight, age, gender, the form of the calcaneum, and the size of the heel pad are all factors that might affect the thickness of the heel pad. With aging, the heel pad's capacity to absorb stress has been discovered to decline.[7] This might be related to the degeneration of fibrous structures and fat in the heel pad, which could be a result of biological changes in material qualities as people age. Under stress, the internal cell compartments of the heel pad break down, allowing for local bulging and displacement, resulting in a thinner pad. Children's heel pads have been observed to have a lower shock-absorbing capacity than adults'.[8] Adults and children may have different body weights, effective mass involved during heel strike, muscle function, and muscle utilization, according to Kuo and Donelan.[9] As a result, the shock absorbency of a child's heel pad may not necessarily be inferior to that of an adult, but rather reflect the child's motion. The characteristics of the heel pad have previously been shown to be sex-dependent. It is possible that men's thicker heel pads are related to higher levels of growth hormones.[10] According to Steinbach and Russell, there was a substantial variation in the heel pad thickness between subjects with acromegaly and normal Caucasian males.[11] Increased levels of estrogen in women can influence the rigidity of fibrous tissues, causing ligament instability in some ligaments. Previous studies have found that there are racial disparities in heel pad thickness.[12] According to research, a 35–400° dorsiflexion of the first and second toes can regulate up to 50% of individual variations in skin mobility.[1] Increased skin density, such as that found in athletes' calloused skin, can enhance the thickness and stiffness of the heel pad. Increasing the thickness of the heel pad does not improve stress absorbance, and because calloused skin is harder and less flexible, it may potentially restrict the function of the internal ligamentous system, lowering shock absorption and function.[13,14]

Different Measurement Methods of Heel Pad Thickness

MRI

Although soreness in the posterior weight-bearing portion of the calcaneus, rather than the more anterior sensitivity found with plantar fasciitis, is commonly associated with plantar fasciitis, the uncomfortable heel fat pad is often confused with plantar fasciitis.[15] Magnetic resonance imaging can indicate variations in signal intensity in some cases of painful heel fat pads, with low-signal-intensity bands reflecting fibrosis and reduced fat pad height. Magnetic resonance imaging can indicate variations in signal intensity in other cases with painful heel fat pads, with low-signal-intensity bands reflecting fibrosis, and reduced fat pad height. Due to its better soft tissue contrast resolution and multiplanar capability, MRI allows for the direct, noninvasive portrayal of the osseous and soft tissue components of the hindfoot. In unclear or clinically equivocal cases, MRI can help establish the cause of heel pain and assess the degree and severity of the condition.[3]

Inflammation of the fat pads can, however, arise as a result of sports injuries in young people. In these cases, MRI reveals edematous changes in the fat pad with ill-defined regions of lower signal strength on T1-weighted images that increase the intensity of the signal on T2-weighted images.[16,17] Magnetic resonance imaging can also be used to detect and evaluate lesions that take up a lot of space in the fat pad.[18] Rheumatoid nodules can develop in the plantar fat pad and close to the Achilles tendon in the heel. These lesions can be painful at times, and they can also break down and become infectious.[18] The histologic composition of heel rheumatoid nodules is reflected in their MRI appearance. In MRI, two morphologic patterns have been identified. On T1- and T2-weighted images, solid lesions, which are formed entirely of chronic inflammatory cells and small arteries, show poor signal intensity but enhance after contrast material.[19,20] On T1-weighted images, the cystic core section of rheumatoid nodules with central necrosis looks hypointense, but the solid peripheral region, which is constituted of palisading inflammatory cellular infiltrate, appears hypointense on both T1- and T2-weighted images. After contrast material injection, a peripheral ring of elevation helps demarcate the unaugmented center area.[19] Rogers et al.[21] recently reported a case-control study that identified MRI and ultrasound-derived imaging biomarkers as being linked to persistent plantar heel pain. According to the study, chronic plantar heel pain is connected to calcaneal bone marrow lesions and plantar fascia imaging biomarkers.

Ultrasonography

For examination of various organs in the body, the most convenient and accessible tool is ultrasound. The technique is fairly cost-effective and fast for the detection of various anomalies. In this method, the individuals are not exposed to ionizing radiation. In not all subjects, ultrasound is found to be suitable. In individuals with the deposition of adipose layers, there may be difficulty in obtaining clear imaging. In addition, the quality of the examination depends largely on the individual's experience conducting the ultrasound.[22,23]

The evaluation of the thickness of the heel pad can be performed efficiently using the high-resolution ultrasonography method. In comparison to the radiographic methods, the use of ultrasonography helps in the determination of actual measurement values rather than slight radiographic magnification that is mainly dependent on the distance of focus and film. In previous evaluations, a value of 16.6 mm for the hill pair was observed in the control subjects. The usual consideration of mean values of less than or equal to 20 has been used by the investigators for the normal.[4] Belhan et al.[3] investigated the heel fat pad thickness in plantar fasciitis patients to examine if there was a relationship between plantar fasciitis and age, profession, body mass index, longitudinal arch, and heel fat pad thickness. A total of 50 individuals were included in this study, all of them had been diagnosed with plantar fasciitis. The findings suggest that ultrasonography is an accurate and reliable imaging tool for determining the heel fat pad thickness in the evaluation of plantar fasciitis, and that the heel pad was smaller in plantar fasciitis patients with painful heels.

Overall, the use of ultrasound has the added advantage of being noninvasive in nature as well as increasing simplicity in performing the technique. Thus, the use of ultrasonography is an effective alternative for assessing the thickness of the heel pad in comparison to radiography. The weight-bearing measurements in comparison to the nonweight-bearing ultrasonography measurements for evaluating the heel pad thickness were found to show similar observations with no significant variations. A few studies have also suggested that ultrasonography, although being a safe technique, lacks efficiency in the error-free measurement of heel pad thickness with and without load. The thickness of symptomatic heel pads was found to be measured similarly to the asymptomatic heel pads.[4]

Radiography

In a variety of circumstances, increased heel pad thickness, also known as the heel pad sign, is defined by a rise in the thickness of the heel pad soft tissue on lateral ankle radiographs.[21,24] Studies on heel pad thickness using nonweight-bearing radiographs have indicated atrophy of the heel pad in the aged and individuals with sedentary lifestyles, and a recent study found that ultrasonic heel pad thickness was substantially higher in patients with unilateral displaced intra-articular calcaneal fractures 21–35 months postinjury.[22,25] Uzel et al.[4] used Jorgenson's approach to investigate the effectiveness of the heel pad in absorbing stress. This method measured the visual compressibility index for heel pad thickness on loaded and unloaded little radiographs. To perform a comparison, the assessment was also conducted using ultrasonography. It is demonstrated that the values of heel pad thickness in individuals suffering from plantar heel pain measured through ultrasonography or direct radiography have similar values. Diagnostic methods and indexes for the measurement of thickness of heel pad were shown in Table 1.

Clinical Implications

Diabetes

Investigations have highlighted that the heel pad thickness in normal individuals ranges from 10.30 to 16.55 mm. The values of heel pad thickness vary significantly between individuals who have diabetes and those who do not have diabetes. The range of heel pad thickness varies from 11.40 to 20.41 mm in the Australian diabetic population. Previous evaluations have highlighted that there is an increase in heel pad thickness in individuals with diabetes.[26] The glycation of proteins is promoted by hyperglycemia, which is the main determinant of diabetes in these individuals. The accumulation of advanced stage glycation end products is the outcome in the human tissues. There is a thickening of the human tissues due to the accumulation of such products in the basement membrane. The investigation conducted by Udoh et al.[1] suggested that the dimensions of the heel pad thickness were almost similar to the difference in gender among the enrolled diabetic individuals, unlike the normal control individuals. The overshadowing effects and supremacy of nonenzymatic glycation in individuals with diabetes may be the reason for the observed results. Thus, in individuals with diabetes, the heel pad thickness is driven by hyperglycemia instead of their genetic composition. In another study, the thickness of

Table 1: Diagnostic methods and indexes for the measurement of thickness of heel pad

Name of the author	*Method*	*Measuring indexes (mm)*	*Clinical significance*	*Conclusion*
Belhan et al.[3]	Weight-bearing ultrasound radiography	19.94 and 6.75 mm	Diagnosis of plantar fasciitis	Ultrasound radiography is an accurate and reliable imaging technique for the measurement of heel pad thickness
Udoh et al.[1]	Small-parts real-time ultrasonography	16.79 ± 1.84 mm (diabetic patients)	Measurement of heel pad thickness	Ultrasonography can be used in detecting heel pad thickness
Roemer et al.[36]	MRI	Not reported	Hoffa fat pad examination	MRI can be used in examining Hoffa fat pad
Hunter et al.[37]	MRI	Scaling range: 0–3	Bone marrow assessment	MRI can be used in assessing the bone marrow validity and osteoarthritis knee
Udoh et al.[38]	Sonography	0.036 ± 0.023 mm	Assessment of heel pad thickness	Sonography can be used in assessing heel pad thickness
Greene[39]	Nonweight-bearing radiography	19.0 ± 2.19	Detection of heel pad thickness	Radiography can be used for the measurement of heel pad thickness
Kerr et al.[40]	Weight-bearing ultrasound	9.80	Compressibility in calcaneal fractures	Ultrasound can be used for the measurement in case of calcaneal fractures
Prichasuk[41]	Weight-bearing radiography	9.85 ± 2.22	Plantar heel pain	Increase in weight was associated with increment in thickness of heel pad and compressibility
Levy et al.[42]	MRI	18.0 ± 4.57	Calcaneal fat pad	There was detailed visualization of the heel pad and its structures in the surrounding with the use of MRI
Gooding et al.[43]	Nonweight-bearing ultrasound	16.6 ± 0.32	Heel pad thickness varies in diabetes and acromegaly	Ultrasound can be used for the measurement of thickness of heel pad
Benard and Stephens[30]	Photography	Not reported	Heel morphology	There is variation in heel shape, width, and length of Achilles tendon insertion, and calcaneal fat pad in different races

the tendocalcaneous was found to be in positive association with low-density lipoproteins and a negative correlation was found with high-density lipoproteins.[27] The glycated hemoglobin is a measure of the past 2 or 3 months' glycemic control. The synthesis of new collagen is enhanced in the case of individuals with diabetes.[28] The connective tissue and skin bear residues of advanced glycation end products that are linked to the severity of hyperlipidemia and hyperglycemia.[29] These findings are indicative of the role of the lipid phenotype in the deposition of collagen and cholesterol in the tissues. This states that the evaluation of heel pad thickness may also be beneficial for the evaluation of glycemic control and dyslipidemia. Moreover, in diabetes, the formation of foot ulcers is very common. Quantification of the heel pad thickness can increase understanding of the tissue condition in diabetic individuals. Hence, to prevent further complications of diabetes, heel pad thickness is recommended.[1]

Acromegaly

The identification of clinical features constitutes the process of diagnosis of acromegaly. The enlargement of the pituitary fossa is demonstrated by the rise in growth hormone levels in the system that are not suppressible by intravenous or oral glucose.[30] The results by Kho et al.[31] highlighted the discriminatory power of heel pad thickness between healthy individuals and people with acromegaly, further reinforcing another previous report by Steinbach and Russell.[11] The use of cut-offs like 21.5 mm in females and 23 mm in males was a misclassification for male as well as female controls. In this study, a heel pad thickness of less than or equal to 25 mm in males and less than or equal to 23 mm in females was observed. The untreated female and male subjects with acromegaly did not have heel pad thickness of less than 21 or 18 mm, respectively. The major help required for the clinician in practice is at this stage of early or milder forms of the disease. According to the experience of endocrinologists, the thickness of the heel pad was found to have a negligible influence on the diagnosis of acromegaly. Post-treatment for tumors in the pituitary, the assessment of the thickness of the heel pad might be vital and more valuable during the time of follow-up in acromegaly individuals. It has been suggested that a decrement of more than 50% in the level of growth hormones in the system is required to highlight a substantial thickness reduction in the heel pad.[31]

Obesity

A study conducted by Jackson[32] tested the hypothesis that obese people are expected to have fat heels. They enrolled 20 patients weighing more than 91 kg, out of which 19 were white men and one was black. None of the enrolled individuals had clinical data of acromegaly, and in most of the cases, lateral skull radiographs taken did not implicate any type of abnormality. Twenty heel pads were measured for 20 individuals, and 26 heel pads (65%) had a measurement of over 20 mm. In 10 individuals who weighed more than 125 kg, 90% of measurements were more than 21 mm, though the thickness was not found to be directly associated with body weight. This study determined that obese individuals with thick heel pads do not necessarily have acromegaly. Numerous investigations have identified obesity as a significant risk factor for the development of heel pad thickness.[3,33]

Plantar fasciitis

Plantar fasciitis is a condition that occurs as a result of voluntary constraint and is a prevalent cause of heel discomfort in adults. It impacts athletic as well as sedentary individuals, and more than 1 million individuals are diagnosed with this condition every year in the United States.[34] The precise etiology of plantar fasciitis remains unknown. Nonetheless, repeated and chronic microtraumas to the heel (planar face) are thought to create microtears at the plantar fascia–calcaneus junction. Inflammatory responses as well as delayed tissue repair are also considered suspects in the pathogenesis of plantar fasciitis. Pes planus is also regarded as a significant risk factor for the development of plantar fasciitis. In a study by Belhan et al.,[3] it was revealed that pes planus was discovered in 24% of individuals with plantar fasciitis. An important risk factor for plantar fasciitis, obesity, was observed to be high in women as compared to men, and the rate of obesity was 66%. Also, they revealed that plantar fasciitis was related to the thickness of the heel fat pad along with loss of elasticity.[3] Obesity exists in nearly 70% of patients suffering from plantar fasciitis. A strong association was observed between plantar fasciitis and increased body mass index in individuals who were not athletes.[35] The evidence also suggests that contrasting weight and height did not show any association with plantar fasciitis. To be more precise, the association is observed between increased weight and plantar fasciitis, but not essentially with height. Fascinatingly, no correlation was observed between plantar fasciitis and weight, body mass index, or height in an athletic population.[35]

Conclusion

The heel fat pad is the adipose tissue that covers the heel's plantar surface. It lies in between the skin and the calcaneum and comprises an intricate structure with vascular, neuronal, fibrous, and elastic constituents found knotted with fat cells. Different methods like photography, radiography, ultrasonography, and MRI have been used for the measurement of the thickness of the heel pad. However, ultrasonography and radiographic methods have found their maximum use in clinical applications for individuals with or without health issues. Although the most widely used method is ultrasound due to its safety and efficacy, this is dependent on the requirements and availability of these methods, which may vary.

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