An Analytical Expression for the D.I.P. – P.I.P. Flexion Interdependence of the Human Finger

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Background

Some clinicians feel the need to investigate the correlation between the flexion ranges of the different finger joints for a clear distinction between a healthy and a pathological finger. When investigating the interrelation of quantities in different (e.g. healthy and pathological) cases, it is often more instructing, not to compare the direct change of the involved quantities, but to compare their rate of change, expressed by the first order derivative. Empirical evidence shows that a strong correlation exists between the flexion angles of the distal interphalangeal joint (D.I.P.), and the proximal interphalangeal joint (P.I.P.) of the human finger. The aim of the study therefore is to find an analytical expression for this correlation, from where the first derivative may be calculated. A line defined by the straight dorsum of the middle phalanx gives the reference from where the flexion angles θ (P.I.P. flexion) and φ (D.I.P. flexion) are measured. This is shown in a lateral view in Fig. 1. Several authors report the measured functional dependence of the D.I.P. angle on P.I.P. flexion [1, 2, 3, 4]. They also state that the interdependence of D.I.P. and P.I.P. flexion is different for healthy individuals and patients suffering from various pathologies. Examples of such pathologies are: peripheral neuropathies and joint diseases such as rheumatoid arthritis (RA) and osteoarthritis (OA) [3, 4].

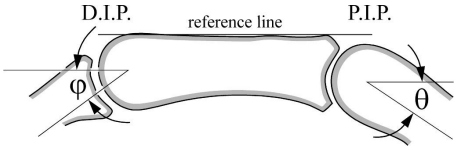

Fig. 1. Definition of D.I.P. – P.I.P. flexion angles. Diagram based on a lateral view of the human finger; left: distal; right: proximal

Method

We developed a kinematical model expressing analytically the D.I.P. – P.I.P. angle correlation as $\varphi = f(\theta)$. In order to get numerical expressions, the model was applied to two experimental data sets, one set for a normal finger, the other for a pathological finger. The anatomical model parameters, as far as they are P.I.P. angle dependent, are, after adapting them empirically to best fit a given data set, expressed by a least squares fit polynomial in the P.I.P. angle θ and inserted into the model expression. We thus obtained an overall analytical formula fitting the given data sets.

Findings

We were able to model the D.I.P. – P.I.P. angle interdependence and to describe it by means of an analytical form. This function allows for any P.I.P. angle to calculate the corresponding D.I.P. angle. After first order differentiation of the analytical expression with respect to the P.I.P. angle, the model also shows the rate of change of the D.I.P. flexion. The function and its first order derivative are applied to two sets of data, for a healthy and a pathological situation respectively. Fig. 2 shows the fit of the healthy state, Fig. 3 the fit of the pathological state, in this case a peripheral neuropathy of the ulnar nerve at the elbow leading to "intrinsic-minus fingers", also known as "clawing fingers" [5, 6].

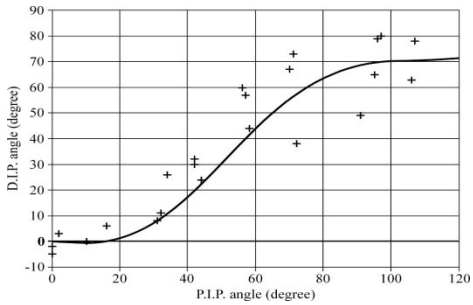

Fig. 2. Experimental data (crosses) and analytical fit (line) of D.I.P. – P.I.P. flexion angles for a healthy finger

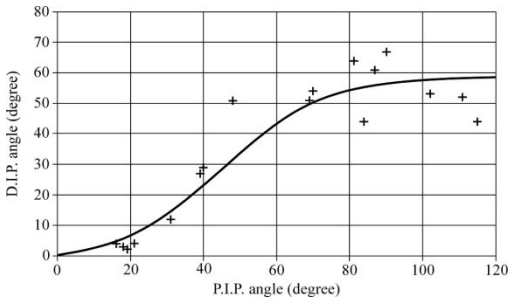

Fig. 3. Experimental data (crosses) and analytical fit (line) of D.I.P. – P.I.P. flexion angles for a pathological finger

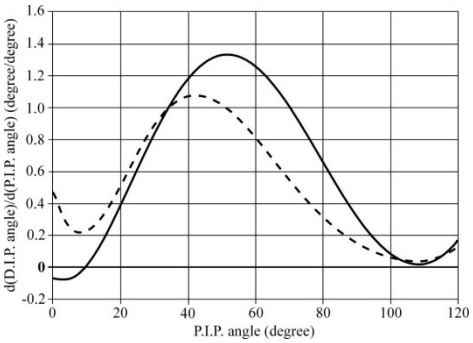

Fig. 4. Calculated derivatives of the analytical fits of the D.I.P. – P.I.P. flexion angles for a healthy (solid line) and a pathological (dotted line) finger

Interpretation

Especially the calculation and visualisation of the rate of change of the D.I.P. flexion versus P.I.P. flexion (Fig. 4) provides an additional and more precise discriminatory tool between normal and pathological states, such as a peripheral neuropathy. As Fig. 4 shows, this rate of change is different for a healthy and a pathological finger. In the pathological finger the maximum of D.I.P. flexion per degree of P.I.P. flexion is lower than in the normal finger. Further on, for the pathological finger the maximum of D.I.P. flexion lies about 10 degrees P.I.P. angle lower than the maximum in the normal finger. Not only reaches the maximum of flexion in the pathological finger only 80% of the maximal flexion of a normal finger, the ability to flex the D.I.P. joint more, declines faster than in a normal finger when going to higher P.I.P. values. In other words, in the intrinsic-minus finger, D.I.P. flexion "runs ahead" of P.I.P. flexion. This

phenomenon may also be held responsible for the kinematic aspects of the intrinsic-minus finger, also called the “claw-finger deformity” [6].

Conclusion

Especially the visualisation of the rate of change of the D.I.P. flexion versus P.I.P. flexion provides an additional and clear-cut discriminatory tool between normal and pathological states of the finger.

References

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