Functions of some finger joints while handling the PC mouse, and their possible relevance for computer aided learning

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Abstract:

Highly intense use of the finger, while handling the computer mouse, as in e-learning, may lead to hand- or finger complaints, e.g. in the elderly. To understand the finger positions concerned, we analysed some of its joints by functional anatomical research. A statically and dynamically stabilised finger arch is needed to prevent complaints.

1 Introduction, material and methods

After the development of several distance learning courses, including study routes, on Human Anatomy for Students of Biomechanics and Health Sciences in Russian-speaking countries (1,2), the present authors became aware of ever-growing health-problems worldwide by the continuous use of personal computers in persons of all ages, including our current e-learning students (3,4). Many of such problems are upper extremity movement disorders, as in hands and fingers (3). As finger movement studies related tot PC use mainly concentrate on the second joint of the finger, known as the proximal interphalangeal (PIP-) joint, this study deals with mobility and stability of this PIP-joint in e.g. handling the PC mouse (5,6). Structures governing the PIP-joint's (and other finger-joints') stabile and coordinated movements were therefore observed by *in vitro* anatomical specimens, supple enough to simulate motion *in vivo*. Collateral ligaments of the PIP-joint, revealed by micro-dissection, were then compared to current literature (7). Motion-behaviour of their various parts was interpreted kinematically. By understanding which elements underlie finger coordinated motion, movement problems by intense use of the PC mouse, possibly occurring in e-learning too, may probably be prevented.

2 Results

2.1 Observations

By their finely tuned positions relative to the axes of each finger's proximal and distal interphalangeal joints, the various tendinous bands within the so-called extensor assembly of the finger, purely mechanically help to guarantee the ratios of coordinated flexion as well as extension in both joints simultaneously. Along the PIP-joint each lateral band is supported by the joint's proper collateral ligament (PCL) (14). This PCL shows its more superficial part, which crosses its deeper part in extension, to shift over the latter in PIP-flexion however. Both parts of the PCL then become taut (7). These two parts, plus the finger's proximal and middle phalanx to which they attach, are thus acting as elements of a crossed four-bar linkage system.

2.2 Proximal interphalangeal joint in man and other primates

At the level of the proximal interphalangeal joint, the disposition in the extended human finger is as follows. The medial tendon or band of the extensor assembly lies on the dorsum of the first phalanx's trochlea, while its lateral bands lie practically dorsally over the strong collateral ligaments of the proximal interphalangeal joint (8). This disposition is determined in man by the trapezoid shape of the trochlea (9). The same shape on cross-section is found in higher primates, whereas in lower primates the trochlea is squarer, becoming even rectangular in primate predecessors like the opossum (10). As a consequence, the lateral bands will mainly stay on the shoulders of the trochlea in these species, impairing a more independent use of their separate fingers as compared to higher primates' fingers, man included (11,12,13).

2.3 Flexion of the proximal interphalangeal joint

In flexion of the human finger, the lateral bands of the extensor assembly, fusing distally into one extensor tendon for the distal interphalangeal joint, glide alongside the flexed proximal interphalangeal joint, thereby acquiring more palmar positions. Thus, by a purely mechanical coupling, their displacements favour the simultaneous flexion of the distal interphalangeal joint, whose extension they normally control (14, 15). In PIP-flexion, their displacements are in turn enhanced by the PIP-joint's collateral ligaments, *viz.* the proper collateral ligaments (PCL) becoming taut whereas the PIP accessory collateral ligaments (ACL) become slack (7).

2.4 Imaging results

In the extended proximal interphalangeal joint, HR-imaging techniques revealed characteristic features of the positions of PIP collateral ligaments, in cross-sections as well as in coronal slices (16,17,18). Undulating trajectories of the PCL fibres in particular, at finger extension, contribute to certain cushioning effects with respect to the extensor assembly's lateral bundles which they support. Thus the lateral bundles maintain dorsal positions in PIP extension (8,14).

2.5 Proximal interphalangeal joint ligaments behaviour

Manipulating anatomical specimens of the finger during micro-dissection enabled us to point out the positions as well as the mechanical behaviour of the proper collateral ligaments (PCL) controlling PIP-flexion. On both sides of the joint, either PCL consists of a superficial part and a deep part that cross each other (7). Together with the bone of the proximal phalanx and the bone of the middle phalanx on which they both insert, these parts (being taut in PIP-flexion) may be interpreted as behaving mechanically like a crossed four-bar mechanism (19).

2.6 Kinematical aspects

A crossed four-bar mechanism in the finger has been suggested, but mainly theoretically (20). With respect to hand prosthetics however, this concept was recently successfully applied (21). The movement pattern of the PIP-joint *in se*, in fact more complicated than that of a simple hinge-joint, was recently described in terms of differing geometries of its joint surfaces (22). Regarding the latter analysis, the paths of motion of the proximal interphalangeal joint, being "generated" by crossed four-bar mechanisms like the one proposed here, do unmistakeably fit.

3 Practical applications

Because of the key-role of the proximal interphalangeal joint of the finger (together with its enigmatic complexity) in relation to finger flexor tendons and the extensor tendon apparatus or extensor assembly, in creating a stabilised arch of the moving finger, functional-anatomical analyses should use *in vitro* micro-dissections as well as *in vivo* HR-imaging techniques (23). After applying these methods, we now could present a concise description of the initial results

Besides, the functional demand of a stabilised arch of the finger will be met, by designing and using those PC mice that are pre-shaped to prevent disorders by intense use of the mouse (24). In current e-learning practice, each student's fingers, hand, and even whole upper extremity, may profit from ergonomically safe working conditions, thus using the computer successfully.

4 Conclusion and discussion

The stabilised arch of the freely moving finger, in contact with the PC mouse, largely depends on positions of its flexor- and its extensor-tendons (the so-called extensor assembly) relative to the proximal interphalangeal joint. We could point out these positions, by micro-dissection *in vitro*, simulating finger movements *in vivo*. The latter, visualised in two healthy individuals (AH; KJvZ) by HR-imaging techniques, showed the extensor assembly's precise positions. PIP-joint collateral ligaments moreover act as a crossed four-bar linkage system, guaranteeing this joint's movements in static and dynamic situations contributing to a stabilised finger arch. To prevent motion complaints, computer mouse designers should take into account these data.

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