

# The Aging Hand

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**Hand function decreases with age in both men and women, especially after the age of 65 years. A review is presented of anatomical and physiological changes in the aging hand. The age-related changes in prehension patterns (grip and pinch strength) and hand dexterity in the elderly population are considered. Deterioration in hand function in the elderly population is, to a large degree, secondary to age-related degenerative changes in the musculoskeletal, vascular, and nervous systems. Deterioration of hand function in elderly adults is a combination of local structural changes (joints, muscle, tendon, bone, nerve and receptors, blood supply, skin, and fingernails) and more distant changes in neural control. These age-related changes are often accompanied by underlying pathological conditions (osteoporosis, osteoarthritis, rheumatic arthritis, and Parkinson's disease) that are common in the elderly population. Assessment of hand function and prehension patterns is needed in order to determine specific treatment approaches.**

THE evolution of the hand has reached its highest degree of development in humans, and it has determined many of the unique functional and creative capabilities of the species. A relatively large area of the central nervous system (CNS), far exceeding that of any other primate, has evolved specifically devoted to controlling the hands, and particularly the thumb. The evolution of the opposing thumb and prehensile grasp are refinements of hand control that have been major factors leading to the dominance of the human species throughout the world in an extensive range of geographic and climatic domains. The hand serves as an important creative tool, an extension of intellect, a means of nonverbal communication, and a major sensory tactile organ. The quality of performance in daily living skills, work-related functioning, and recreational activities is determined to a large degree by hand function and manual dexterity. The hand has to be able to undertake extremely fine and sensitive movements and must also be able to perform tasks requiring considerable force.

The hand is the most active and important part of the upper extremity. The anatomy and functional biomechanics of the hand are extremely complex. Hands undergo many physiological and anatomical changes associated with aging, though the effects of normal aging on adult hand function and dysfunction are still poorly understood. Clinicians, therapists, and researchers need to understand both normal and abnormal hand functioning, including age-related functional deterioration. Several intrinsic and extrinsic factors may be involved in the age-related decline in manual functioning (Table 1). These aging changes may be genetically determined (1,2). Common metabolic and skeletal diseases in elderly adults, such as osteoarthritis, rheumatoid arthritis, and osteoporosis, and hormonal changes are important factors in impaired hand function. Malnutrition may also be a contributory factor in elderly adults and may involve an imbalance in homeostasis of minerals, in particular disturbances in calcium metabolism, or a lack of specific nutritional factors (3). Behavioral

factors associated with aging, such as declining physical activity, reduced exercise levels, and sedentary lifestyles, may also contribute to impaired hand function (4,5). Disuse atrophy is common in elderly adults and involves reduction in skeletal muscle mass and functioning (6). In parallel, there are age-related declines in peripheral nervous system (PNS) parameters such as excitation–contraction coupling or impaired performance of high-threshold motor units (7). It is also possible that age-associated changes in the nervous system may lead to hand muscle fatigue (8). Specific degenerative diseases of the CNS common in elderly adults, such as Parkinson's disease, also profoundly affect hand function. Reduced visual acuity in elderly adults (myopia) may be a contributory factor to problems with fine precision grip movements.

## PREHENSION

Changes in prehension patterns have to be understood and addressed in order for the age-related changes in human hand function to be understood. Prehension is defined as the act of seizing or grasping, whereas prehensile describes the adaptation of an organ for grasping or wrapping round an object. In humans the hand is the only prehensile organ, whereas in many primates this capability is also found in feet and in the tail. There is considerable disparity in the terminology used by clinicians regarding prehension of the hand. Prehension consists of various aspects of hand movement, including reaching, and postural motility (9). The conventional classification of prehension according to Sollerman and Sperling (10) divides the hand grip into three main prehensions: (i) **precision thumb–finger pinch grips** (tip to tip, pad to pad, pad to side, and three fingers pad to pad), (ii) **passive palm pinch grips** (buttresses pad to side, extended three-jaw chuck, cradle four and five-jaw chuck), and (iii) **power grip** (cylindrical–diagonal, spherical, and hook–extension grip).

Because the human hand performs as an integrated functional unit, functional task analysis requires integrated

Table 1. Factors Affecting Function in Aging Hands

Intrinsic Factors	Extrinsic Factors
Genetic factors	Environmental factors (ultraviolet radiation, chemical irritants)
Endocrine factors	Physical activities (work related, recreational sports, and hobbies)
Metabolic disorders	Nutrition
Diseases (osteoarthritis, rheumatoid arthritis, osteoporosis)	Traumatic injuries
Pathological changes	
soft tissues (muscles, tendons, blood vessels, nerves)	
hard tissues (bone, hyaline cartilage, fingernails)	

examination of the role of individual components. Although it is fairly difficult to isolate any single prehension function as being the most important among those examined, grasp or hand grip has been the most researched, possibly because it is the easiest to test. The hand-grip strength test, based on the eight most common grips, is widely used as a measure of specific hand grip, total body strength, and poor muscle strength in aging (11). The hand-grip test has been shown to be useful in predicting functional limitations and disabilities (12).

#### HAND MUSCLES

One of the most common changes in aging skeletal muscle in the body is a major reduction in muscle mass ranging from 25% to 45%, which is sometimes described as “sarcopenia of old age” (13). The diminished muscle strength of the aging hand (14) has been attributed to decreasing muscle mass (15). The decrease in muscle mass in the hand is not, however, as prominent in elderly adults in hand muscle groups as in other skeletal muscle groups, such as those of the upper forearm.

There are 11 intrinsic muscles and 15 extrinsic muscles with direct functional roles in the hand. Extrinsic and intrinsic hand muscles produce the force required for gripping objects (grip force). After 60 years of age there is a rapid decline in hand-grip strength, by as much as 20–25% (16,17). This is accompanied by a substantial loss of muscle fibers and decreased muscle-fiber length, particularly in the *Thenar* muscle group, and contributes an important role in reduction of action potential (18). The thumb intrinsic musculature constitutes approximately 40% of the total intrinsic musculature of the hand (19). Three of the main muscles (*Oblique adductor pollicis*, *Opponens pollicis*, and *Flexor pollicis brevis*) play important roles in stabilizing the thumb during strong pinch grips of objects (20), and these commonly show age-related dysfunction. The contractile capacity of the *Thenar* muscle in elderly people has been assessed by tetanic stimulation of the *median* nerve (21). The higher muscle fatigue resistance in elderly adults has been attributed to differences in both the PNS and CNS. There is a significant reduction in both action potentials and in the number of viable motor units associated with the hand muscles in the elderly.

#### HAND TENDONS

Tendons are composed of dense connective tissue, primarily formed by densely packed, orderly arranged,

collagen fibers. These contribute to the white color of tendons and also provide the tendons with extremely high tensile strength. To a large degree, the tendons have a very poor blood supply and are virtually avascular in the regions of tendon insertion. The primary function of tendons is to attach muscles to bone and to transmit muscle force to the skeletal system with limited stretch or elongation. The attachment and the function of the long narrow tendons of the extrinsic muscles in the aging hand are complex. These long hand tendons possess extremely high tensile strength. The tendons of the *Flexor digitorum superficialis* and *profundus* muscles have been investigated because of their major importance for the surgeon. In addition, special attention has also been given to the intrinsic hand muscle in general and the *Thenar* group in particular, because of their crucial role in hand function (22). The tendons in the distal palm and digits are enclosed in synovial sheaths lined by a glistening smooth synovial layer continuous with a proximal mesotendon. More proximally, they are surrounded by a thin adventitia called a paratendon. Synovial sheaths enhance the gliding of the tendon and are thickened in segments to form pulleys (*Vinculum breve* and *longum*), which biomechanically are critical for efficient tendon functioning and muscle force and physiologically contain small blood vessels that provide the limited blood supply to the tendon. In aging, aberrations in this system result in reduced microcirculation of the vaginal segment (23), causing difficulties in the ability to adapt to environmental stress, decreased range of joint motion, and decreased flexion power; they may cause flexion contractions of the overlying joint (24). The tensile strength of tendons is a measure of elongation of the tendon during tensile testing. It has been found that the ultimate tensile strength of hand tendons ranges from 50 to 150 kg/mm. The ultimate tensile strength values for aged tendons decrease by 30–50%. Biochemical changes in the aging tendons result in a stiffer, more irregular dense connective tissue. This involves a reduction in water content accompanied by a loss of proteoglycans and also degradation of the collagen type I fibers.

#### INTRINSIC BONES AND JOINTS

With aging, the hand bones (19 long bones and 8 short bones) and joints, especially the synovial joints, are accompanied by morphological and pathological changes common to aging skeletal tissues. Aging hands and fingers are especially prone to osteoarthritis (25,26) and rheumatoid arthritis (27). These conditions constitute very common and

important problems in the elderly population and provide major challenges for gerontologists and therapists. Considerable efforts are being undertaken to understand the etiology of these hand afflictions and to develop new and more effective drugs to ameliorate pain and hand dysfunction (28).

Osteoarthritis of the hand and finger joints is a disease process that destroys interphalangeal cartilage, synovial membranes, and the joint capsule (29). Consequences of osteoarthritis of the fingers include pain, swelling, joint deformities, bone spur formation, restricted range of motion of wrist and fingers, and difficulty in performing manual activities that require grip and pinch (26). In postmenopausal women the incidence of osteoarthritis is markedly increased, possibly related to the consequences of loss of estrogen and postmenopausal osteoporosis. Various means have been used to determine reductions in bone density in the aging hand. Quantitative ultrasound clearly demonstrates enhanced bone loss in the hand phalanges with aging (30). X-ray microdensitometry used in longitudinal studies has shown that the cortical bone-thinning rate of metacarpal bones of index fingers of the nondominant hand of Japanese women is affected by aging and especially by postmenopausal status (31). This was confirmed by digital-image-processed determinations of bone density of the index finger of proximal phalangeal and metacarpal bones of the nondominant hand (32). After the age of 50, the bone density of the hand decreases by approximately 0.72% per year. Magnetic resonance imaging (MRI) has also proved a useful diagnostic tool for osteoarthritis and osteoporosis of the hand (33) and has been used to evaluate the status of hyaline cartilage and compact and trabecular bone in the distal interphalangeal joints of the human fingers. All of these clinical techniques have proved useful in demonstrating the differences between normal aging changes in the human hand and those induced by osteoarthritis and osteoporosis.

#### FINGERNAILS

Nails are composed of flattened plates of hard, nonpigmented, translucent keratin derived from epithelial cells of the matrix of the nail root. Functionally, nails are important tools for fine grip and manipulation of small objects in various ways. The rate of fingernail growth diminishes with aging (34). Until the age of 60 years, nail growth is more rapid in males than in age-matched females. After the age of 80 years, the rate of female fingernail growth is greater than in males. Nails show restricted growth during the night, and the rate of nail growth is also slower during the summer months (June–August) in the Northern Hemisphere (34). Age-associated nail changes are common in elderly people. These may involve discoloration with changes in color from white-pink to yellowish-gray, changes in contour (longitudinal ridges, or less concave shape), and changes in the thickness and roughness of the nail surface. Structural changes may result in brittle nails, and various pathological conditions such as onychia (hypertrophic nail) and subungual exostosis (a variant of osteochondroma) (35). The most common disorders of aging fingernails are common fungal infections. Although

these do not pose serious medical concerns, they do mainly constitute cosmetic problems, which can be extremely disturbing, especially in aging female patients. Female adults typically demonstrate considerably greater concerns regarding the cosmetic appearance of their fingernails than male adults, show greater awareness of changes in aging nail conditions, and are more prone to referral for treatment. Nail management particularly in elderly adults should be a part of routine hygiene and should not be neglected (36). With the loss of manual dexterity with aging, elderly adults may not be able to cut their own nails and commonly require manicural assistance. Several of the changes in aging fingernails may be symptoms of underlying disease or metabolic disorders and can provide diagnostic indications for the physician. The translucent nature of the nail plate enables the coloration of the underlying nail bed, predominantly provided by the dermal vascularization, to be seen; this can provide an indication of problems such as anemia.

#### NERVE CHANGES AND HAND MOTOR CONTROL

The PNS of the hand includes cutaneous nerves (dermatomes C6–C8, and T1) and motor nerves (ulnar, median, and radial nerve). The different techniques used to investigate the accurate innervation of hand muscles have been recently documented and reported (37). Loss of functioning of motor neuron and ventral root axons has been demonstrated in the elderly population, with data strongly indicating that approximately 25% of the motor axons in hand muscles are lost in old age (38). There is a reduction in the number of myelinated nerve fibers from the seventh and eighth cervical nerve roots, together with diminished nerve fiber diameters (39). Muscle twitches become smaller and slower (40). The number of motor units of the median nerve (*Thenar* muscles) and the ulnar nerve (*Hypothenar* group) have also been studied (41). In these muscles there are losses of motor units after age of 60, although they are less obvious in the *Hypothenar* group (42). The motor units in the *Thenar* and *Dorsal interossei* muscles (43–45) decrease significantly with age, but remain constant in the *Biceps brachii*. The excitable muscle fiber mass, as reflected in the peak-to-peak amplitude and the area of the maximum M wave, was diminished in hand muscles.

Muscles in elderly adults have fewer, but on average larger and slower, motor units, with important implications for both motor control and function. There is a critical decline in age-related motor performance, which has been attributed to loss of motor neurons (45). Noninvasive techniques have been developed to track longitudinally the contractile and electrical properties of specific single *Thenar* motor units, even over several years (46). The human *Thenar* motor unit pool undergoes significant age-related increase in motor unit size and slowing of contractile speed. This adaptation may help overcome the age-related loss of *Thenar* motor units (47,48).

There is evidence indicating that age-related changes occur in both neurohistology and in responses to neurotransmitters (49). The integrity of the CNS is reflected in the cognitive and psychomotor ability of the individual. For the successful elaboration of a prehension task, CNS control processes of negative and positive feedback mechanisms are

needed. This motor task requires the integrity of a circuit of interconnected hand-related areas, including a ventral subdivision of the premotor and sensorimotor cortical areas (50), the cerebellum, and the basal ganglia (51). The greater fatigue resistance of hands in elderly adults can be explained by increased fatigue resistance at the *Thenar* muscle level as well as by changes in the CNS.

#### SENSORY CHANGES IN THE AGING HAND

It is a widely accepted concept that our senses and sensory integrity decline with aging (52,53). In many cases, changes in sensory perception are studied with regard to specific areas of the body only, such as the area of the knee joint, whereas sensory changes in other important areas of the body such as the hand are neglected. Age-related cutaneous sensory deficits are more often reported in the lower extremities than the upper extremities, despite the importance of age-related sensory changes in the hand and upper limb. An understanding of the somatosensory system of the hand is important for clinicians and therapists. Accurate functional sensory input is essential for well-controlled precision manipulation of small objects needed for many different activities of daily living. This requires refined coordination of forces exerted on the object by the tips of the finger and thumb (53,54). A peripheral decrement in tactile sensibility may contribute to slowness in processing afferent information associated with hand movement (55). The effects of old age on fingertip force responses have indicated degraded central information processing and a deterioration of cutaneous mechanoreceptors (56). Fingertip force automatic responses, measured when a grasped handle was pulled unexpectedly, showed response latency times three times longer for an old group (average age 78) versus a young group (average age 30). Age and vision are important factors during the grip-lift phase (time from object contact to liftoff from its support surface), with the expected finding that the "old" group required more time than the "young" group, regardless of visual status (57,58). The main conclusion was that tactile impairments alone could not explain the effects of age on a grasp and lift task.

#### SKIN CHANGES IN THE AGING HAND

Apart from the head, the hands are the structures most exposed to the stresses of the environment. The skin of the hands is subject to more minor injuries (abrasions, cuts, lacerations, and chemical and thermal burns) than that of any other part of the body. The skin of the hands is divided into two distinct histological and functional types. The skin of the dorsal surface is typical thin skin with a thin layer of keratin, hairs, sebaceous glands, and sweat glands. The skin of the palmar surface of the hands and fingers is characterized as thick skin. This has a much thicker epidermis with a thick keratin layer. This thick skin lacks hair, pigment (melanin), and sebaceous glands. Thick skin of the fingers serves a major protective function against abrasions and is the site of many tactile and mechanosensory receptors (Pacian corpuscles, Meissner corpuscles, and Merkel cells). Mitotic activity and replacement of

keratinocytes in the epidermis in elderly adults is much slower than that in younger persons. After injury, the repair processes in elderly skin are much slower than those of younger people.

The microvasculature of the dermis of the skin of the hand has been examined by means of scanning electron microscopy (59) and by laser Doppler (60). Both studies showed changes in vascular patterns in the skin of the aged hand. A decline in the number of capillary loops results in a decrease in heat-induced cutaneous blood flow and blood volume, and it interferes with thermal adaptation in elderly adults. Elderly people are more susceptible to feeling cold in their hands than younger people, and this is probably due to the poorer blood flow in the elderly hands. Impaired peripheral circulation with aging results in decreased muscle bioenergy metabolism and oxygenation (61). Reduced sensitivity to local heat sources or slower reflexes may explain the increased incidence of burns to the hands of the elderly population (hot water scalding).

The thin skin of the dorsal aspect of the hand undergoes morphological changes with aging and becomes much thinner (62). The numbers and activities of sweat and sebaceous glands are also reduced in elderly people, who find it more difficult to accommodate to environmental heat stress. It has been speculated that anticholinergic substances may contribute to the decline in sweat gland functioning. One of the consequences of the thinner dorsal hand skin in elderly adults is that it is more fragile, drier, and heals more slowly after injury. One of the more obvious signs of dorsal skin aging of the hand is wrinkling and loss of elasticity. This results from changes in the amount and biomechanical properties of the elastic fibers in the dermis. These changes may appear earlier and be more pronounced in elderly hands exposed to sunlight and ultraviolet radiation. The main cosmetic concerns of the aging hand are related to excess skin and prominent veins (63). A common feature of the dorsal skin of the hands in elderly people is the appearance of various skin pathologies, including changes in skin pigmentation and pigmentation patterns. Unlike the thin skin of most of the body, the dorsal skin of the hand overlies a very thin hypodermis only.

Aging changes in the thick (glabrous) skin of the ventral surface of the palms and fingers are less apparent than those in the thin skin of the dorsal hand. The reduction in tactile sensation of fingers in elderly adults is due to loss of the various sensory mechanoreceptors (Pacian corpuscles, Meissner corpuscles, etc.)

#### FUNCTIONAL MOVEMENTS OF THE HAND AND FINGERS

There is still a wide gap in our understanding between aging studies of specific tissues involved in hand movement (muscles, nerves, and blood vessels) and studies of an older person's ability to perform activities of daily living. It is clear that common tasks involving precision dexterity, two-hand coordination, such as are needed to thread needles, open buttons on clothing, or fine-grip tasks as in holding a pen or cutlery, become increasingly difficult with aging. This is also true with regard to simple hand-grip tasks requiring strength such as opening bottles. The difficulty of

performing such tasks may be in part due to declining vision.

Whereas basic research attempts to describe the quality of specific tissues involved in producing hand or finger movements, outcome studies tend to focus on the individual's ability to complete a task successfully without regard to the condition of the tissues. Tests show that in elderly people the largest declines in upper extremity functioning (greater than 50%) are in hand-force steadiness, speed of hand-arm movements, and vibration sense (64). Hand function remains fairly stable until the age of 65 years, after which it diminishes slowly (65). After the age of 75 years, age differences in performance become more apparent as seen in prehensile pattern frequency, hand strength, performance time, and range of motion. Furthermore, the percentage decrease in strength with age is similar for men and women regardless of their lifestyle (65). Old people over aged 70 demonstrate average declines in wrist flexion (12%), wrist extension (41%), and ulnar deviation (22%), and these declines double during the following decade (66). By the age of 90, an individual may be expected to have wrist range-of-motion (ROM) values that are approximately 60% of those of average 30-year-old individuals. This reduced wrist motion and joint strength of elderly adults puts them at greater risk for developing cumulative trauma disorders.

Age-related atrophy of the interossei muscles (particular the first *interosseous* and *adductor pollicis*) resulting in clawing hand has been reported. Difficulties to adduct the thumb cause elderly people to substitute thumb adduction by using thumb flexors to compensate for their weakness (Froment's sign is positive). Thus, once such weakness occurs, the predominance of *extensor digitorum* (ED) tension, even in relaxation, is evidenced by metacarpal phalangeal (MCP) hyperextension posture assumed by each finger of the hand at rest. Because the function of the lumbricals is dependent only on intact tension in the extensor mechanism (ED), they are also relatively weak in aged people, resulting in difficulties in flexion of the MCP. Weakness of interossei and lumbricals and slacking of ED tendon results in an inability to generate sufficient tension to cause interphalangeal extension. In a lift task, the grip force must first be established and after a short delay (60–70 ms) the load force develops. The relationship between grip and load force is linear. In young people, the ratio of the two forces is controlled and enables an optimal *safety margin*, which is defined as the difference between the actual grip and the load force (67). When a hand *perturbation* occurs (i.e., sudden load change), a young subject usually would not lose his or her grip rather than adjust the grip to the external force automatically. In contrast, old people typically use a slower, probing strategy that lacks a smooth anticipatory ramp increase in grip force. Moreover, old people present diminished proactive buildup of grip force even though the perturbations are expected. A deficit in anticipatory movement might explain the overall difficulties aged people encounter in controlling their hand forces. The *Thenar* muscles are active in most grasping activities. Thumb abduction range and strength declines from the age of 60 (68).

Because the entire upper limb is geared toward execution of movement of the hand, it is appropriate to complete a comprehensive assessment of the upper limb before examining the hand. A comparison of the functional performance of young and old adult women on two types of tasks (familiar and unfamiliar) indicated that older adults show age-related decline even when those tasks are familiar, practiced, meaningful, and ecologically valid (69). A battery of hand tests used to assess a broad range of hand functions required for activities of daily living showed significant positive correlations between age and the time needed to complete the various tests, and analyses of variance revealed significant differences between subjects in their eighties and those in their sixties and seventies (70).

A recent experimental study has confirmed that aging has marked degenerative effects on hand function (71). This study showed age-related declines in hand and finger strength and the ability to control submaximal pinch posture, manual speed, and hand sensation. Moreover, a gender difference was also found, with elderly women experiencing more serious declines in fine manual dexterity and strength than men of a similar age.

#### ERGONOMIC DEVICES FOR THE AGING HAND

Many of the common tools of everyday living are not designed for elderly people with age-related problems of the hands. Use of a mobile phone is beyond the manual capabilities of the large majority of elderly people. Miniaturization has resulted in mobile phones with buttons that are too small and too close, and screens that are hard to read for the elderly population, especially those with impaired vision. Elderly people are, however, increasingly finding the delights and benefits of communication with their relatives via e-mail and the wonders of the Internet. Unfortunately, many of the most widely used keyboards or mice are not ergonomically suited for elderly adults. The reduced range of motion of the wrist may put elderly people at greater risk of developing cumulative trauma disorder (71,72). Much more thought has to be given to the topic of modifying tools and instruments of daily living for the elderly population, especially those with impaired functioning of the hands. These include basic items such as cutlery, pens, scissors, nail clippers, hairbrushes, and combs.

#### THERAPEUTIC EXERCISES FOR THE AGING HAND

Functional aging changes in hands can possibly be retarded by introducing suitable simple regular exercise programs for hand strengthening and hand flexibility (5). These can use very simple equipment such as squeezable rubber balls, or elastic bands on fingers. Such exercises should be designed to strengthen grip and maintain joint flexibility of fingers and the wrist. The biological axiom of "use it or lose it" applies to hand function, as it does to any other part of the musculoskeletal system in the body. The proof of such advice can probably be deduced from many great pianists and violinists, whose manual dexterity was retained into ripe old age, presumably as a result of regular hand exercise (73). In contrast, it is important that the exercises selected are appropriate and do not lead to damage or overexertion. In particular, after stroke the hand may

become flexed and in such cases efforts to strengthen grip are inappropriate.

### Conclusions

Elderly people commonly present difficulties with hand functioning and manual dexterity requiring fine precision grip, and loss of hand strength that can affect simple everyday actions. Functional ability seems to stay unchanged until the age of 65 years, after which it declines gradually. Deterioration in hand function occurs as a result of both normal aging and established disorders frequently encountered in older people, such as osteoporosis, osteoarthritis, and rheumatoid arthritis. Ideally, hand assessment should identify the specific prehension patterns needed for specific tasks, and the treatment approaches can then specifically address the problems contributing to the hand dysfunction.

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