PICTORIAL REVIEW

Skeletal muscle disease: patterns of MRI appearances

¹D J THEODOROU, MD, PhD, ²S J THEODOROU, MD and ³Y KAKITSUBATA, MD, PhD

¹Department of Radiology, General Hospital of Ioannina & National Health Care System, Ioannina, Greece, ²Department of Radiology, University of Ioannina School of Medicine, Ioannina, Greece, and ³Department of Radiology, Miyazaki Shikaihoken Hospital, Miyazaki, Japan

ABSTRACT. Although the presumptive diagnosis of skeletal muscle disease (myopathy) may be made on the basis of clinical–radiological correlation in many cases, muscle biopsy remains the cornerstone of diagnosis. Myopathy is suspected when patients complain that the involved muscle is painful and tender, when they experience difficulty performing tasks that require muscle strength or when they develop various systemic manifestations. Because the cause of musculoskeletal pain may be difficult to determine clinically in many cases, MRI is increasingly utilised to assess the anatomical location, extent and severity of several pathological conditions affecting muscle. Infectious, inflammatory, traumatic, neurological, neoplastic and iatrogenic conditions can cause abnormal signal intensity on MRI. Although diverse, some diseases have similar MRI appearances, whereas others present distinct patterns of signal intensity abnormality. In general, alterations in muscle signal intensity fall into one of three cardinal patterns: muscle oedema, fatty infiltration and mass lesion. Because some of the muscular disorders may require medical or surgical treatment, correct diagnosis is essential. In this regard, MRI features, when correlated with clinical and laboratory findings as well as findings from other methods such as electromyography, may facilitate correct diagnosis. This article will review and illustrate the spectrum of MRI appearances in several primary and systemic disorders affecting muscle, both common and uncommon. The aim of this article is to provide radiologists and clinicians with a collective, yet succinct and useful, guide to a wide array of myopathies.

Received 2 March 2012
Revised 15 May 2012
Accepted 7 June 2012

DOI: 10.1259/bjr/14063641

© 2012 The British Institute of
Radiology

Skeletal muscle disorders have a wide variety of causes, treatments and prognoses, and are commonly seen in orthopaedic, neurology or internal medicine practices. The diagnosis of muscle disease (myopathy) has traditionally relied on clinical examination, coupled with histological analysis of a muscle biopsy specimen in complex cases that may be clinically obscure. Because patients with these conditions present with vague symptoms of myalgia, weakness, fatigue and disability, the abnormalities are often initially overlooked or even underestimated as a source of pathology [1, 2]. Furthermore, clinical assessment of the integrity and performance of skeletal muscle can be problematic, owing to the complex compartmental anatomy and several anatomical variations in muscle [3]. Early recognition of abnormalities is, however, critical to implementing an appropriate management regimen that facilitates patients' prompt and safe return to function and activity.

Given the relatively non-specific clinical presentation of the spectacular array of primary and systemic disorders affecting skeletal muscles, imaging plays a key role in achieving the correct diagnosis. Although

radiography allows for evaluation of certain muscle derangements (e.g. infection, heterotopic ossification), it is limited by relatively poor sensitivity and lack of anatomical detail [4, 5]. CT facilitates the diagnosis of conditions similar to those detected by radiography in a cross-sectional display, but it provides limited contrast resolution for muscle. MRI has emerged as the advanced imaging method of choice for skeletal muscle, providing excellent soft-tissue contrast resolution and multiplanar tomographic display. Although many of the disorders affecting muscle may manifest with non-specific imaging signs, MRI allows detection and characterisation of these lesions, which helps to formulate a reasonable diagnosis or to establish a limited differential diagnosis. Furthermore, MRI can depict selective abnormality within individual muscles that may be challenging to detect clinically because of the presence of unaffected synergistic muscles [6]. We present the MRI findings seen with a wide range of primary and systemic neuromuscular and orthopaedic disorders that can aid the clinician when assessing the cause of pain and dysfunction in muscle. Although this work is not an exhaustive presentation of muscular pathology, we aim at presenting a concise, helpful and practical imaging review of the basic MRI findings associated with common and uncommon musculoskeletal disease processes.

Address correspondence to: Dr Stavroula J Theodorou, Department of Radiology, University of Ioannina, School of Medicine, 13 Papadoupoulus Street, Ioannina 45444, Greece. E-mail: rjtheodorou@hotmail.com

(a)

(b)

Figure 1. A 10-year-old male who sustained a low-grade (Grade 1) strain in the rectus femoris muscle, 4 days after an injury that occurred while playing basketball. (a) Axial short-tau inversion-recovery (STIR) MR image of the anterior thigh demonstrates faint increased signal (arrowhead) in the rectus femoris muscle adjacent to the thickened myotendinous junction. (b) Coronal STIR MR image shows hyperintense signal (arrowheads) in the rectus femoris muscle surrounding the thickened myotendinous junction and tracking along the muscle fascicles, in a feathery pattern (arrow).

Figure 2. Adductor longus tear in a 16-year-old male, 2 days after a bowling injury. Coronal T_2 weighted MR image of the anterior thigh demonstrates fluid signal (arrow) collecting at the site of complete fibre disruption, indicating a high-grade (Grade 3) injury.

Figure 3. Delayed-onset muscle soreness in a 24-year-old female hairdresser, 1 day after intense manual labour. Axial short-tau inversion-recovery image demonstrates increased signal intensity (arrow) in the extensor carpi radialis brevis muscle. Soreness subsided within 1 week of rest.

(a)

(b)

Figure 4. Adductor magnus muscle contusion in a 24-year-old male hockey player, 2 weeks after a direct blow to the thigh. (a) Axial T_1 weighted image of the right mid-thigh shows only minimal signal alteration (arrow) in the adductor magnus muscle representing sub-acute haemorrhage into the muscle. (b) Axial T_2 weighted MR image shows abnormal high signal intensity within the substance of the adductor magnus muscle (arrow) due to oedema and haemorrhage, which also outlines adjacent femoral neurovascular structures (arrowheads). Perifascial oedema (open arrowheads) is also seen.

(a)

(b)

Figure 5. Rhabdomyolysis in a 13-year-old male with gradual onset of pain in his arms after an intense weight-lifting workout. (a) Axial T_1 weighted MR image of the left arm shows subtle increased signal (asterisk) in the medial head of triceps brachii muscle. (b) Sagittal T_2 weighted MR image through the upper arm displays diffuse increased signal intensity in the triceps brachii muscle (arrowheads). Note that oedema-like signal tracks along the muscle fascicles assuming a characteristic feathery appearance (arrow) that reflects the architecture of the muscle. Associated myoglobinuria confirmed the diagnosis of exertional rhabdomyolysis of the left triceps brachii. H, humerus.

MRI technique

The proposed simplified MRI protocol used at our institution was developed based on our experience in evaluating suspected muscle pathology using a 1.5 T MR unit (Signa; GE Healthcare, Madison, WI). The patient is comfortably placed in the supine position to avoid pain, motion and compression of different muscle groups. Occasionally, a marker (*i.e.* a nitroglycerin capsule) is used to indicate the exact source of pain. Coronal and axial spin-echo T_1 weighted [repetition time (TR)/echo time (TE), 650–800 ms/15–20 ms] and fast spin-echo T_2 weighted (TR/TE, 3300–4550 ms/90–140 ms) sequences

with fat suppression are performed. Alternative to the fat-suppressed T_2 weighted sequence is a short-tau inversion-recovery (TR/TE, 3000–3665 ms/15–35 ms; inversion time, 150 ms) sequence. Images in a sagittal plane are occasionally acquired to match individual requirements, and intravenous administration of gadolinium-containing contrast material is advised as appropriate.

Pathophysiology

Muscle fibre constitutes the basic structural element of skeletal muscle. The architecture and integrity of fibres in muscle is directly related to the muscle's function and mechanical behaviour. Normal skeletal muscle function is dependent on intact muscle fibres, normal innervation and sufficient blood flow. The application of abnormal mechanical stresses on muscle as well as certain neurogenic disease processes causing neuropathic muscle dysfunction, several neuromuscular junction diseases and different types of myopathies (*e.g.* metabolic, congenital) are all associated with net damage to the muscle cells, having variable effects on strength or motion [1, 2, 6]. Injury to the muscle–tendon–bone unit, which represents the structurally weakest portion of the muscle where muscle fibres join the tendon, also known as the myotendinous junction, is common and can vary by age. For instance, muscle injuries are more common in the young and tendon tears are more common in the elderly.

Skeletal muscle responds to various insults with only a limited number of non-specific biological responses (*e.g.* oedema, atrophy, fibrosis). For example, in physical trauma the healing process represents repair in the form of a fibrous scar rather than true regeneration of the injured muscle. Indeed, a wide array of primary and systemic disease processes affecting muscle can present with similar gross pathological features. MRI plays an important role in detecting alterations in muscle

Figure 6. Acute compartment syndrome in a 46-year-old male who developed severe proximal thigh pain 1 day after injury in a motor vehicle accident. Axial short-tau inversion-recovery image shows diffuse hyperintensity of the anterior compartment muscles (arrowheads), but no osseous abnormalities. A small haematoma (arrow) is present in the vastus intermedius muscle. Compartment pressures were subsequently measured and confirmed the diagnosis of compartment syndrome.

Figure 7. A 52-year-old male with poorly controlled diabetes who presented with sudden onset of severe pain in the proximal thigh and buttocks and muscle infarction. (a) Coronal, fat-suppressed T_2 weighted MR image shows extensive intramuscular oedema in the anteromedial thigh involving the obturator externus, pectineus and the adductor brevis and longus muscles (arrow). A small collection of fluid (arrowhead) is noted between the obturator externus and pectineus muscles. (b) Axial T_2 weighted MR image displays diffuse oedema in the adductors extending through the gluteus maximus muscle. High signal intensity fluid is seen in the adductors (arrowhead).

Figure 8. Polymyositis in a 26-year-old female who presented with bilateral lower extremity pain and muscle weakness. (a) Axial T_2 weighted MR image of the thighs shows abnormal, widespread feathery oedema in the vastus lateralis, intermedius, medialis and the rectus femoris muscles (arrows). Note the preservation of normal muscle architecture. T_1 weighted imaging (not shown) did not display signal alteration or atrophy in affected muscles, or otherwise contribute to diagnosis in this case. (b) Coronal fat-suppressed T_2 weighted MR image of both legs also shows extensive oedema signal in the muscles of the calf (arrows). The medial head of the right gastrocnemius muscle appears spared (arrowhead).

Figure 9. Idiopathic myositis in a 57-year-old male with sudden onset of muscle weakness, tenderness and inability to walk. Coronal short-tau inversion-recovery MR image through the pelvis, hips and the thighs shows diffuse oedema of the pelvic and thigh muscles. Muscle biopsy disclosed “non-specific” myositis. The symptoms resolved over a 6-month period, and the patient was able to resume full physical activity.

morphology and signal intensity characteristics associated with many disorders. Because the MRI findings of muscle disease may reflect the gross underlying pathology rather than provide specific features for imaging diagnosis, a range of differential diagnoses may eventually need to be considered. To facilitate the challenging diagnostic process, MRI and associated pathological changes of parenchymal alterations in skeletal muscle

Figure 10. Infectious myositis manifesting as oedema in the right quadriceps muscles (asterisks) of a 34-year-old human immunodeficiency virus-positive male, who presented with a swollen painful thigh and fever. Notably, there is no abscess formation that would have caused a mass-like appearance on MR images.

are systematically classified into three major patterns based practically on the presence of oedema, fatty infiltration or a mass, as presented below [1, 7].

Major patterns of muscle involvement

Muscle oedema pattern

Acute or recent muscle insult is characterised most commonly by oedema, vascular engorgement and

(a)

(b)

Figure 11. Sarcoid myopathy in a 52-year-old female presenting with muscle weakness, myalgias and elevated muscle enzyme levels. (a) Coronal T_2 weighted MR image shows abnormal high signal intensity changes in the adductor muscles, consistent with oedema (arrows). (b) Axial fat-suppressed T_2 weighted MR image through the thighs shows extensive, high signal intensity oedematous changes involving all muscle compartments, in both thighs. Biopsy revealed non-caseating, granulomatous, lymphocytic infiltration, and muscle necrosis.

Figure 12. A 53-year-old female with muscle oedema after radiation therapy for lung cancer. Coronal T_2 weighted MR image shows oedematous and enlarged paraspinal muscles (arrowheads), in the radiation field.

inflammatory cellular infiltration [2]. Generally, these non-specific pathological changes correspond to areas of low to intermediate signal intensity on T_1 weighted images and high signal intensity on T_2 weighted and inversion–recovery images. Many conditions reflecting a recent insult or a biologically active process can produce similar changes in signal intensity, including traumatic injury (e.g. strain, contusion), muscular exertion (e.g. delayed onset muscle soreness), rhabdomyolysis, vascular insults (e.g. compartment syndrome, diabetic infarction), myositis (e.g. autoimmune, idiopathic, infectious, sarcoid myopathy), early myositis ossificans, subacute denervation and radiation therapy [1, 4, 5, 8–10]. Representative cases are illustrated in Figures 1–12.

Fatty infiltration pattern

Chronic muscle insult results in abnormal fatty infiltration of muscle and is characterised by the presence of fat signal intensity on both T_1 weighted and T_2 weighted images. Associated muscle atrophy is common. Severe muscle injury or chronic musculotendinous injury (e.g. tendon tear), chronic disuse, chronic denervation, myopathy (muscular dystrophy, mitochondrial myopathy), lipomatous lesions and corticosteroids are among the conditions associated with fatty infiltration atrophy [1, 2, 6, 7, 11–13]. Selected cases are illustrated in Figures 13–19. These pathological changes result in muscle contraction and stiffness, which, in turn, alter biomechanics and predispose weakened muscle to further injury during weight-bearing and muscle exertion.

Figure 13. Old partial disruption of the proximal gastrocnemius muscle fibres at the musculotendinous junction (MTJ) region in a 27-year-old male who was injured while running a marathon. Coronal T_1 weighted MR image of the calf shows increased signal intensity within the medial gastrocnemius muscle (asterisk) and high signal intensity adjacent to the aponeurosis owing to abnormal deposition of fat (arrowheads). Findings of a chronic partial tear of the proximal gastrocnemius fibres at the MTJ region (arrow) are seen.

Mass lesion pattern

The mass lesion pattern refers to the presence of a space-occupying lesion in muscle. The MRI characteristics of lesions producing a mass effect are variable and typically different from those of normal muscle on all pulse sequences. Infection (e.g. pyomyositis, abscess, parasitic infection), traumatic injury (e.g. haematoma), myositis ossificans, myonecrosis, muscular sarcoidosis and neoplasms (e.g. lipoma, liposarcoma, leiomyosarcoma) are all associated with an intramuscular mass

(a)

(b)

Figure 14. Chronic disuse in a 58-year-old female with recurrent dislocations of the shoulder that resulted in limited use of her right arm. (a) Coronal T_1 weighted MR image shows extensive fatty infiltration of the infraspinatus (asterisk), teres minor (arrowhead) and deltoid (open arrowhead) muscles as a result of disuse. (b) Sagittal T_1 weighted MR image displays concomitant atrophy and fatty infiltration of the supraspinatus muscle (arrows).

Figure 15. Chronic disuse in a 43-year-old male who had below-knee amputation after a motorcycle accident 12 years earlier. Sagittal T_1 weighted MR image shows increased signal, indicating fatty infiltration of the gastrocnemius and popliteus (asterisk) muscles.

Figure 16. Charcot-Marie-Tooth disease (hereditary motor-sensory neuropathy) in a 58-year-old male with left leg swelling and weakness. Axial T_1 weighted MR image of the left calf shows diffuse abnormal high signal intensity in enlarged soleus and gastrocnemius muscles (arrows), reflecting gross fatty replacement.

Figure 17. Chronic denervation of the left psoas muscle in a 56-year-old male who had had poliomyelitis at age 3. Axial T_1 weighted MR image shows fatty infiltration of the left psoas (arrowhead) with a marked decrease in muscle volume. The contralateral psoas muscle appears hypertrophic (arrow).

Figure 18. Mitochondrial myopathy in a middle-aged male. An axial T_1 weighted MR image of the thighs shows almost symmetrical fatty infiltration and atrophy of the quadriceps muscles (asterisks).

Figure 19. Fatty infiltration in a 52-year-old female receiving long-term corticosteroids for rheumatoid arthritis. Coronal T_1 weighted MR image shows prominent fatty infiltration and atrophy of the gluteal muscles (arrows). Bilateral, steroid-induced osteoporotic sacral fractures are apparent (arrowheads).

Figure 20. Muscular *Echinococcus* infection in a 46-year-old farmer with painful swelling of the musculature in the proximal thigh and hip. Coronal fat-suppressed T_2 weighted MR image shows large, loculated hyperintense parasitic cysts (arrows) in the muscles of the left thigh and hip.

(a)

(b)

Figure 21. Pyomyositis with abscess formation in a 59-year-old male who sustained direct trauma to the hip and presented with pain of the left thigh, fever and malaise. (a) Coronal T_1 weighted MR image shows large, sausage-like fluid collections in the left iliopsoas and iliacus muscles (arrowheads), extending from the pelvis to the hip. (b) Corresponding coronal T_2 weighted MR image shows multiple, extensive high signal intensity abscesses (arrowheads) adjacent to the wing of the ilium and anterior to the hip joint on the left side. Cultures of the abscess material showed *Staphylococcus aureus*.

Figure 22. Intramuscular haematoma caused by a direct blow to the right calf in a 15-year-old male during a hockey game 1 week earlier. Axial T_1 weighted MR image (a) and coronal T_2 weighted MR image (b) show a subacute haematoma of homogeneous high signal intensity in the gastrocnemius muscle (arrow). F, fibula; T, tibia.

lesion [4, 5, 9, 10, 14–16] (Figures 20–26). MRI provides a characterisation of mass composition that may reveal clues to the nature of a given lesion.

MRI differential diagnosis

In addition to the aforementioned signal intensity changes, other interesting MRI features of muscle derangement may include abnormal low signal intensity on T_2 weighted images representing calcification, fibrosis, haemosiderin deposition, gas and foreign bodies. The presence of methaemoglobin in muscle, proteinaceous material, melanin or a gadolinium-based contrast material may account for high T_1 signal intensity in muscle. As expected, some of the conditions affecting muscle are

self-limited and respond faster to conservative management, whereas others require surgical intervention and a longer recovery period. Other muscle disorders, however, take a more severe clinical course and are refractory to treatment or have an ominous prognosis.

Conclusion

MRI plays a central role in delineating muscle anatomy and morphology, and providing characterisation of muscle composition and its alterations. Although eventually biopsy may be necessary to establish diagnosis, MRI helps to limit substantially the broad differential diagnosis, influencing the treatment and predicting prognosis in patients with muscle complaints.

Figure 23. Myositis ossificans presenting as a painful and palpable mass in the left quadriceps musculature. (a) Axial T_1 weighted MR image shows a well-defined, low signal intensity area (arrow) in the vastus intermedius and lateralis muscles adjacent to the proximal femur. Another lesion of increased signal intensity is seen in the gluteus maximus muscle (arrowhead). (b) Corresponding axial T_2 weighted MR image shows a mature ossifying lesion of low signal intensity adjacent to the proximal femur (arrow), and a high signal intensity mass in the surrounding soft tissue (arrowhead). Abnormal high signal intensity corresponding to oedema is seen infiltrating the gluteus maximus muscle (asterisk). On excision, the mass in the gluteus maximus was found to be immature myositis ossificans, while mature bone was retrieved from the lesion in the quadriceps muscles.

Figure 24. Skeletal muscle injury and myonecrosis. In this patient, a contaminated wound in the right thigh that occurred after a fall has led to infective myonecrosis. (a) Axial T_2 weighted MR image shows the enlarged adductor and biceps femoris (muscles) with diffuse high signal intensity due to oedema. A central area is seen in the adductor magnus muscle (arrowhead) consistent with a collection of fluid. (b) Coronal fat-suppressed T_2 weighted MR image shows diffuse oedema in the posterior compartment of the proximal thigh (arrow). Intramuscular gas with its signal void is seen (arrowhead) indicating the presence of serious infection (gas gangrene). Cultures of the infected area showed *Clostridium tetani*.

Figure 25. Nodular-type muscular sarcoidosis in a 67-year-old male with painful soft tissue masses in the left thigh and leg. (a) Axial T_1 weighted MR image shows low signal intensity nodules in the gastrocnemius and tibialis anterior muscles of the left leg (arrows). (b) Axial T_2 weighted MR image shows intramuscular calf lesions (arrows) of central low signal intensity surrounded by a thick margin of high signal intensity (arrowheads). (c) Coronal fat-suppressed T_1 weighted MR image of the left thigh obtained after intravenous administration of gadolinium contrast material shows a large elongated lesion of central decreased signal intensity with avid rim-like enhancement in the quadriceps muscle (arrows). Biopsy disclosed non-caseating granulomas. T, tibia.

Figure 26. Leiomyosarcoma in a 78-year-old female who presented with right leg pain, swelling and inability to walk. (a) Axial T_1 weighted MR image through the calf shows a large, lobular, well-defined mass lesion (arrows) of predominantly low signal intensity in the tibialis anterior and tibialis posterior muscles. The mass extends to subcutaneous tissue (arrowhead). Because of diminished physical activity, muscles in the posterior compartment of the tibia show prominent fatty infiltration (asterisk). (b) Axial T_2 weighted MR image with fat suppression shows an intramuscular lesion of predominant high signal intensity (arrows) with a peripheral necrotic region of low signal (open arrowhead). On this fat-suppressed image, compare the appearance of the low signal intensity, fat-replaced muscle in the posterior tibia (asterisk) with that in part (a), in which no suppression of fat was used. (c) Axial T_1 weighted MR image with fat suppression shows inhomogeneous enhancement of the mass (arrows). Biopsy of the mass lesion disclosed leiomyosarcoma of the tibial muscles. T, tibia.

References

1. Fleckenstein JL. Muscle weakness and myalgia. *MRI Clin North Am* 1995;3:773–90.
2. Powell ST, Bracker MD. Orthopedic perspective: muscle and tendon disease. In: Pedowitz R, Chung B, Resnick D, eds. *Magnetic resonance imaging in orthopedic sports medicine*. New York, NY: Springer; 2008. pp. 21–44.
3. Robinson G, Hine A, Richards P, Heron C. MRI abnormalities of the external rotator muscles of the hip. *Clin Radiol* 2005;60:401–6.
4. Theodorou SJ, Theodorou DJ, Resnick D. MR imaging findings of pyogenic bacterial myositis (pyomyositis) in patients with local muscle trauma: illustrative cases. *Emerg Radiol* 2007;142:89–96.
5. McCarthy EF, Sundaram M. Heterotopic ossification: a review. *Skeletal Radiol* 2005;34:609–19.
6. Sookhoo S, MacKinnon I, Bushby K, Chinnery P, Birchall D. MRI for the demonstration of subclinical muscle involvement in muscular dystrophy. *Clin Radiol* 2007;62:160–5.
7. May D, Disler D, Jones E, Balkissoon A, Manaster B. Abnormal signal intensity in skeletal muscle at MR imaging: patterns, pearls, and pitfalls. *Radiographics* 2000;20:S295–315.
8. El-Khoury GY, Brandser EA, Kathol MH, Tearse DS, Callaghan JJ. Imaging of muscle injuries. *Skeletal Radiol* 1996;25:3–11.
9. Garcia J. MRI in inflammatory myopathies. *Skeletal Radiol* 2000;29:425–38.
10. Theodorou SJ, Theodorou DJ, Resnick D. Imaging findings of complications affecting the upper extremity in intravenous drug users: featured cases. *Emerg Radiol* 2008;15:227–39.
11. Elliott J, Galloway G, Jull G, Noteboom J, Centeno C, Gibbon W. Magnetic resonance imaging analysis of the upper cervical spine extensor musculature in an asymptomatic cohort: an index of fat within muscle. *Clin Radiol* 2005;60:355–63.
12. Kang C, Shin M, Kim S, Lee S, Lee C. MRI of paraspinal muscles in lumbar degenerative kyphosis patients and control patients with chronic low back pain. *Clin Radiol* 2007;62:479–86.
13. Kader D, Wardlaw D, Smith F. Correlation between the MRI changes in the lumbar multifidus muscles and leg pain. *Clin Radiol* 2000;55:145–9.
14. Moore S, Teirstein A. Musculoskeletal sarcoidosis: spectrum of appearances at MR imaging. *Radiographics* 2003;23:1389–99.
15. Crundwell N, O'Donnell P, Saifuddin A. Non-neoplastic conditions presenting as soft-tissue tumours. *Clin Radiol* 2007;62:18–27.
16. Vilanova JC, Woerler K, Narvaez J, Barcelo J, Martinez S, Villalon M, et al. Soft tissue tumors update: MR imaging features according to the WHO classification. *Eur Radiol* 2007;17:125–38.