ICSV13 - Vienna
The Thirteenth International Congress on Sound and Vibration
Vienna, Austria, July 2-6, 2006

THE INFLUENCE OF FINGER POSITION ON PERCUSSION SOUNDS

K. J. van Zwieten*[1], V. V. Potekhin[2], P. L. Lippens[1], V.A. Sholukha[2], K. P. Schmidt[1], and A.V. Zinkovsky[2]

[1]Department of Anatomy, Hasselt University, BioMed Institute, Agoralaan, Gebouw D, B-3590 Diepenbeek, Belgium
[2]Department of Biomechanics, Saint-Petersburg State Polytechnical University, Grazhdansky Prospekt 28, 195220 Saint-Petersburg, Russia
koosjaap.vanzwieten@uhasselt.be (e-mail address of lead author)

Abstract

Percussion sounds of the chest are resonant sounds induced by striking one finger upon another finger applied firmly to the chest. They have the greatest content of energy in the range of 150 - 200 Hz. The character of the percussion sounds may change due to pathological processes (Sovijärvi *et al.*, 2000). The striking finger must be flexed in both interphalangeal joints simultaneously, to acquire a stable arched finger position. This condition is due to local shifts within the so-called extensor assembly of the finger, which is the anatomical structure where tendons of extrinsic and intrinsic finger muscles converge (Van Zwieten *et al.*, 2002). The stability of the arch of the striking finger contributes to its rigidity, thus influencing the quality of percussion sounds produced.

INTRODUCTION

Historical background

Auenbrugger (1754) developed a new technique of physical examination, which he called percussion. He tapped on the chest of patients with his fingertips with the hand drawn closed, and noted of the sounds that were conveyed to identify a site of abnormality. He referred to these "percussed" sounds as either high pitched, muted or dull (Soiferman and Rackow, 2006). Percussion sounds of the chest are resonant sounds which have the greatest content of energy in the range of 150 – 200 Hz. The character of percussion sounds may change due to pathological processes (Sovijärvi *et al.*, 2000).

The current technique of percussion is as follows (Figure 1) . Hyperextend the middle finger of one hand and place the distal interphalangeal joint firmly against the patient's chest. With the end of the opposite middle finger, use a quick flick of the wrist to strike first finger (Rathe, 2000).

Wintrich (1854) recommended a “percussion hammer” instead of the striking finger, which was used to strike a “pleximeter” (a device, used instead of the middle finger against the patient's chest) during percussion. This “improvement” later became out of fashion, so that nowadays percussion is currently applied as described above (Figure 1).

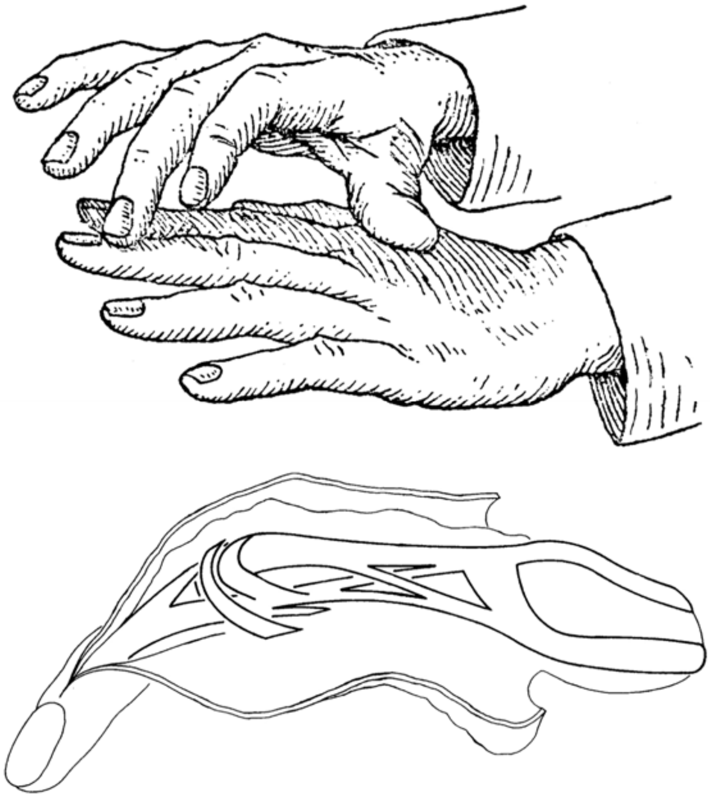


Figure 1 – Striking finger in percussion after Jordan (1968), and its morphology.

STATING THE PROBLEM

Although in medicine this technique of percussion is generally practiced, some questions still remain unsolved, for example how a slightly bowed percussing finger can acquire such stable qualities equal to those of a “percussion hammer”. So now, rather than technically analyzing the percussion sounds produced, as has been already successfully done by Korenbaum *et al.* (2003), we would like to concentrate here on an analysis of the **stability** of the striking finger during percussion. To elucidate this phenomenon, an anatomical review of the finger is given, with emphasis on its extension and flexion positions, and starting with a quite schematical representation.

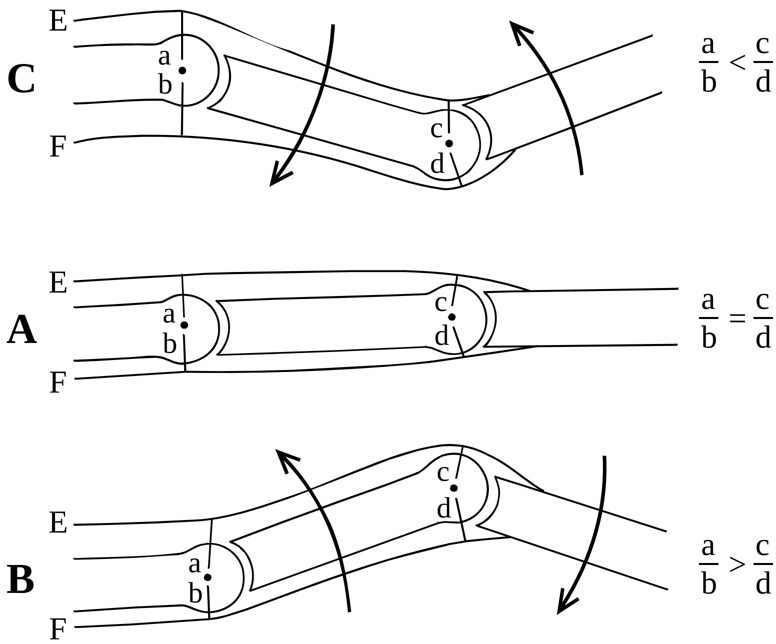


Figure 2 – Diagram of a free moving finger, represented as a biarticular system (see text). After Srinivasan (1985).

FINGER DIAGRAM

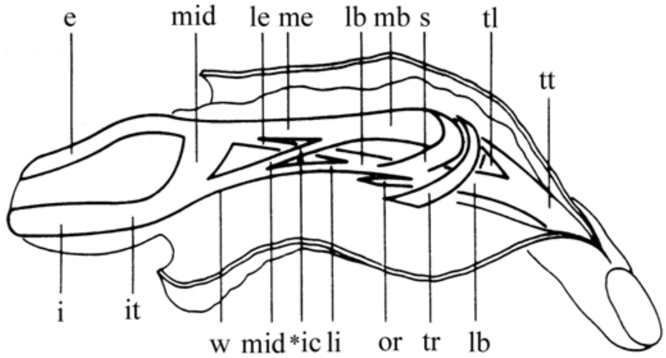
During unresisted motion, the freely moving finger may be observed as a system in equilibrium, consisting of three rigid bodies, interconnected by two hinge joints. (Figure 2, to be read from left to right). Such a biarticular system, under the influence of two opposing forces of equal value, exerted by respectively tendon E (from the Extensor muscle) and tendon F (from the Flexor muscle), will be stable in a given posture (i.e., stay in a posture without moving away from it) if the ratios of their moment arms at the two joints are equal (Figure 2A).

If not, the joint with the higher ratio will move in the direction of the numerator and the other joint will move in the opposite direction, i.e. the system will collapse in a zig-zag manner (Figures 2B and 2C). The biarticular bitendinous system has no freedom to move away from this pattern (Srinivasan, 1985).

MORPHOLOGY OF THE FINGER

In reality, the anatomy of the finger shows an extra set of opposing tendons at the first joint (in the finger diagram, Figure 2, the joint at the left) with an approximately constant ratio of moment arms. Stabilization of the whole system thus comes into view. But in contrast to the situation at the Flexor side of the finger (Figure 3 below), the moment arm of the Extensor tendon for the second joint (in the finger diagram, Figure 2, the joint at the right) is not constant with respect to the the centre of rotation of the first joint. Therefore, theoretically, this Extensor tendon for the second joint may pass below instead of above the centre of rotation of the first joint during finger movement. In this respect, the Extensor tendon would theoretically act as a flexor with respect to the first joint, which is an unwished situation.

In order to explain these relations, and also to demonstrate that finger morphology normally will prevent such a situation, the anatomy of the finger is now presented more in detail, especially its extensor aspect (Figure 3 above).



The extensor assembly of the finger

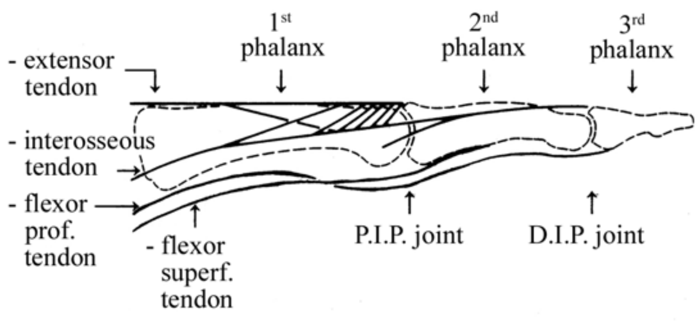


Diagram of finger extensor and flexor tendons

Figure 3 – Details of the extensor and the flexor tendons of the finger, in dorsal view (above) and lateral view (below). Meaning of the abbreviations of the anatomical structures: see text.

Anatomy of the finger, extensor aspect

The so-called extensor assembly of the finger consists of tendon fibres from the long extensor digitorum muscle, the interosseous muscles, and the lumbrical muscle. Ligamentous fibres also join the extensor assembly.

The proximal interphalangeal (P.I.P.) joint and the distal interphalangeal (D.I.P.) joint of the finger (Figures 3) are extended by the extensor assembly, and flexed by the tendons from respectively the superficial flexor digitorum muscle and the deep (profundus) flexor digitorum muscle.

Abbreviations :

e : long extensor tendon; i : interosseous muscle; it : interosseous tendon; mid : medial interosseous fibres; w : wing tendon; le : lateral part of long extensor tendon; me : medial part of long extensor tendon; * ic : intercrossing fibres; li : lateral interosseous fibres; lb : lateral bundle; mb : medial bundle; s : spiral fibres; or and tr : retinacular ligaments; tl : triangular lamina; tt : terminal tendon

Simulation model of subsequent flexion of the finger joints

To demonstrate some of the subsequent positions of finger flexion, a mathematical simulation model of finger motion is now used (Van Zwieten *et al.*, 2002). In this kinematical model, tendons and tendon fibre bundles are supposed to be non-elastic and non-contractile, such as ropes for instance (Figure 4 a.).

P.I.P.-flexion by the tendon of the flexor superficialis muscle (←) includes a distal shift of the extensor assembly (→) (Figure 4 b.). The medial bundle thereby follows the curvature of the flexed P.I.P. joint, staying in its pulley over this joint.

The lateral bundles, and the spiral fibres however rearrange themselves along the contours of the flexed P.I.P. joint. There is a certain descent of the lateral bundle alongside the flexed P.I.P. joint. Compared to the medial bundle, the lateral bundle will follow a shorter course along the flexed P.I.P. joint. Extra length is thus yielded for the terminal tendon for the D.I.P. joint, which is the direct continuation of the lateral bundle.

Now this terminal extensor tendon is slack enough to shift more distally - it does no longer act as an antagonist of the tendon of the flexor profundus muscle (←) during subsequent flexion of the D.I.P. joint. Hereby the spiral fibres (indicated from S_1 to S_5 in Figure 4), which suspend the lateral bundle, simply fan out (Figure 4 c.).

So the un-resisted distal shift of the terminal tendon for the third phalanx (↓) enables D.I.P.-flexion. This biomechanical coupling of P.I.P.-flexion to subsequent D.I.P.-flexion favours the motion of the freely moving finger.

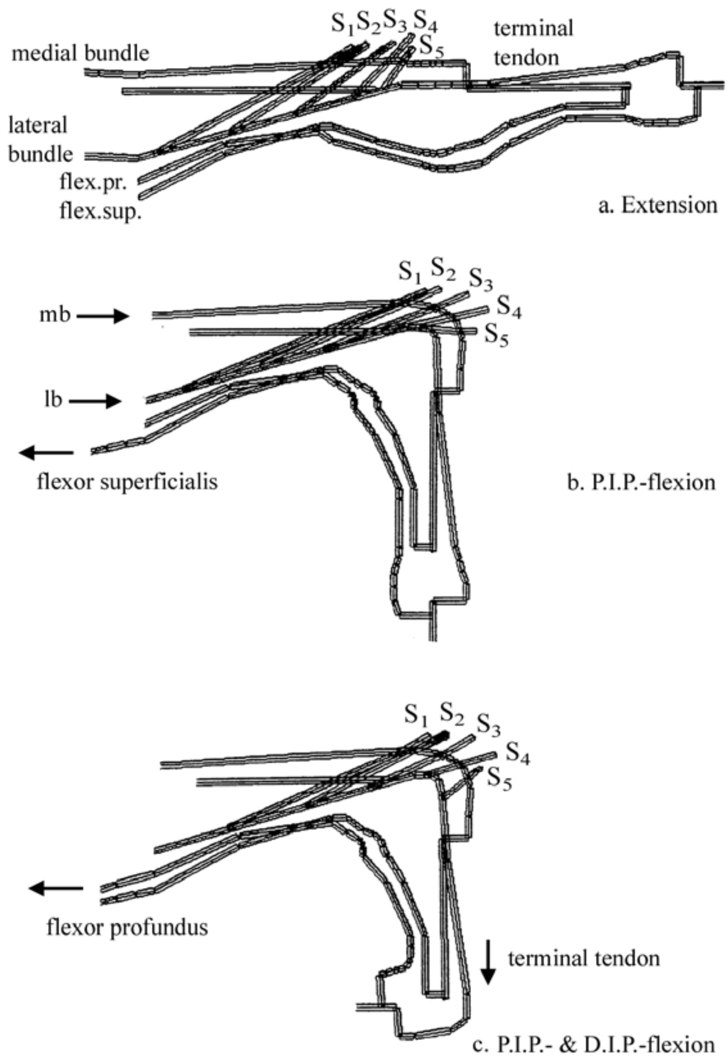


Figure 4 – Mathematical model of finger tendons in subsequent positions of finger flexion.

Simultaneous flexion of the finger joints

Instead of the stepwise subsequent interphalangeal flexion as described above, the two interphalangeal joints can also be flexed simultaneously, as normally occurs in various types of grips and precision handling. A movie-sequence of simulation by mathematical modelling of such finger flexion was recently published (Sholukha *et al.*, 1998).

One initial frame from this sequence in particular (Figure 5), represents the actual situation of the striking finger during percussion. From this representative finger position, it is clear that the spiral fibres have loosened the lateral bundle and its continuation the terminal extensor tendon for the D.I.P. joint, just enough to allow such amount of D.I.P. flexion, as is appropriate for the necessary amount of P.I.P. flexion. This is depicted in the diagram (Figure 5) of the slightly bowed finger position (Sholukha *et al.*, 1998) in which a variety of forces can be applied, as was done by Sancho-Bru *et al.* (2001), and by Valero-Cuevas (2005). The resultant of all forces accounts for the eventual stability of the whole finger during free movements.

If all resulting angles of D.I.P. flexion are plotted against all angles of P.I.P. flexion, experimentally (Van Zwieten and Lippens, 1993) as well as theoretically (Braido and Zhang, 2004), a linear relationship may be observed (Figure 6).

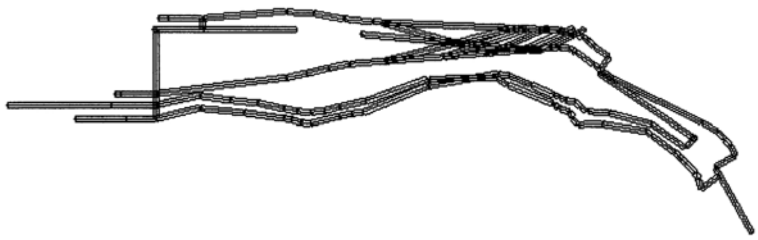


Figure 5 – Mathematical model of finger tendons in a slightly curved position of the finger.

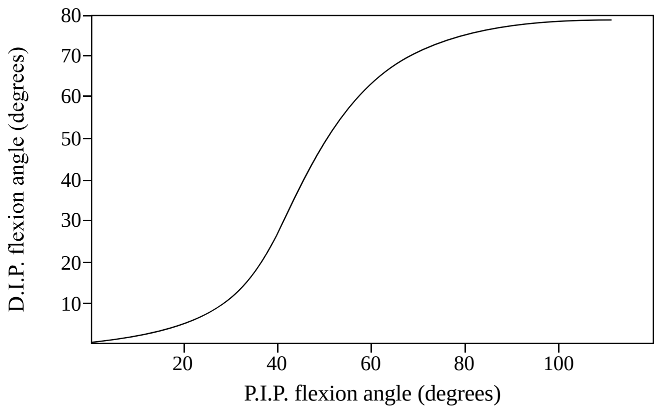


Figure 6 – Ratio of the angles of interphalangeal flexion in free movement of the finger.

CONCLUSIONS

In diagnostic percussion, the stability of the striking finger, that influences the resulting resonance sounds, is determined by a.o. the spiral fibres of its extensor assembly. Keeping the lateral bundle along the flexed proximal interphalangeal joint, they control the accompanying flexion of the distal interphalangeal joint. In all free movements of the finger there is a linear ratio of flexion of both interphalangeal joints.

REFERENCES

J. L. Auenbrugger, Inventum novum ex percussione thoracis humani ut signo abstrusos interni pectoris morbos detegendi *(New discovery that enables to detect the diseases hidden within the chest from percussion of the human thorax)*. (J. Th. Trattner, Vienna, 1761)

E. Soiferman, E. Rackow, "A brief history of the practice of percussion", http://www.antiquemed.com/percus.html (2006)

A.R.A. Sovijärvi, F. Dalmasso, J. Vanderschoot, L.P. Malmberg, G. Righini, S.A.T. Stoneman, "Definition of terms for applications of respiratory sounds", European Respiratory Review, **10**, 77, 597-610 (2000)

R. Rathe, "Examination of the chest and lungs", University of Florida, http://medinfo.ufl.edu/year1/bsc/clist/chest.html (2000)

F.L.J. Jordan, *Handleiding voor het algemeen lichamelijk onderzoek.* 7e druk (J. Bijleveld, Utrecht, 1968)

V.I. Korenbaum, A.A. Tagil'tsev, Y.V. Kulakov, E.M. Batishev, I.A. Boyko, D.N. Mokeev, I.A. Pochekutova, A.Y. Kostiv, "Acoustic lung imaging based on the spectral analysis of percussion sounds", Proceedings of the XIII Session of the Russian Acoustical Society, Moscow, August 25-29, 2003, 454457 (2003)

H. Srinivasan, "Biomechanical aspects of finger deformities", Proceedings of the International Conference on Biomechanics and Clinical Kinesiology of Hand and Foot, December 16-18, 1985, Edited by K. Mothiram Patil and H. Srinivasan, Indian Institute of Technology, Madras, 53-56 (1985)

K.J. van Zwieten, P.L. Lippens, P. Geusens, M. Kowalski, V.A. Sholukha, A.V. Zinkovsky, "Clinical application of finger mathematical modelling", Acta of Bioengineering and Biomechanics, **4**, 1, 354, ISBN 83-7085-639X (2002)

V.A. Sholukha, K.J. van Zwieten, P.L. Lippens, A.V. Zinkovsky, "Finger tendons kinematics assessing from motion dynamics computer oriented modeling", Journal of Biomechanics, **31**, 1, 29 (1998)

J.L. Sancho-Bru, A. Pérez-González, M. Vergara-Monedero, D. Giurintano, "3-D dynamic model of human finger for studying free movements", Journal of Biomechanics, **34**, 1491-1500 (2001)

F.J. Valero-Cuevas, "An integrative approach to the biomechanical function and neuromuscular control of the fingers", Journal of Biomechanics, **38**, 673-684 (2005)

K.J. van Zwieten, P.L. Lippens, "Alternative model of interphalangeal flexion", Book of Abstracts, 1st Congress of the Federation of the European Societies for Surgery of the Hand, Brussels, Longman Group UK Ltd, ISSN 0266-7681, 5-6 (1993)

P. Braido, X. Zhang, "Quantitative analysis of finger motion coordination in hand manipulative and gestic acts", Human Movement Science, **22**, 661-678 (2004)