POWER GRIP AND PRECISION HANDLING

BY

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The recent study by Napier (1956) of the prehensile movements of the human hand is of outstanding importance because it points out that the "nature of the intended activity finally influences the pattern of the grip" (p. 906). He distinguishes between the "precision grip" and the "power grip" and states that these patterns, "either separately or in combination, provide the anatomical basis for all prehensile activities, whether skilled or unskilled" (p. 902). In the precision grip the thumb is *abducted* in both the metacarpophalangeal and the carpometacarpal joints, whereas in the power grip both joints are *adducted*.

With the abduction (combined with flexion) the thumb also rotates medially, so that the pulp surface becomes directly "opposed to the pulp surface of one or all of the remaining digits for the purposes of (precision) prehension" (p. 908).

Napier (1952) positively stated that this abduction with related rotation took place not only in the carpometacarpal joint, but also in the metacarpophalangeal joint; this had been previously observed by Duchenne (1867) and Bunnell (1938), but neither they nor Napier offered any substantial evidence in support of this idea.

In the power grip the combined fingers form one jaw of the clamp with the palm as the other jaw. The fingers are more or less flexed according to the size of the object, and they are laterally rotated and inclined towards the ulnar side of the hand. The power grip should therefore be manifested in grasping a cylindrical object. The thumb—in the adducted position—is pressed with the pulp surface against the object to be grasped, and this, according to Napier, introduces an element of precision into the power-grip complex. If the object is heavier and the possibility of precision more limited, then the thumb will gradually become more abducted and will be thrown over the object.

In the precision grip the abduction of the thumb ensures that the pulp surfaces of the thumb and

fingers can place themselves opposite to each other; the fingers are now described as being flexed and abducted at the metacarpophalangeal joints.

The characteristics of both grips come into play in grasping globular or cylindrical objects. Napier states that the position of the hand is determined not so much by the shape of the object as by the quality of the grip, which in its turn depends on the purpose for which the instrument is grasped. For example, a pinhammer has about the same diameter as a pen or pencil and, although in both cases an element of precision is involved, a pinhammer is clearly held and used differently from a pen.

The problem which Napier raises is extremely important, not only in the actual anatomy, but also in the evaluation of incongruity, the correction of deformities, and the reconstruction and rehabilitation of the hand. He gives very apt examples of objects with the same shape that can be used in different ways, according to the power or precision required.

It is necessary for those concerned in the rehabilitation of crippled or deformed hands to study the whole subject of the various positions which the normal hand is capable of assuming according to the object grasped and the use to which it is to be put. Napier uses the terms "precision grip" and "power grip" "in a dynamic as well as a static sense in the same way that flexion and extension are employed to describe both the posture and the movement" (p. 903). The dynamics of gripping produce a particular grip, and the static concept indicates the final state of gripping. This concept is given little consideration by Napier; he does not say whether both forms of grip may be regarded as a variant of the final state, or whether the movements leading to this final state may be taken in both cases as variants of an equivalent movement pattern.

Consequently it seems justifiable to attempt to discover how the dynamic and static stages of these

"grips" present themselves. In performing what Napier calls the "power grip", the object must be *taken hold of*, and then the fingers must clench themselves around the object to hold it firmly. Thus, in the dynamic phase, the hand must be open and the fingers and thumb must take up a position suitable for grasping the object; the fingers in this position can then make closer contact with the object, and further power can then be exerted for gripping or clenching. In this process the dynamic and static phases can be clearly distinguished. The duration of the dynamic phase is unimportant; the fact that it is usually short does not mean that it is not absolutely essential to the establishment of a good grip. It comprises a series of voluntary acts:

- (a) The opening of the hand;
- (b) The positioning of the fingers;
- (c) The approach of the fingers to the object;
- (d) The transition to the static phase—the actual grip.

The grip itself may be accomplished in very many ways, a spherical object can be clenched in a power grip with the thumb in opposition, and a cylindrical object with the thumb in adduction or in opposition, to the other fingers.

To distinguish Napier's so-called "precision grip" from the "power" grip, it is necessary to characterize its quality, for the precision grip does not involve any forceful grasping of the object. As soon as the *taking hold* is established, the pattern of the power grip is present regardless of how much power is exerted, but in the precision grip there can be no such antagonism between the fingers (and thumb) and the middle hand (including the thenar and hypothenar) and a different form of antagonism is brought into use, namely an interdigital or contradigital antagonism. The object is held between the tips of the fingers, and because a very small degree of power is exerted the quality indicated by the word "grip" is absent from the movement pattern. Nor is there any possibility of a gradual transition to an increasingly more powerful grasp when the object is held in the finger tips. It is possible to hold the object immobile between the finger tips, but this is not typical for this form of "grip", the chief purpose of which is to operate the object with precision by means of the fingers. This is the cardinal difference from the "power" grip, in which the static phase is characterized by the fact that the gripping can retain a rigid relation to the object while it moves in relation to the wrist, elbow, or shoulder. In the precision "grip" there is no question of a static phase, since the fingers themselves manipulate the object, and there is no

point in distinguishing dynamic and static phases in this movement pattern.

For this reason the term "grip" is not applicable, and it is therefore suggested that this manoeuvre should be called "handling".

In "precision handling", therefore, the first requirement is that the fingertips be so placed that the object can be held, and for this the opposition (with rotation) of the thumb is indispensable. After this the motion of the fingers in relation to each other perform the actual *handling or manipulation*.

Napier explicitly states that the term "prehensile" should be reserved for "movement in which an object is seized and held partly or wholly within the compass of the hand", whereas "non-prehensile" movements are those "in which no grasping or seizing is involved, but by which objects can be manipulated by pushing or lifting motions of the hand as a whole or *of the digits individually*" (p. 902). It is therefore strange that Napier described precision handling by the term "precision-grip".

ANATOMICAL ASPECTS

POWER GRIP

In recent studies on the anatomy of the articulated finger (Landsmeer, 1955, 1958, 1961), it was affirmed that the movements of both interphalangeal joints were co-ordinated. Because of the presence of joint clefts and bi-articular and polyarticular muscles, one may speak of a "chain of joints", in which each bone except the terminal phalanx is an intercalated unit. This process was described by Gilford, Bolton, and Lambrinudi (1943) in their paper on "link joints". In view of the anatomical evidence of the existence of a *joint chain*, bridged by bi-articular and polyarticular muscles, it is not sufficient to consider the equilibrium or the motion (actually a series of balance states) of *one* joint; it must first of all be determined which grouping of joints or which articulated member can be considered as an anatomically-bonded entity. Because one of the long flexors and also the extensor bridge both the elbow and wrist joints, the actual finger areas can be considered separately because they can be stabilized independently. It is necessary, however, to investigate the significance of the flexors and the extensor in the articulation of the forearm.

An intercalated bone in a bi-articular system, bridged by two bi-articular antagonistic muscles, cannot be kept in equilibrium. A bi-articular tendon system can be shortened in its entirety only by a pattern of zigzagging, *i.e.* by changing the angles of the two joints in the opposite sense. Two muscles can equilibrate only one joint. In such a case the whole system cannot be shortened because

the shortening of one tendon always requires the lengthening of its antagonist. In contrast, the shortening of one muscle in a bi-articular system can take place while the antagonist remains isometric. It will be clear that a tendon bridging a bi-articular system can remain isometric only by zigzagging the system.

The direction of this zigzagging—of the turning of the intercalated bone—depends on the ratio of the distance from the tendon to the joint-axis in the two joints involved.

The principle is illustrated diagrammatically in Fig. 1(a), which shows only one of the muscles. Now, it is supposed that this muscle runs in such a way that it remains isometric when the system zigzags as the two joints change their angle by the same degree. The question is, how does the antagonist run when it is shortened as a result of this zigzag pattern? The answer is that the tendon must "gain" in the "flexing" joint more than it "loses" in the "extending" joint. Or that its distance from the axis in the "flexing" joint must exceed its

distance from the axis in the "extending" joint (Fig. 1b). It may be deduced that, if the tendons run as assumed, their contraction will produce a zigzag in the same direction, since in that event the entire tendon system shortens. In other words, a pair of antagonistic bi-articular muscles will shorten as a system when the system zigzags in such a way that the change of angle in each joint leads to the shortening of the tendon with the relatively largest beam (Fig. 1c).^{*} So long as the shortening of the system as a whole cannot be prevented by some other effect, e.g. by a third muscle, the zigzagging will proceed until one of the joints has reached its end-state.

Thus, the proximal phalanx, considered as an intercalated bone, may be assumed to be bridged by the long flexor and the extensor, and will immediately arrive at its end-state, in which

^{*} In a previous paper (Landsmeer, 1961), it was explained that the "relative beam", which can be measured directly, is generally a reliable approximation for the "relative shortening", the latter being a more proper term for expressing the position of a muscle.

(a) The joints change their angle in opposite directions. Tendon R remains taut and the same length. It is assumed that the tendon runs so that the joints change their angle to the same degree.

(b) When tendon L gains more in Joint I than it loses in Joint II, the whole tendinous system will become shorter. This will happen when $d > b$.

(c) The bi-articular bi-muscular system in its general form. When $a/b > c/d$ the intercalated bone will make a clockwise turn, as when muscles R and L both act.

Fig. 1.—Diagrams to explain the phenomenon of zigzagging in a bi-articular bi-muscular system.

extension in the metacarpophalangeal joint and flexion in the proximal interphalangeal joint will occur until the possibility of excursion of one of them is exhausted. In theory, this could be established by the fact that the ratio "distance extensor-joint axis: distance flexor-joint axis" for the metacarpophalangeal joint exceeds this ratio for the proximal interphalangeal joint. The extensor has the relatively largest beam in the metacarpophalangeal joint, and the flexor profundus (and also the sublimis) in the proximal interphalangeal joint. By means of a third muscle, the intercalated bone can be held in each state of equilibrium, provided that this muscle can operate *antagonistically*. The third muscle can be either bi-articular or mono-articular. In this way the first phalanx can be controlled by one of the flexors, the extensor, and the bilateral wing-tendons of the interossei or lumbricales (Fig. 2). The fact that the *flexor profundus* is not directly inserted on the middle phalanx does not prevent the inclusion of this muscle in the bi-articular system, since the operation of both *interphalangeal joints* is co-ordinated (Landsmeer, 1958).

Opening the Hand.—This is a motion by which the interphalangeal and the metacarpophalangeal joints are moved *simultaneously*.

Choice of Finger Position.—This is more or less simultaneous with the preceding phase. The fingers are adjusted metacarpophalangeally while the desired curving is carried out interphalangeally. The bilateral wing-tendons determine by mutual co-ordination the position for abduction or adduction.

Approach.—The movement of metacarpophalangeal joint is independent of the interphalangeal joints; as the fingers approach the object the metacarpophalangeal joint moves while the interphalangeal joint changes but little.

Grip.—As the fingers take hold of the object, they are powerfully drawn by the *flexor profundus*, so that they remain in a position which ensures an efficient grip. The so-called phalangeal tendons of the *interossei*, which include that of the *abductor digiti V*, are pre-eminently suited to contribute the power involved in the actual grasping. They are present on only one side of each finger; the ulnar side of the little and ring fingers and the radial side of the first and middle fingers. These tendons have no identical antagonist, which is certainly remarkable for a muscle in a lateral position. This anatomical situation suggests that the phalangeal tendons will hold the metacarpophalangeal joint in a terminal abducted position, and will work

(a) Bi-articular system composed of the proximal interphalangeal and the metacarpophalangeal joints bridged by the extensor and both flexors.

(b) The proximal phalanx in this system will make a counter-clockwise turn.

(c) The interosseous (wing tendon) acts antagonistically to the common effect of the extensor and flexors.

Fig. 2.—Diagrams of a finger with its tendinous system.

antagonistically not in relation to a heterolateral partner (which occurs only exceptionally in the middle finger), but in relation to other functional units of the hand. The osseous insertion of the interossei will cause abduction (and rotation) of the *extended* proximal phalanx, but rotation only of the *flexed* proximal phalanx.

The choice of position and the final position in which the grasp is made are principally determined by the shape of the object. With a spherical object, the metacarpophalangeals of the little and ring fingers are in maximal ulnar abduction, and the lateral rotation of these joints is obvious. The first finger is in maximal radial abduction, which is otherwise limited in relation to the axis of the metacarpal. The middle finger can be in an intermediate position. The thumb is in opposition to the other fingers, while the little and third fingers are laterally rotated, the index finger shows no medial rotation whatever, and the middle finger

retains a free choice according to the needs of the situation (Fig. 3).

Fig. 3.—Position of the fingers in the spherical grip. Notice the opposition of the thumb and the lateral rotation of both the ring and little fingers.

The part played in this pattern by the phalangeal tendons on the ulnar side of the little and third fingers and on the radial side of the first finger is clear. These fingers are abducted in a terminal position.

In grasping a cylindrical object, the situation is somewhat different (Fig. 4). The little and ring fingers are now more sharply bent. The phalangeal interossei bring the metacarpophalangeal joints to a state of maximal lateral rotation. Both fingers are projected over the palm of the hand. The index and middle fingers with the thumb, which lies in the palm of the hand, form a pincer, and the phalangeal tendon on the radial side of the index and middle fingers is now in antagonism to an adducted pollux. Thus an initial dynamic phase and a terminal static phase can be observed in anatomical terms in the power grip.

Precision Handling

The central fact in "handling" is that the object can be manipulated by means of the fingers. The metacarpophalangeal and interphalangeal joints

Fig. 4.—Position of the fingers in the cylindrical grip. The ring and little fingers are laterally rotated to a maximum.

move independently. When the *profundus* is active, the terminal phalanx will move in a co-ordinated pattern with the middle phalanx. When the *sublimis* acts as the flexing muscle, the terminal phalanx is beyond muscular control. With pressure on the volar side it will consistently turn dorsally, even when the proximal interphalangeal joint is flexed. This situation is far from rare; it occurs frequently in the index finger in the manipulation of a pen.

Brand (1958), discussing the paralytic claw-hand, precisely stated that "as soon as the metacarpophalangeal hyperextension is relaxed in beginning to close the hand, the interphalangeal joints again lose all extension power. The patient therefore always closes the hand by closing his terminal joints first" (p. 618). The patient can grasp only little objects, for with larger objects "the presenting finger tips and nails push the object out of the palm instead of surrounding it by the palmar surface and pulps of the fingers which should reach out to encircle it. This reaching out of the fingers is a purely intrinsic action and is the preliminary to all normal grasp and pinch" (p. 619).

In this important observation Brand touched upon the true nature of the bi-articular system, controlled by two muscles only; in such a system one of the joints will always fall into a terminal position

because of the zigzagging tendency. For the system involved in handling, the terminal position for the combined interphalangeal joints is *flexion* and that for the metacarpophalangeal joint is *extension*. This holds good as long as the intrinsics are out of action. The first metacarpal tends to turn dorsally, a movement which can be equilibrated by the interossei or lumbrices (Fig. 2). The intrinsics being disregarded, *either the metacarpophalangeal joint will be extended, or the interphalangeal joints will be flexed*. The finger can be moved in accordance with a *well-defined pattern; the interphalangeal joints can be flexed and extended only when the metacarpophalangeal joints remain extended, while the metacarpophalangeal joints can be flexed and extended only when the interphalangeal joints are flexed*. Starting from the extended position, the interphalangeal joints will be flexed first, and only when they are fully flexed will the metacarpophalangeal joints be taken into flexion. The invalidity of the human hand in cases of functional disorder of the intrinsics is identical with the fixed pattern of movement.

As for the abductory action of the so-called phalangeal interossei, Eyler and Markee (1954) have commented on the dorsal bipennate part of the dorsal interossei (our phalangeal tendon): "The dorsal component of each dorsal interosseus is anatomically best suited to forcefully deviate its respective digit"; and on the wing-tendons: "Each volar interosseus and volar component of each dorsal interosseus is in position to exert greatest force on the lateral bands of the extensor aponeuroses, to forcibly flex the metacarpophalangeal joint, extend the interphalangeal joints, and to a less degree deviate its digit" (p. 8).

Finally, the position of the grasping hand in relation to the forearm is important. The human hand can grasp cylindrical objects so that the pronation movements are translated as a rotation of the object. In this way a screwdriver is held in a cylindrical power-grip and the same applies to the posture of the hand in fencing. But in unscrewing the lid of a jar, in the initial phase of loosening the lid, the spherical power grip gives the hands a firm contact with both the lid and the jar. The forearms are then used as levers in line with the radius of the lid and of the jar. By means of the upper arms, tangential forces are applied to the proximal ends of the forearms, and these considerably enhance the effort.

Summary

On the basis of a fresh analysis of the pattern of movement and posture of the human hand, a distinction is suggested between *power-grip* and

precision-handling. In the former, a dynamic, initial phase can be distinguished from a static, terminal phase, and the position of the fingers depends upon the shape of the object; in the latter there is no static phase.

The dynamic phase includes the opening of the hand, the positioning of the fingers, and the grasping of the object. The functional anatomical processes of these movements have been subjected to closer analysis.

The finger represents a chain of joints, bridged by bi-articular and polyarticular tendons. Two bi-articular systems can be discerned: that of the metacarpophalangeal joint and proximal interphalangeal joint, with the proximal phalanx as the intercalated bone; and that of the interphalangeal joints, with the middle phalanx as the intercalated bone. The latter is a co-ordinated system, but in the former two joints can be moved independently. Abductions in the metacarpophalangeal joint are accompanied by rotations. The movements involved in "gripping" and "handling" are further analysed, with remarks on the position of the grasping hand in relation to the forearm, and the specific manner in which the object or tool is to be used.

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Capacité de saisir et précision manuelle. Une analyse des mouvements préhensiles de la main humaine

RÉSUMÉ

Sur la base d'une analyse nouvelle du mécanisme des mouvements et de la position de la main humaine, on propose une distinction entre la *capacité de saisir* et la *précision manuelle*. Dans le premier cas on peut distinguer une phase initiale dynamique d'une phase terminale statique et la position des doigts dépend du contour de l'objet; dans le deuxième cas la phase statique est absente.

La phase dynamique comprend l'ouverture de la main, la mise en position des doigts et l'action de saisir l'objet.

Le fonctionnement anatomique au cours de ces mouvements fut soumis à une analyse détaillée.

Le doigt représente une chaîne d'articulations reliée par des tendons bi- et poly-articulaires. On peut distinguer deux systèmes bi-articulaires: celui de l'articulation métacarpo-phalangienne et de l'interphalangienne proximale, où la phalange proximale est un os intercalé, et celui des articulations interphalangiennes, avec la phalange moyenne comme os intercalé. Ce dernier est un système coordonné, mais dans le premier les deux articulations peuvent être mues indépendamment. Les abductions dans l'articulation métacarpo-phalangienne s'accompagnent de rotations.

On procéda à d'autres analyses des actions de saisir et de manipuler, et on nota la position de la main au moment de saisir par rapport à l'avant-bras et la manière spécifique dont un objet ou un outil doivent être manipulés.

Poder de asimiento y precisión manual. Un análisis de los movimientos prensiles de la mano humana

SUMARIO

Sobre la base de un análisis reciente del tipo de movimientos y de la postura de la mano humana se sugiere

una distinción entre *poder de asimiento* y *precisión manual*. En el primero puede distinguirse una fase inicial dinámica de una terminal estática y la posición de los dedos depende del contorno del objeto; en el segundo no existe fase estática.

La fase dinámica comprende la apertura de la mano, la colocación de los dedos y el asimiento del objeto. El funcionamiento anatómico del proceso de estos movimientos fué sometido a un análisis más detallado.

El dedo representa una cadena de articulaciones apoyadas por tendones inter y poli-articulares. Dos sistemas inter-articulares pueden ser puestos de manifiesto: el de la articulación metacarpo-falangiana y de la interfalangiana proximal con la falange proximal como hueso intercalado, y el de las articulaciones interfalangiennes, con la falange media como hueso intercalado. El último es un sistema coordinado, pero en el primero las dos articulaciones pueden ser movidas independientemente. Abducciones en la articulación metacarpo-falangiana son acompañadas de rotaciones.

Más adelante se analizan los movimientos de asimiento y de manipular y se nota la posición de la mano al asir en relación con el antebrazo y el modo específico en que el objeto o herramienta ha de ser usado.