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The Intrinsic Muscles of the Hand

Function, Assessment and Principles for Therapeutic Intervention

dt. Titel
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Zusammenfassung

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Schlüsselwörter
xxx · xxx · xxx

Abstract

This article reviews the functional anatomy of the intrinsic muscles of the fingers (palmar interossei, dorsal interossei, hypothenar and lumbrical muscles) and discusses the pathokinesiology of the hand with intrinsic muscle paralysis and its consequences for Activities for Daily Living. The assessment of muscle strength: manual and instrumental and principles for therapeutic intervention are also discussed.

Key words
xxx · xxx · xxx

Introduction

Many valuable studies have been published about the anatomy [1–5], mechanics [6–10], and architectural design [11], of the intrinsic muscles of the hand. Understanding the mechanics of human dexterity requires an appreciation of the kinetic chains that comprise the hand, and the intricate interplay of muscles and ligaments that control its movements. In these chains, the intrinsic muscles of the hand are of paramount importance for efficient hand function [11].

There is a considerable decrease in functional efficiency in hands with loss of intrinsic muscle function, often referred to as the claw hand or intrinsic minus hand (Figure **1**) [12–14].

A comprehensive analysis of hand function should include assessment of the strength and length of the intrinsic muscles. This will provide important information and assist the assessor in determining nerve function, deciding which muscle group(s) may need to be strengthened, if and what splint maybe needed and what surgery needs to be considered e. g. nerve graft, tendon transfer, or of conservative management is still indicated.

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Fig. 1 Long-standing paralyses of all intrinsic muscles can cause severe clawing of the fingers.

Although assessment of muscle strength and length are important elements of hand examination other functions, such as mobility, sensibility and central properties of the brain, are equally or even more important for hand function. Co-ordination and speed of hand movements are difficult to assess quantify but nevertheless important features of muscles, which control hand function.

Hand function tests have been developed by e.g. Moberg [15], Bendz [16], Sollerman et al [17], and Light et al [18]. Most of these tests would record the time it takes to finish a set of activities. Clinicians often observe that patients with impairments of the hand quickly learn to compensate for lost functions. Therefore, tests for hand function may only assess the ability of the patient to compensate for lost function.

There is little consensus about classifications of prehensile patterns of hand function [19]. The general characteristics remain largely consistent with the following categories: pinch grips (tipp pinch, lateral or key pinch, and tripod or chuck pinch) and three modes of gripping: (power grip, spherical or flexion grip, and extension grip in intrinsic plus position) [18]. It is estimated that for a full range of naturally common grips, a spherical grip is required for 10%, a tripod grip for 10%, a power grip for 25%, a lateral grip for 20%, a tipp grip for 20%, and an extension grip for 10% of E activities of daily living. Without intrinsic muscles a power grip is somewhat weaker but still possible. For all grips the intrinsic muscles play an important role.

The aim of this paper is fourfold:

a) to review the functional anatomy of the intrinsic muscles of the fingers.
b) to discuss the pathokinesiology of the hand with intrinsic muscle paralysis, its consequences for Activities for Daily Living (ADL) and muscle shortening.
c) to present possibilities for the assessment of muscle strength: manual and instrumental.
d) to discuss principles for therapeutic intervention: prevention of complications and strengthening exercises.

The hypothenar muscles will be discussed as a separate group and the intrinsic muscles of the thumb will be discussed in a companion paper.

For this paper the authors have selected studies mainly from rehabilitation, hand surgery, hand therapy and biomechanical journals.

Intrinsic muscles of the fingers

In general, each finger has six muscles controlling its movements: three extrinsic muscles (two long flexors and one long extensor) and three intrinsic muscles (dorsal and palmar interosseous and lumbrical muscles). The little finger and the index finger each have an additional extrinsic extensor.

1 Dorsal and palmar interosseous

1.1 Functional anatomy

Most textbooks state that there are four dorsal (DI) and three palmar (PI) interosseous muscles. Stack et al. [20] suggested that it might be more useful to divide the interosseous into proximal and distal, as it is their insertion rather than the origin, which dictates their action. Most dorsal interosseous muscles have a more proximal attachment while the palmar interosseous have a more distal attachment similar to the lumbricals [17]. According to Zancolli [21] there are three types of insertions of the interosseous:

Type I most proximal, attached to:
a) tubercle of proximal phalanx,
b) transverse and oblique fibres of extensor apparatus
c) the volar plate.

Type II is like type 1 except that there is no attachment to the bone (a) and part of the insertion is into:
d) the lateral band.

Type III has all four attachments a, b, c and d.

The first dorsal interosseous (1 DI) insertion is of type I. All other DI are of type III. All PI have a type II insertion, but variations are possible [22]. Because of its insertion, the strongest activity of the 1 DI is in key pinch when the thumb is pressed against the mid-phalanx of the index finger. The 1 DI is also active in tipp pinch, when the tipp of the thumb is pressed against the tipp of the index finger. In that case the main action is as a flexor at the metacarpophalangeal (MCP) joint. The first palmar interosseous (1 PI) muscle is more active in tipp pinch activities and produces some supination of the index finger to get good approximation with the pulp of the thumb. In this respect we might consider the 1 PI as the „opponens indices“ muscle.

The insertion into the lateral band of the extensor apparatus (d) is important for extension at the proximal interphalangeal (PIP) joints.

Without interosseous the finger is unstable and will collapse into the „claw“ (i.e. intrinsic minus) position of (hyper) extension of the MCP joint and flexion of the IP joints when loaded. Therefore

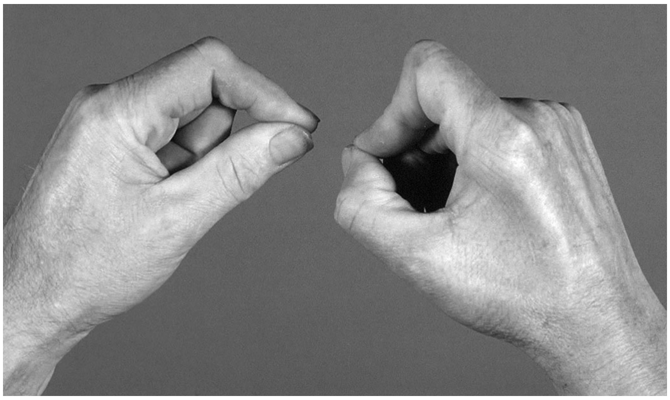

Fig. 2 Mannerfelt and Froment sign on left hand of patient with ulnar nerve paralysis.

the interosseous (or interossei) muscles are sometimes referred to as the „anti-claw" muscles [13]. The primary function of the interosseous (see above) is MCP flexion/stabilisation with extension of the interphalangeal (IP) joints. This is especially evident during pinch in which the „collapse" of the index PIP joint is apparent in and results in „hyper" flexion, often > 90°. This is a sign of interosseous muscle weakness and is sometimes referred to as the Mannerfelt sign [23] (Figure **2**).

Recording the moments of the intrinsic muscles that were (are) generated after electrical stimulation, Lauer et al. [9] found that the dorsal interosseous muscles were strong abductors of the fingers and that they also generated a significant moment in MCP joint flexion and IP joint extension. Similarly, Ketchum et al. [12] found that the interosseous muscle of the index finger contributes 73 % to the overall moment for flexion of the MCP joint. Li et al. [10] investigated the role of the interosseous muscles during finger flexion tasks. When an external-volar force is applied proximally to the PIP joint, the extensor mechanism (intrinsic muscle group) contributes the largest (70 %) force (of all flexors). Thus the interosseous muscles are important flexors of the MCP joint together with the long flexors: flexor digitorum profundus (FDP) and flexor digitorum superficiales (FDS). However, at the PIP joint the long flexors, primarily the FDS, and the interosseous are antagonists.

When the PIP joint is flexed, some reduction of the extension moment of the interosseous at the PIP joint level takes place, due to the volar displacement of the lateral bands (of about 4 mm). At full flexion of both the PIP and distal interphalangeal (DIP) joints, the lateral bands approach the flexion-extension axis of the PIP joint, thereby further minimising the extensor moment [8].

The action of the interosseous muscles can be studied separately from the extensor digitorum communis (EDC) muscles in patients with a radial nerve paralysis. If the patient is asked to extend the fingers, no extension of the MCP joint will occur, but the finger IP joints will extend because of the action of the interosseous and lumbrical muscles (or the intrinsic extensors). However, in some patients the fingers, in particular the index may extend in the MCP joint to some degree. This is due to the fact that the angle of attachment of the dorsal interosseous muscles is only 0 – 5°. When the tension on the extensor tendon is increased especially when the wrist is flexed, this angle will go beyond the 0° and thus the interosseous muscle becomes an extensor of the MCP joint. This angle of approach to the extensor mechanism for the palmar interosseous muscles is 20 – 25° and for the lumbrical muscles 35° [1].

In a high median nerve paralysis, the index finger is deprived of all long flexors and the lumbrical muscle. The only active muscles are the long extensors and the two interosseous. In an attempt to flex the fingers the index finger will remain extended in the IP joints. This is accurately described as the „pointing finger" where the IP joints are fully extended and the MCP joint is flexed. The long finger is also deprived of the long flexors, but will usually flex in grip. This is due to the attachments between the FDP tendons of the long finger and the ring finger and is called the Quadriga phenomena [24, 25]. This term suggests a symmetrical organisation of the four tendons. However, the connections between the FDP of the index and middle finger are usually absent. A strong connection between the flexor pollicis longus (FPL) and the FDP of the index finger can also exist. In such instances we may observe index flexion when flexing the thumb IP joint.

1.2 Pathokinesiology

The deficiency due to loss of interosseous muscles is usually given in textbooks as loss of abduction and adduction of the fingers. The loss of this action is important for those who play musical instruments or operate keyboards, but in most patients this is not recognised as a severe deficit. The loss of MCP flexion and PIP extension, synchronised finger flexion, is a much more significant loss. In acute paralysis of interosseous muscles this will sometimes only be visible as a mild hyperextension at the MCP joints and slight flexed position of the PIP joints when the patient is asked to extend the fingers. This deformity, however, usually progresses depending on the joint laxity and use of the hands. Long, thin and hyper-mobile fingers will develop a so-called claw hand much quicker than thick, stiff fingers. In the mobile hands the volar ligamentous structures stretch more easily, causing increased hyperextension and subsequently less PIP extension.

Extension of the PIP joints is only possible by contraction of the EDC when the MCPs are „blocked", either actively (internally) through muscle contraction or passively (externally) through the examiners hand or a splint, preventing hyperextension of the MCP joints. This is called assisted extension, and is used to assess the integrity of the extensor apparatus. This manoeuvre has also been called the Bouvier test, while Bourrel prefers to call this test the „the metacarpophalangeal stabilization test" [26].

Other factors that may contribute to the development of a claw hand are: hand dominance, continued use of the hand (or lack of it), compliance of the patient to perform routine exercises to prevent joint stiffness, and use of (night) splints.

Without interosseous muscles the hand can still make a full fist, except that the MCP flexion lags behind, or is „delayed". In patients with a „high" ulnar lesion, the FDP muscles of the 4th and

Fig. **3** Thomas sign: compensation movement when interosseous muscles are weak; flexion of the wrist in an attempt to gain a better opening of the hand, i. e. by means of increasing the pull on the EDC.

5th fingers are paralysed. The clawing posture is often less compared to the „low" ulnar nerve lesion, because the flexion moment at the PIP joints is decreased. We may conclude from this observation that the degree of clawing may also be the result of visco-elastic tension of FDP. When the ulnar nerve recovers, the 4th and 5th finger will often show increased clawing. Long-standing flexed position of the IP joints may result in a physiological shortening of the long flexors. This may further increase the PIP flexion position, which in turn may contribute to further deterioration of PIP flexion contractures. This is an additional reason to maintain the length of the extrinsic flexors in patients with intrinsic muscle paralyses.

Another sign of interosseous muscle weakness is known as the Thomas sign [27] (Figure **3**). This is the tendency of a patient with weak interosseous muscles to flex the wrist in an attempt to gain a better opening of the hand, i. e. MCP extension, by means of increasing the pull on the EDC.

In long-standing interosseous muscle weakness this movement will increase the hyperextension of the MCP joints and adds to the progress of the development of the claw hand. This „trick" movement is adopted very quickly and, even when the interosseous have regained their strength, will often take a long time to „un-learn".

In long-standing paralyses of the interosseous muscles, the PIP joints are continuously in a flexed position. This may cause a gradual stretching of the dorsal expansion (sometimes called the tri-angular ligament) over the PIP joint, which secures the lateral bands of the extensor tendon in their dorsal position. In the normal finger, the lateral bands shift dorsally when the PIP joint is extended. In flexing the PIP joint the lateral bands need to move volarly towards the flexion-extension axis of movement. When the dorsal expansion is elongated, the lateral bands are displaced volarly, resulting in a loss of PIP joint extension moment. In chronic flexion position of the PIP joint, the oblique retinacular ligament (ORL), or Landsmeers ligament, is slack most of the time and will adjust to this new situation by shortening. This may result in hyperextension of the DIP joint. A similar progression of changes, as in an extensor tendon central slip injury, may result in a Boutonnière deformity [28].

Chronic hyperextension of the MCP joints may cause some bowstringing of the EDC tendons, stretching the sagittal bands. The laxity of the sagittal bands will result in an inability to maintain the EDC tendon at a central position on the MCP joint. The migration of the luxating tendon into the groove between the MCPs is especially observable when flexing the MCP joint. This is sometimes called „guttering" because the tendon drops into the „gutter" between the MCP joints.

Shortening of the interosseous muscles is called intrinsic tightness (IT), and is often caused by trauma of the hand. The interossei are situated in rather tight compartments. Therefore swelling will cause an increase in pressure in these compartments, resulting in anoxia and muscle fibre death, with subsequent fibrosis of the muscle and shortening. This process is identical to the cause of Volkmann's ischemic contracture in the forearm [29].

The IT test consists of two parts. First, the range of passive PIP flexion is tested with the MCP joint extended. Next, passive PIP flexion is tested with the MCP joint flexed. Intrinsic tightness is present if there is a large difference in PIP flexion between the two MCP positions. The long-term complications of IT can result in decreased MCP extension and a swan neck finger, i. e. hyperextension of the PIP joint with secondary DIP joint flexion. A long-standing swan neck deformity might result in a painful snapping of the lateral bands at the PIP level when the finger moves into flexion. This test is sometimes called the Bunnell intrinsic-tightness test [30]. Intrinsic muscle tightness may also play an important role in the pathogeneses of MCP joint subluxation in rheumatoid arthritis [31, 32].

Another interesting observation is what may be called „interosseous plus". By this we mean paradoxal extension of the PIP joint when the patient wants to flex the finger. The harder the patient tries to bend the finger, the more the finger will extend in the PIP joint. This phenomenon is sometimes seen in patients in whom the interossei have been the only flexor of the finger for some time e. g. in high median nerve palsy, or in the case of adhered flexor tendons. Although the flexors are active and can bend the finger, when a stronger grip is required the finger will extend.

In a strong grip, the stronger the flexors are pulling, the more the intrinsic muscles become active to stabilise the PIP joints and prevent luxation. If the long flexor is weak or poorly activated, the interosseous will overpower the long flexor causing PIP extension. This paradoxal extension appears to be similar to the lumbrical plus phenomena (see lumbricals) and might be called „interosseous plus". The patient has to be taught to, gently, contract the long flexors without the action of the interosseous muscles.

1.3 Assessment possibilities (manual and instrumental)

Although the interosseous muscles have short a fibre length, some are strong and have physiological cross-sectional areas comparable to the FDS muscles [28].

In standard textbooks on muscle testing, the tests suggested are usually: abduction for dorsal and adduction for palmar interosseous muscles [33, 34]. These tests are useful for isolated (specific) testing of the interosseous. For example, patients with an ul-

Fig. **4** Testing the strength of the intrinsic muscles in the fingers.

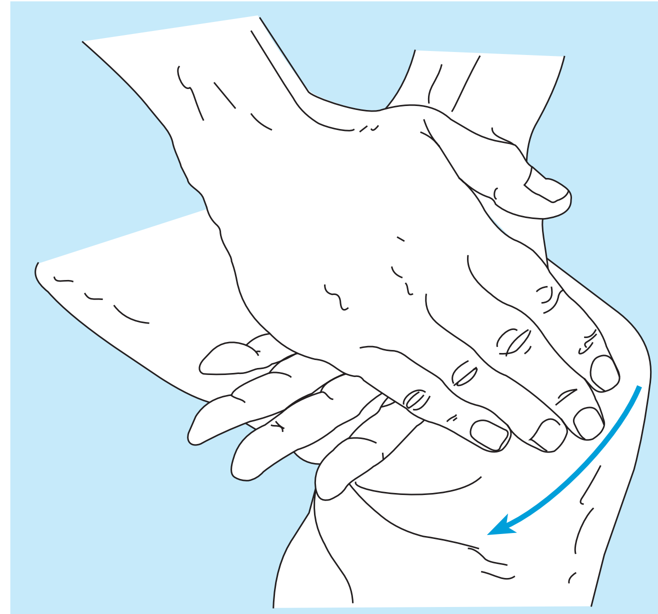

Fig. **5** Prevention of IP flexion contractures by massaging the fingers.

nar nerve paralysis can not move their middle finger sideways, which has been called the Egawa sign [27]. Functionally, it is much more meaningful to test the interosseous muscles in the intrinsic plus position, by giving resistance to flexion of the MCP joints at the proximal phalanx with extension of the PIP joint [35, 36] (Figure **4**).

The contribution of the interossei to grip strength, some suggest, can be measured indirectly through measuring the grip strength of the hand with e. g. a Jamar dynamometer. Janda et al. advocated to use the smallest distance between handle positions of the Jamar because the intrinsic muscles were most active in that position [37]. Research has shown that when using the 5 different handle positions, normally a „bell shaped" curve will show. In weakness or paralysis of the interosseous this bell shape will flatten.

Kozin et al. [14] tested 21 healthy persons who underwent median and ulnar nerve blocks at the wrist. The average decrease in grip strength was 38 % after ulnar nerve block. Pinch data in the study by Kozin et al. revealed a significant decrease in key pinch of 77 % after ulnar block and 60 % after median block [14]. Therefore, for evaluation and monitoring the motor function of the ulnar nerve, pinch strength measurements would seem to be more useful than grip strength measurements.

Isolated strength measurements of the first dorsal interosseous muscle can be done with dynamometers such as the RIHM, [38, 39] the Intrins-o-meter of Mannerfelt [40], or the Preston pinch gauge device in a modified use of it [41].

1.4 Therapy principles (prevention complications, strengthening, ADL)

In the hand with paralysis of the intrinsic muscles the PIP joints are the joints that are at risk.

The patients needs to be taught how to exercise to prevent PIP flexion contracture with assisted extension exercises; blocking the MCP joints with their hands and routinely massaging to extend the IP joints (Figure **5**). When they choose not to exercise, wearing a splint becomes more necessary.

A (night) splint with the MCP joints in flexion and IPs in extension is sometimes advisable. Increased hyperextension of the MCP joints, due to stretching of the volar plate, is also prevented in this position.

During the day the so-called „knuckle-bender" can assist the patient in some ADL functions. This splint will also help to move the PIP joint into full extension during the day and will maintain the integrity of the extensor mechanism.

Preferably exercises to strengthen the interosseous muscles are aimed at movements, which flex the MCP and extend the IP joints. Therefore, exercises for the interosseous muscles are all activities in intrinsic plus position: e. g. grasping a book, plate or a cylindrical object like a large bottle. The first dorsal and -palmar interosseous can be trained in activities that require tip- and key pinch pinch.

To correct the long flexor tightness, the patient is taught to „stretch" the flexors by holding the hand flat on a table and by moving the forearm towards an angle perpendicular to the table. In a similar fashion, the patient could sit on the dorsum of the hand and then pulls the forearm towards the body, thereby extending the wrist. A splint with the fingers and wrist in extension may be necessary in severe cases.

2 Lumbricals

2.1 Functional anatomy

The lumbrical muscles are unique muscles in several aspects. They connect two extrinsic antagonistic muscles. Proximally the lumbricals are attached to the FDP and distally they are inserted into the lateral band of the extensor tendon. The third and fourth lumbricals also connect, by their bi-penal origin, two adjacent FDP tendons.

The function of the lumbrical muscles is much debated. Brand suggested that the lumbrical muscles are not important for MCP flexion. He explained this with an illustration of a father carrying a child; it does not matter what the child (i.e. lumbrical) is carrying, the father (i.e. FDP) has to carry it anyway [28]. Therefore, the lumbrical muscles have a unique ability to contract without adding flexion torque at the MCP joint. This contrasts with the interosseous muscles which, when extending the IPs, need a stronger contraction of the EDC to counteract the flexion moment at the MCP joint. The lumbricals are more efficient for IP extension than the interosseous. Any contraction of the lumbrical muscle for IP extension reduces the visco-elastic force of the FDP tending to flex the IP joints. Accordingly, the lumbricals can be regarded as a „deflexor" of the PIP joint. Its direct contribution to MCP flexion is small and in the flexed finger may be non-existent, but its indirect contribution to IP joint extension by decreasing the flexion torque is substantial [42].

With the smallest physiological cross-sectional area of all intrinsic hand muscles, it is certainly not a strong muscle. The lumbricals, however, have a very long fibre length (40–48 mm), which indicates that they are designed for large excursions. If the lumbrical fibre length would be short, FDP excursion could stretch the lumbrical sarcomeres to a point that they were unable to generate active force [11].

The lumbrical muscles are richly endowed with muscle spindles. Their passive elongation by contraction of the FDP may inhibit finger extensors and facilitate wrist extensors [42–45]. For this reason the lumbrical muscles have been called „tensiometers" between the flexors and extensors [46]. Leijnse and Kalker [25] concluded that the lumbricals are in an optimal position for proprioceptic feedback regarding PIP-DIP joint movements. The unique properties of the lumbricals indicate that they are probably important in fast, alternating movements, e.g. in typing and playing musical instruments [47].

2.2 Pathokinesiology

In low median nerve injuries the lumbrical muscles of the index and middle finger are paralysed. In these hands it is difficult to discover any problems in the motion of these fingers [48]. A mildly diminished extension of the DIP joint has been noticed in a few patients, which might be explained by the decreased extension force on the extensor apparatus. Electromyography studies in functional activities on lumbrical minus fingers could reveal further insights in the role and function of these fingers.

The „lumbrical plus" sign is a situation in which there is a FDP tendon rupture distal of the lumbrical origin, or is also present in the situation where a graft has been used that was too long. The FDP now pulls through the lumbrical muscle rather than through its tendon, causing PIP extension [49].

Colditz has recently investigated the effect of shortening of the lumbrical muscles [50] which might also disturb the muscle balance of the fingers.

2.3 Assessment possibilities (manual and instrumental)

Manual muscle strength testing (MMST) of the lumbricals is practically impossible because of the synergistic action of the interosseous muscles. Strength testing is most likely less relevant than evaluating the co-ordination and dexterity of a finger as in tapping. However, no studies have been found in which this may have been done.

In patients with an ulnar nerve paralyses the strength can be measured in isolation of the interosseous muscles, where the index and long fingers have only the lumbrical to maintain the intrinsic plus position. One study measured a mean MCP joint flexion strength in the index and long finger of 0.8 kg (range 0.3–1.5) compared with 6.4 kg (range 4.6–7.9) in the non-involved hand. Thus, the affected fingers have only about 12% of the strength of those of the non-involved hand [51]. This strength is often not enough to prevent clawing in long-standing loss of the interosseous muscles of the fingers.

2.4 Therapy principles (prevention complications, strengthening, ADL)

There is no specific exercise program for strengthening of the lumbrical muscles. Strength training is similar to interosseous muscle training, with perhaps more focus on speed and co-ordination.

3 Hypothenar muscles

The muscles of the hypothenar are from ulnar to radial: abductor digiti minimi (ADM), flexor digiti minimi (brevis) (FDM), and opponens digiti minimi (ODM). The palmaris brevis (PB) is the most superficial muscle overlying these muscles transversely and originates from the aponeurosis palmaris. All the hypothenar muscles are ulnar innervated. Isolated paralysis is rare, however. In Cyclist palsy pressure of the ulnar nerve can cause particular patterns of muscle weakness depending on the level of the entrapment [52, 53]. Because there are functionally only minor differences between these muscles, they are discussed here as a group. The abductor digit minimi in its function could be compared to a dorsal interosseous.

3.1 Functional anatomy

The most ulnar-situated muscles (especially ADM) have the strongest ulnar abduction action of the little finger. The ODM, attached to the 5th metacarpal bone, has an important role in opposition of 4th and 5th rays. All the hypothenar muscles are active in the intrinsic plus position of the fingers, except for the ODM and the PB. In this position, similarly to the interosseous of the fingers, they flex the MCP joint of the little finger and extend the IP joints.

3.2 Pathokinesiology

The 4th and 5th metacarpals are much more mobile in the CMC joints as compared to the 2nd and 3rd. This makes it possible to adjust the hand around an object, but also e.g. the handle of a hammer. Flattening of the palmar arch of the hand (MCP joints) is another sign of weakness of the interosseous and hypothenar muscles. Flexion of the 4th and 5th metacarpal bones at the CMC joints is diminished. This results in a flattening of the arch of the hand and also in a weaker and less secure grip (Figure **6**). The loss of cupping function of the hand can go unnoticed in many patients, but for people accustomed to eating with their hands, can cause some trouble [28].

Fig. **6** Loss of the metacarpal arch in a patient three months after ulnar nerve injury in right hand.

In patients in whom the ulnar nerve is paralysed a Wartenberg sign can be seen. This is usually described as a sign of activity of the long extensor tendons of the little finger running radially of the MCP joint. The extensors produce an abduction force on the little finger which is not opposed by the paralysed intrinsic muscles [54]. In hands in which the ulnar nerve innervated muscles are recovering, the abducted position of the little finger often increases. In this situation we think that this may also be a sign of poor recovery of the third palmar interosseous muscle, resulting in a disbalance between the intrinsic abductors and adductors.

3.3 Assessment possibilities (manual and instrumental)

Due to their superficial location, the hypothenar muscles can be well observed and palpated during MMST [36]. This is very useful to assess the recovery of the ulnar nerve function. When testing the abduction of the little finger the ADM and FDM are tested. In the intrinsic plus position, pressing against the volar side of the PIP of the 5^{th} finger, the same muscles can be tested as a group. The ODM is tested in the cupping of the hand, when flexion of the CMC of the 5^{th} ray is asked for. Abduction strength of the 5^{th} finger is possible with dynamometers such as the RIHM and Mannerfelt's Intrins-o-meter.

3.4 Therapy principles (prevention complications, strengthening)

Similar training activities as described for the interosseous can be recommended. Grasping round objects emphasizing the cupping of the hand is specifically trained, and attention is given to the shaping of the arch of the hand in grasping large objects and handles.

Discussion

Sterling Bunnell considered the father of hand surgery, wrote in hic classic book about hand surgery [30], in a chapter which was dedicated to the intrinsic muscles of the hand, „the intrinsic muscles of the hand, though tiny, are important because, with the long extensors and long flexors, they complete the muscle balance in the hand. Normal position, normal motion, and even strength of the grip of the hand are dependent on this nice balance of these three sets of muscles". He also stated, „regarding the function of the intrinsic muscles controlling the fingers is still in the controversial stage". It is still open to discussion how at the same time the role of the intrinsic muscles can be important and controversial, and to what extent the strength of the grip is dependent on the intrinsic muscles.

The function of a muscle can be divided into three aspects: force or strength (N), endurance (sec) and velocity (m/sec). In most muscle testing methods, the first aspect, maximum strength is tested, which is sometimes referred to as the maximum voluntary contraction (MVC). In grip and pinch strength measurements this MVC is generally used by asking the patient to squeeze or push „as hard as you can" and has been shown to provide reliable data. In ADL, however, these maximum muscle contractions are rarely used, except for some specific actions, e.g. when lifting a heavy suitcase or opening a tight jar. Usually, a much lower level of strength is needed to perform most of our ADL, especially in white-collar workers. The second aspect, endurance or muscle fatigue, is probably particularly relevant in patients with impaired muscle function due to e.g. multiple scleroses, amyotrophic lateral sclerosis and hereditary motor and sensory neuropathy (HMNS). Videler et al. [55] studied muscle fatigue of grip in patients with HMSN. Many patients with HMSN indicate that during daily activities they experience most difficulty when an activity has to be maintained for a longer period of time [56,57]. Videler and colleagues studied the reproducibility of a fatigue test with measurements of three sets of 15 grip and pinch contractions with a handgrip dynamometer on two separate occasions with a 1-week interval, but found that reproducibility was poor.

The relation between loss of the intrinsic muscle strength and activities of daily life (ADL) and participation still needs further study. It has been shown that loss of nerve function has an important effect on e.g. hand function and the patients' abilities to perform certain tasks. In a group of 81 ulnar and/or median nerve injured patients the mean time off work was more than 31 weeks. Within one year after combined nerve injuries only 24% versus 80% after isolated median, and 59% after ulnar nerve injuries, returned to their work [58]. In a similar group of patients, Rosen found that patients with peripheral nerve injuries had difficulty in picking up coins, putting nuts on bolts and doing up four buttons [59]. Handling these small objects was especially difficult for patients with median nerve loss possibly because of the loss of sensibility of the index and thumb, or due to impaired muscle strength of the thumb [60].

An Indian study of 62 patients with loss of nerve function due to leprosy investigated the relation between grip and pinch strength and (using an Indian designed questionnaire) the basic activities of daily living (BADL) [61]. The study showed a significant relationship between grip and pinch strengths (in particular the tripod pinch) and the BADL questionnaire.

In a long-term study of patients with peripheral nerve injuries, the relation between the DASH questionnaire and grip strength and sensibility measurements (Semmes Weinstein filaments) was analysed. A strong association was shown between the outcome as measured with the DASH questionnaire for both the sensory and motor recovery [62,63]. Evidently, both functions of the nerve, i.e. sensation and muscle strength, can have an important influence on ADL.

In a study comparing the strength of the hand muscles in 46 patients with HMSN, the correlations between the different strength measurements of intrinsic and extrinsic muscles and hand function measured with the modified Sollerman and the DASH [64] was studied [65]. It was found that the intrinsic muscle strength measures were more strongly correlated with the Sollerman test, which specifically measures fine motor tasks. In contrast, the extrinsic strength measurements were more strongly correlated with the DASH, which is a more global measure of upper extremity function.

Interpreting the outcome of tests, which assess the patient's ability to perform a certain task by measuring the time (Sollerman) taken or by asking if the patient experiences problems in hand function (DASH) has some important drawbacks. Firstly, the loss of sensation will have an important influence, secondly, such tests might only assess the patient's ability to adapt or the patient's creativity in finding coping strategies, e.g. in using the non-injured hand or certain trick movements.

Finally, an important component of muscle i.e. function; the velocity also needs further study. The ability to rapidly move the hand is another important attribute, which determines the co-ordination of the hand. The importance of the lumbrical muscles in fast movements (rather than in maximum strength circumstances), as suggested by Leijnse et al [47] is interesting and warrants further clinical study.

Outcome studies involving hand function should be presented in the three different domains of function, activities and participation as was suggested by the 2001 World Health Organization report as the International classification of functioning, disability, and health (ICF) [66].

References

1 Eyler DL, Markee JE. The anatomy and function of the intrinsic musculature of the fingers. J Bone Joint Surg 1954; 36-A: 1 – 10

2 Eladoumikdachi F, Valkov PL, Thomas J, Netscher DT. Anatomy of the intrinsic hand muscles revisited: part II. Lumbricals. Plast Reconstr Surg 2002; 110 (5): 1225 – 1231

3 Eladoumikdachi F, Valkov PL, Thomas J, Netscher DT. Anatomy of the intrinsic hand muscles revisited: part I. Interossei. Plast Reconstr Surg 2002; 110 (5): 1211 – 1224

4 Schroeder HP von, Botte MJ. The dorsal aponeurosis, intrinsic, hypothenar, and thenar musculature of the hand. Clin Orthop Relat Res 2001; (383): 97 – 107

5 Dell PC, Sforzo CR. Ulnar intrinsic anatomy and dysfunction. J Hand Ther 2005; 18 (2): 198 – 207

6 Landsmeer JM, Long C. The mechanism of finger control, based on electromyograms and location analysis. Acta Anat 1965; 60 (3): 330 – 347

7 Srinivasan H. Patterns of movement of totally intrinsic-minus fingers based on a study of one hundred and forty-one fingers. J Bone Joint Surg Am 1976; 58 (6): 777 – 785

8 Linscheid RL. Historical perspective of finger joint motion: the hand-me-downs of our predecessors. The Richard J. Smith Memorial Lecture. J Hand Surg [Am] 2002; 27 (1): 1 – 25

9 Lauer RT, Kilgore KL, Peckham PH, Bhadra N, Keith MW. The function of the finger intrinsic muscles in response to electrical stimulation. IEEE Trans Rehabil Eng 1999; 7 (1): 19 – 26

10 Li ZM, Zatsiorsky VM, Latash ML. Contribution of the extrinsic and intrinsic hand muscles to the moments in finger joints. Clin Biomech (Bristol, Avon) 2000; 15 (3): 203 – 211

11 Jacobson MD, Raab R, Fazeli BM, Abrams RA, Botte MJ, Lieber RL. Architectural design of the human intrinsic hand muscles. J Hand Surg [Am] 1992; 17 (5): 804 – 809

12 Ketchum LD, Thompson D, Pocock G, Wallingford D. A clinical study of forces generated by the intrinsic muscles of the index finger and the extrinsic flexor and extensor muscles of the hand. J Hand Surg [Am] 1978; 3 (6): 571 – 578

13 Brandsma JW. Intrinsic minus hand: (patho) kinesiology, rehabilitation and reconstruction. [Thesis]. Utrecht: University of Utrecht, 1993

14 Kozin SH, Porter S, Clark P, Thoder JJ. The contribution of the intrinsic muscles to grip and pinch strength. J Hand Surg [Am] 1999; 24 (1): 64 – 72

15 ASHT, editor. Clinical Assessment Recommendations. 2nd ed. Garner, NC: American Society of Hand Therapists, 1992

16 Bendz P. Systematization of the grip of the hand in relation to finger motor systems. A kinesiologic study using a new method for recording finger joint motions. Scand J Rehabil Med 1974; 6 (4): 158 – 165

17 Sollerman C, Ejeskar A. Sollerman hand function test. A standardised method and its use in tetraplegic patients. Scand J Plast Reconstr Surg Hand Surg 1995; 29 (2): 167 – 176

18 Light CM, Chappell PH, Kyberd PJ. Establishing a standardized clinical assessment tool of pathologic and prosthetic hand function: normative data, reliability, and validity. Arch Phys Med Rehabil 2002; 83 (6): 776 – 783

19 Landsmeer JMF. Anatomical and functional investigation on the articulation of the human finger. Acta Anat 1955; 60: 330 – 347

20 Stack HG. Muscle function in the fingers. J Bone and J Surg 1962; 44B: 899 – 909

21 Zancolli EA. Structural and Dynamic Bases of Hand Surgery. 2nd ed. Philadelphia: Lippincott, 1979

22 Sollerman C, Sperling L. Evaluation of ADL-function – especially hand function. Scand J Rehabil Med Suppl 1978; 6: 139 – 143

23 Mannerfelt L. Studies on the hand in ulnar nerve paralysis. A clinical-experimental investigation in normal and anomalous innervation. Acta Orthop Scand 1966; (87): 61 – 86

24 Neu BR, Murray JF, MacKenzie JK. Profundus tendon blockage: quadriga in finger amputations. J Hand Surg [Am] 1985; 10: 878 – 883

25 Leijnse JN, Kalker JJ. A two-dimensional kinematic model of the lumbrical in the human finger. J Biomech 1995; 28 (3): 237 – 249

26 Bourrel P. The metacarpophalangeal stabilization test beevor or bouvier? Ann Chir Main 1985; 4 (1): 31 – 35

27 Tubiana R. The Hand Vol II. In. Philadelphia: WB Saunders, 1985: 518

28 Brand PW. Clinical Mechanics of the Hand. St. Louis: CV Mosby, 1999

29 Pinal F Del, Herrero F, Jado E, Garcia-Bernal FJ, Cerezal L. Acute hand compartment syndromes after closed crush: a reappraisal. Plast Reconstr Surg 2002; 110 (5): 1232 – 1239

30 Bunnell S. Surgery of the Hand. 2nd ed. Philadelphia: J. B. Lippincott Company, 1948

31 Hueston JT, Wilson WF. The role of the intrinsic muscles in the production of metacarpophalangeal subluxation in the rheumatoid hand. Plast Reconstr Surg 1973; 52 (4): 342 – 345

32 Smith PJ, Ross DA. The central slip tenodesis test for early diagnosis of potential boutonniere deformities. J Hand Surg [Br] 1994; 19 (1): 88 – 90

33 Daniels C, Worhtingham L. Muscle Testing: Techniques of Manual Examination. 4th ed. Philadelphia: WB Saunders, 1980

34 Kendall FP, McCreary EK. Muscles: Testing and Function. 3rd edition ed. Baltimore: Williams & Wilkins, 1983

35 Brandsma JW, Schreuders TAR, Birke JA, Piefer A, Oostendorp R. Manual muscle strength testing: intraobserver and interobserver reliabilities for the intrinsic muscles of the hand. J Hand Ther 1995; 8 (3): 185 – 190

36 Brandsma JW, Schreuders TAR. Sensible manual muscle strength testing to evaluate and monitor strength of the intrinsic muscles of the hand: a commentary. J Hand Ther 2001; 14 (4): 273 – 278

37 Janda DH, Geiringer SR, Hankin FM, Barry DT. Objective evaluation of grip strength. J Occup Med 1987; 29 (7): 569 – 571

38 Schreuders TAR, Roebroeck M, Kar TJ van der, Soeters JN, Hovius SE, Stam HJ. Strength of the intrinsic muscles of the hand measured with a hand-held dynamometer: reliability in patients with ulnar and median nerve paralysis. J Hand Surg [Br] 2000; 25 (6): 560 – 565

[39] Schreuders TAR, Roebroeck ME, Jaquet JB, Hovius SE, Stam HJ. Measuring the strength of the intrinsic muscles of the hand in patients with ulnar and median nerve injuries: reliability of the Rotterdam Intrinsic Hand Myometer (RIHM). J Hand Surg [Am] 2004; 29 (2): 318 – 324

[40] Mannerfelt LG. Studies on ulnar nerve compression neuropathies with a new computerised instrument – the intrins-o-meter. Scand J Plast Reconstr Surg Hand Surg 1997; 31 (3): 251 – 260

[41] Fischer T, Nagy L, Buechler U. Restoration of pinch grip in ulnar nerve paralysis: extensor carpi radialis longus to adductor pollicis and abductor pollicis longus to first dorsal interosseus tendon transfers. J Hand Surg [Br] 2003; 28 (1): 28 – 32

[42] Ranney D, Wells R. Lumbrical muscle function as revealed by a new and physiological approach. Anat Rec 1988; 222 (1): 110 – 114

[43] Ranney DA, Wells RP, Dowling J. Lumbrical function: interaction of lumbrical contraction with the elasticity of the extrinsic finger muscles and its effect on metacarpophalangeal equilibrium. J Hand Surg (Am) 1987; 12 (4): 110 – 114

[44] Backhouse KM, Catton WT. An experimental study of the function of the lumbrical muscles in the human hand. J Anat 1954; 88 (5): 133 – 141

[45] Devanandan MS, Ghosh S, John KLT. A quantitative study of the muscle spindles and tendon organs in some intrinsic muscles of the hand. Anat Rec 1983; 207: 263 – 266

[46] Rabischong P. Basic problems in the restoration of prehension. Ann Chir 1971; 25 (19): 927 – 933

[47] Leijnse JN. Why the lumbrical muscle should not be bigger – a force model of the lumbrical in the unloaded human finger. J Biomech 1997; 30 (11 – 12): 1107 – 1114

[48] Schreuders TAR, Stam HJ. Strength measurements of the lumbrical muscles. J Hand Ther 1996; 9 (4): 303 – 305

[49] Parkes A. The 'lumbrical plus' finger. J Bone Joint Surg Br 1971; 53 (2): 236 – 239

[50] Colditz JC. Lumbrical tightness: testing and stretching. In: FESSH 8th & EFSHT 7th congress; 2002. Amsterdam: Churchill Livingstone, 2002: 64

[51] Schreuders TAR, Stam HJ. Strength measurements of the lumbrical muscles. J Hand Ther 1996; 9 (4): 303 – 305

[52] Brandsma JW. Manual muscle strength testing and dynamometry for bilateral ulnar neuropraxia in a surgeon. J Hand Ther 1995; 8 (3): 191 – 194

[53] Akuthota V, Plastaras C, Lindberg K, Tobey J, Press J, Garvan C. The effect of long-distance bicycling on ulnar and median nerves: an electrophysiologic evaluation of cyclist palsy. Am J Sports Med 2005; 33 (8): 1224 – 1230

[54] Blacker GJ, Lister GD, Kleinert MD. The abducted little finger in low ulnar nerve palsy. J Hand Surg [Am] 1976; 1 (3): 190 – 196

[55] Videler AJ, Beelen A, Aufdemkampe G, Groot IJ de, Leemputte M Van. Hand strength and fatigue in patients with hereditary motor and sensory neuropathy (types I and II). Arch Phys Med Rehabil 2002; 83 (9): 1274 – 1278

[56] Brooke MH, Miller R. Fatigue testing. Muscle Nerve 1990; 13, Suppl: 35 – 37

[57] Lindeman E, Leffers P, Reulen J, Spaans F, Drukker J. Reduction of knee torques and leg-related functional abilities in hereditary motor and sensory neuropathy. Arch Phys Med Rehabil 1994; 75 (11): 1201 – 1205

[58] Bruyns CN, Jaquet JB, Schreuders TAR, Kalmijn S, Kuypers PD, Hovius SE. Predictors for return to work in patients with median and ulnar nerve injuries. J Hand Surg [Am] 2003; 28 (1): 28 – 34

[59] Rosen B. Recovery of sensory and motor function after nerve repair. A rationale for evaluation. J Hand Ther 1996; 9 (4): 315 – 327

[60] Rosen B. The sensational hand. Clinical assessment after nerve repair. (Thesis). Malmo: Lund University, 2000

[61] Rajkumar P, Premkumar R, Richard J. Grip and pinch strength in relation to function in denervated hands. Indian J Lepr 2002; 74 (4): 319 – 328

[62] Jaquet JB, Luijsterburg AJ, Kalmijn S, Kuypers PD, Hofman A, Hovius SE. Median, ulnar, and combined median-ulnar nerve injuries: functional outcome and return to productivity. J Trauma 2001; 51 (4): 687 – 692

[63] Jaquet JB, Schreuders TAR, Stam HJ, Hovius SER. Relationship between DASH and functional recovery after nerve injury. to be submitted

[64] Solway S, Beaton DE, McConnell S, Bombardier C. The DASH Outcome Measure User's Manual. Second Edition. ed. Toronto: 2002

[65] Selles RW, Ginneken B van, Schreuders TAR, Janssen WGM, Stam HJ. Comparing strength measurements of the arm and hand muscles in Hereditary Motor and Sensory Neuropath: the usefulness of dynamometer measurement of the intrinsic hand muscles. submitted

[66] WHO. International classification of functioning, disability, and health (ICF). Geneva: World Health Organization, 2001