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Review

Musicians' Hand Problems: Looking at Individuality

A Review of Points of Departure

Prof. Dr. med. Christoph Wagner

Various strategies on how to uncover the causation of musicians' hand problems have been outlined. Little attention, however, has been paid to the interaction of the numerous biomechanical factors involved and the extent of their inter- and intra-individual variation. A systematic biomechanical analysis is presented considering three basic elements: a) size and shape of the hand, b) resistance of the joints involved, and c) muscle forces acting on these joints. Results of the individual hand measurement are summarized as a "Hand Profile." It shows the instrumentalist's biomechanical constellation in comparison with a control group of healthy professional musicians, serving as a base to advise musicians from a medical perspective and/or with regard to playing technique. From hand research as a whole, we may recognize that there is in fact little reason for generalizing manual abilities. *Med Probl Perform Art* 2012; 27(2):57–64.

How to Find the Origin?

"I remember catching myself training scales during a recording session for a radio broadcast station. I had never needed to train scales!," a pianist once reported (Subject K 20, Hanover, 13 May 1985). He in fact developed severe problems in playing the instrument years later. Hand problems often have a long history, and the doctor usually has little chance to observe the real beginning. In order to get closer to the origin of playing-related disorders, looking at the entire community of musicians is suggested, whether diseased or healthy—both sides may learn from each other.

One should not overlook the fact that of all musicians, it is only a portion who develops disorders, despite being exposed to equal conditions (e.g. playing the violin in orchestra, combined with constantly high musical demand). Is this due to different behavior only ("wrong technique"), or is it also the individuality of predisposition, which plays a role here?

We all know that human characteristics differ—so do hands. This knowledge, however, is mostly rather vague, and therefore we tend to rely on "normality." How far do we do justice to the individual this way?

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Analytical Studies

Already in the beginning of performing arts medicine, Alice Branfonbrener, in her comprehensive survey on epidemiology, emphasized, "that unless all of the etiological factors are taken into consideration, successful treatment may be difficult to develop"[1(p27)] and she pointed out "those risks which come about as the result of the individual's physical characteristics. . . ."[1(p61)] Consequently, we should ask whether the individual quality of the hand also might be considered as a possible risk.

Numerous epidemiological studies have been conducted since; it is difficult, however, to summarize them due to methodological limitations. Bragge et al.,[2] in their systematic literature review, found a wide range of prevalence in pianists of 26–93% and no consensus regarding the risk factors. Even if age and gender were to be proven as being significant risk factors,[3] we would need to consider these characteristics as merely "general" terms behind which a considerable series of behavioral and biomechanical factors are hidden.

A further effort was to understand the pathomechanisms of playing-related injuries. Sakai,[4] in a study with (predominantly female) Japanese pianists, demonstrated the pathogenic effect of playing especially strenuous piano techniques such as octaves, chords, arpeggios, fortissimo dynamics, etc. with relatively small hands, concluding that hand size could be considered a risk factor in piano playing.

In a later study with 200 pianists showing overuse syndromes, Sakai[5] analyzed the relationship between pain symptoms, special movements used in piano technique and their corresponding anatomical structures. Without understanding these connections, we are unable to devise adequate prevention strategies—the question, however, is whether and how the instrumentalist is at all able to change his or her movements or joint positions. What is the individual scope of available movements?

The opportunity for systematic studies of the hand-instrument relation emerged, when in the 90ties David Steinbuhler (Steinbuhler & Company, Titusville PA), presented new reduced-size keyboards, 15/16 and 7/8 compared to the standard size. Christopher Donison instead revived the old idea that one should better fit the instrument to the hand than the other way around.[6] I would like to emphasize that his suggestion had not only the aim to prevent piano-related pain, but that he also wanted to help the countless piano players

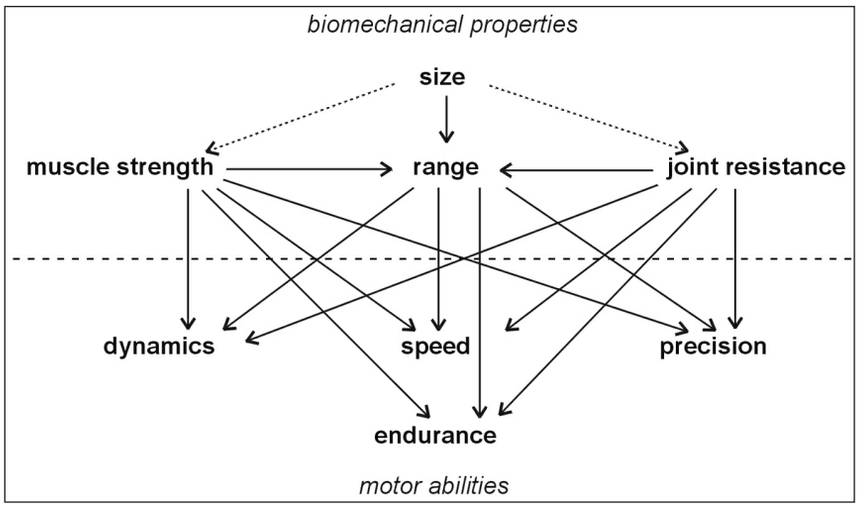

FIGURE 1. Interaction of the biomechanical components and their influence upon the qualities of music performance. From Wagner Ch. *Hand und Instrument: Musikphysiologische Grundlagen, praktische Konsequenzen*. Wiesbaden: Breitkopf & Härtel; 2005; with permission.[22(pp122)]

suffering from loss of enjoyment due to the discrepancy between their hands and the instrument. Such unfavorable psychological and physical experience might contribute to the development of disorders at an early stage.

Later, Wristen et al.,[7] in a pilot study compared the effect of a reduced-size keyboard (7/8) with the standard keyboard on two "small-handed" pianists ("small-handed" was defined by a span width 1–5 of 8 inches or less). The self-perceived greater ease at the smaller keyboard, combined with better performance, was understandable: Electrogoniometry showed that the span's maximal angle was about 15° smaller than with the traditional keyboard, and also the average joint angles were smaller. Furthermore, the transition between the two keyboards proved not to be an essential problem.

In a statistical approach, Yoshimura and her colleagues[8] investigated the possible influence of anthropometric and functional variables on piano-related pain. Most of the correlations they found were negative, some of them were significant. We should consider that a part of the numerous independent variables are inevitably connected among themselves for organic reasons. The authors are right in stating that "knowledge of these factors is needed to help understand why piano players report pain."[8(p123)] They found the span width 3–4 (right hand, measured as angle) to be an important risk factor. This is probably not the only limiting factor; flexibility of all four MCP joints II-V has been shown as another critical characteristic.[9,10,11]

As a consequence of their previous studies, Yoshimura and Chesky[12] compared the effect of a reduced-size keyboard to the standard keyboard, with regard to occurence of playing-related pain. Again, their results showed the advantage of a reduced-size keyboard for small-handed pianists.

Subjective Experience

Apart from other aspects, Boyle & Boyle[13] systematically collected the subjective experience of instrumentalists who had already practiced on the reduced-size keyboard for some time. One central question was, which of the special pianistic skills could be positively supported by using the smaller keyboard (e.g. legato playing, leaps, balance etc.)? Even if based on self-assessment, we get an interesting view of rather different improvement of the single skills. The study should become helpful when designing further experimental work.

It probably will take a long time until reduced-size keyboards are available to everyone, if ever. Meanwhile, we should remember the chance offered by certain historical instruments[14] because of their different keyboard sizes and mechanics, which in some respect may better comply with individual biomechanics of the hand.

Instruments Besides the Piano

Piano playing is a reasonable research model to reflect upon the relationship between hand and instrument. Basic questions are the same with other instruments, but their importance is different. Difficulties in adapting to the instrument should lead to ergonomic alterations, ideally at a very early stage of formation. Meanwhile, there exist many suggestions.[15]

A Note on Methodology

All piano experts are aware of the fact that problems of keyboard technique are not restricted to the horizontal plane. The vertical dimensions of today's keys (height, depth, resistance) can cause further problems. Nevertheless, hand size—especially the span widths 1–5, 1–2 and 2–5—are seen as most important criteria for piano playing. Is it sufficient, however, to rely upon one or a few parameters only? How closely related are the ten finger spans to each other and to hand size? What are the individual's options to use the whole chain of joints behind the fingertips when adapting to the keyboard? What hides within a "small hand," really?

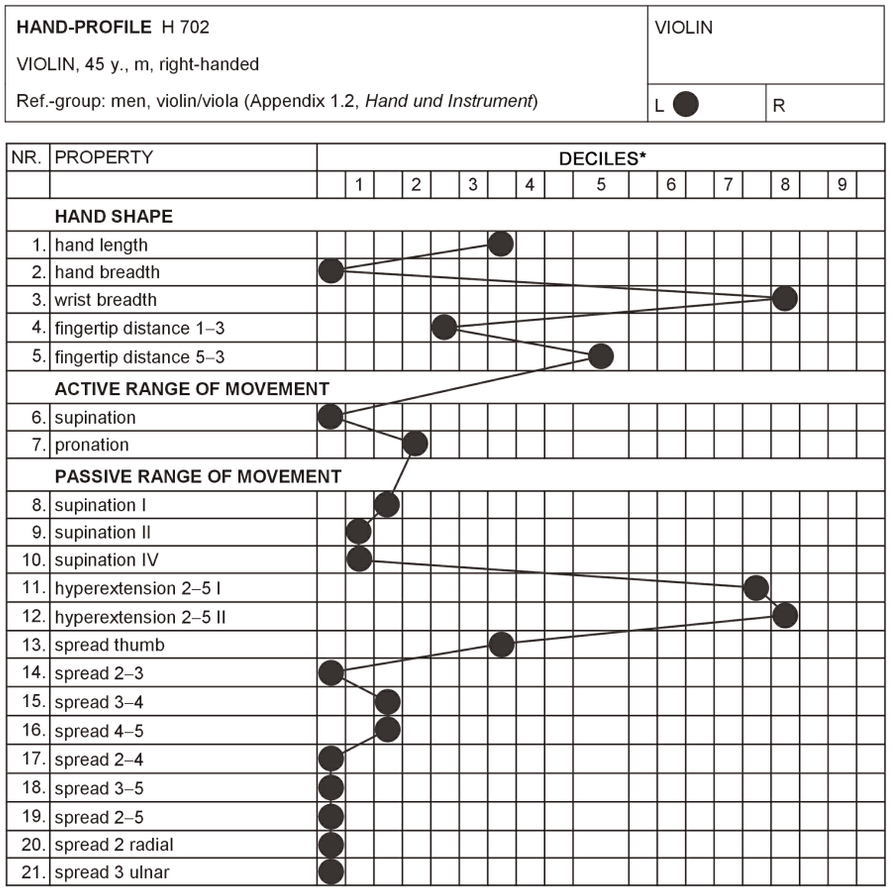

FIGURE 2. Subject H 702: *Physio-psychological interaction*: Violinist, member of a leading orchestra, 45 years. Experienced playing the violin as extremely strenuous from the beginning. Now considerable complaints in his left arm. Great effort to optimize conditions by muscle training, stretching, sport, Alexander Technique, psychotherapy over years, everything with no effect. Increasing anxiety level, finally unable to work, admission to a psycho-somatic hospital. The biomechanical limitation (supination, lateral flexibility of the MCP joints II–V) could have been seen during the time he was a student. [Deciles divide ranked data into 10 equal sections.] From Wagner Ch. *Hand und Instrument: Musikphysiologische Grundlagen, praktische Konsequenzen*. Wiesbaden: Breitkopf & Härtel; 2005; with permission.[22(pp208)]

If in her youth Alicia de Larrocha had asked whether she might choose the piano as her instrument, probably most teachers would have had their doubts because of her "tiny hands"[16(p166)]—and she made a world career. Later, however, she reported to be intensively concerned about the condition of her hands.[17]

This and similar stories (compare Fig. 3) remind us to be extremely cautious when giving advice. Piano playing is achieved by the interaction of quite different biomechanical elements (to say nothing about the central nervous activity). At the end, the question remains: Which of the manual components may support the individual instrumentalist, and which are definitely limiting factors in a given case (if there are at all limitations)? What criteria should we take as a guideline?

Should we take the instrument itself as the measure for manual requirement, e.g., the key distance of an octave? Or should we better look at the hands of successful instrumentalists? These musicians are the evidence of what can be compensated for, if necessary. Or should we look at performance itself, at joint positions, velocities, forces, using electro-myography, electrogoniometry,[7,18] three-dimensional movement analysis,[19,20] or the MIDI-technology to document the musical outcome[21]? The examination of performance may help to exemplify individual solutions for a technical problem, but it tells little about the individual's biomechanical reserves or limitations. From outside, nobody knows the subject's real effort, except under awkward experimental control.

In an individual case, to assess manual freedom and limitation respectively, we should know all biomechanical components on which the instrumental skills depend and we should know the extent of their variation. This quantitative aspect of individuality has been of less interest in previous research.

A Biomechanical Concept of Looking at the Musician's Hand

The biomechanical background of instrument playing consists basically of three components:[11]

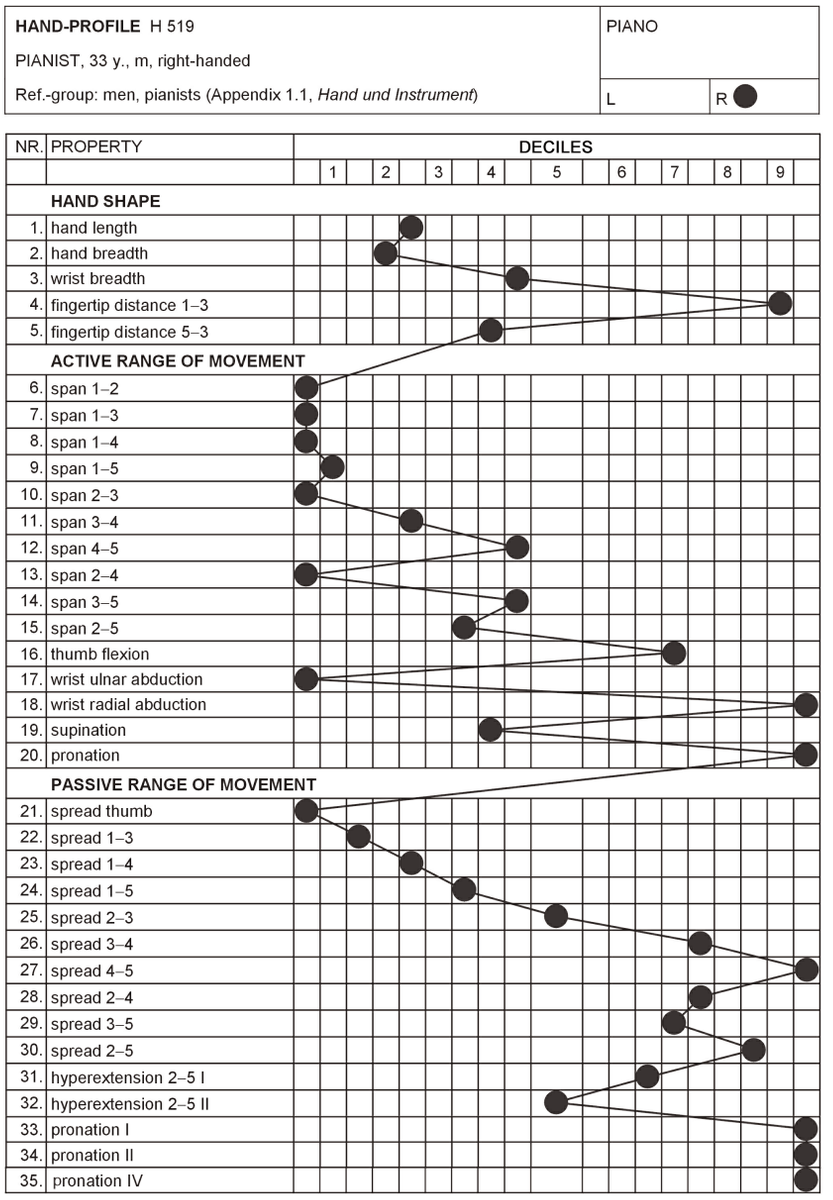

FIGURE 3. Subject H 519: *Thumb as the only limiting factor*. No physical complaints at all. Two unsuccessful operations of the thumb to improve mobility. The pianist now considered giving up his profession after 20 years of high commitment. The restriction could have been seen when he started playing piano. From Wagner Ch. *Hand und Instrument: Musikphysiologische Grundlagen, praktische Konsequenzen*. Wiesbaden: Breitkopf & Härtel; 2005; with permission.[22(pp202)]

- Size and shape of the body parts involved
- Resistance of the joints involved (synonymous with passive mobility)
- Available muscle strength acting on the joints.

These are the "tools" the brain has to cope with, how individually different they may be. Fig. 1 shows the interaction of the biomechanical components and their influence upon the qualities of musical performance. Therefore, any judgment on a hand's potential should consider each of the three components simultaneously by means of measuring, if possible.

In 1965 we started the research project "Hand Diagnostics for Instrumentalists" ("hand" including wrist and elbow joint) at the *Max-Planck-Institut für Arbeitsphysiologie*, Dortmund. The first phase of the project was confined to the piano, the second, to strings. Later, further instruments were included. From 1974 to 1993 the program was applied at the *Institute of Music Physiology, Hanover University for Music and Drama*, Germany.

Details of methodology, results, and experiences from consultations are presented in *Hand und Instrument: Musikphysiologische Grundlagen, praktische Konsequenzen* by Ch. Wagner (www.musikerhand.de).[22] Data of several hundred musicians (see *Hand und Instrument*, charts in Appendixes 1–3)[22] served as a basis to assist instrumentalists in regard to technique or playing-related pain and injury. The full routine examination (called Biomechanical Hand Measurement,

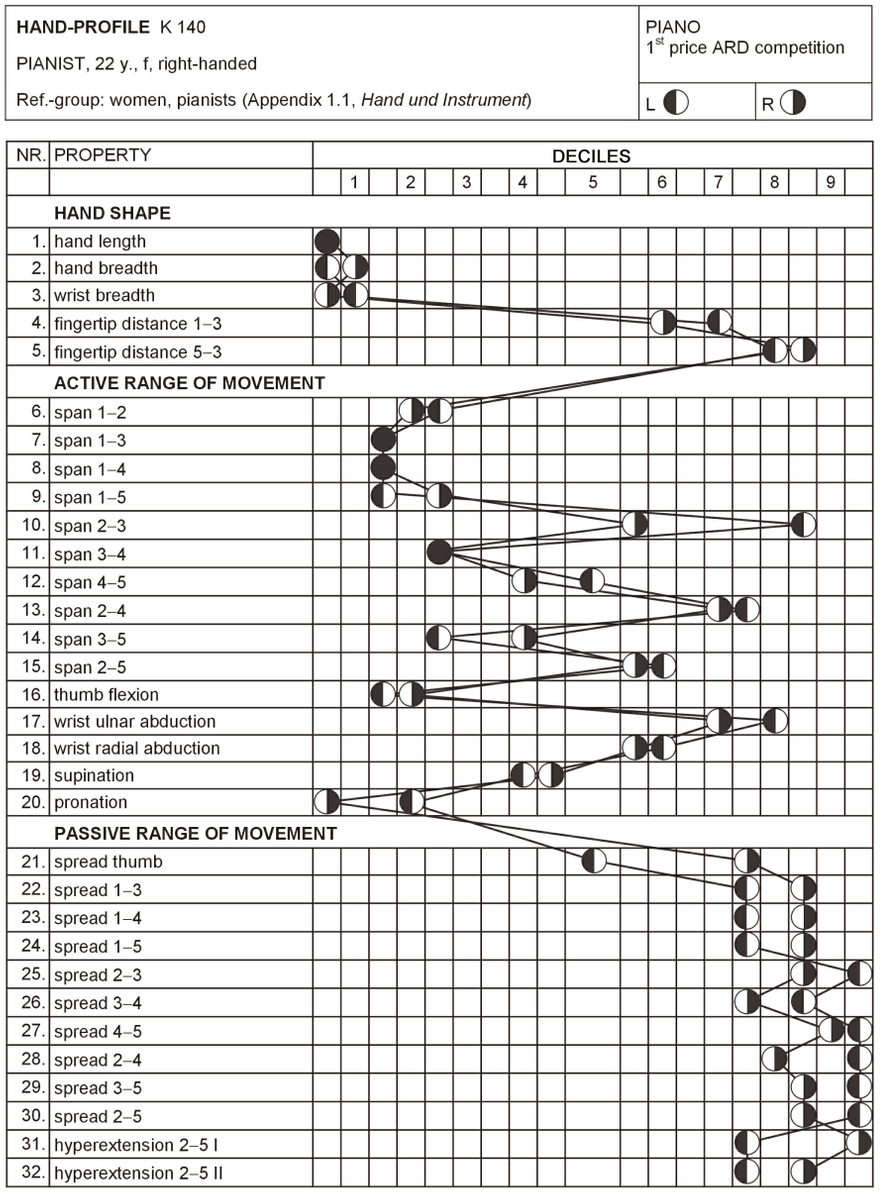

FIGURE 4. Subject K 140: *Hand size and virtuosity*: 1st prize International Competition Munich (ARD). The very small hand size is obviously compensated for by a high degree of passive mobility (and possibly strength). From Wagner Ch. *Hand und Instrument: Musikphysiologische Grundlagen, praktische Konsequenzen*. Wiesbaden: Breitkopf & Härtel; 2005; with permission.[22(pp234)]

BHM) comprised about 40 characteristics for one hand. Corresponding to the instrument, the measurement could be reduced to the functionally important factors.

The program of measurements:

- *Size and shape of the hand*:
  Hand length, hand breadth, hand index, wrist breadth, fingertip distance 1–3, 5–3
- *Active range of movement*:
  Span width 1–2, 1–3, 1–4, 1–5, 2–3, 3–4, 4–5, 2–4, 3–5, 2–5; flexion MCP joint I; wrist ulnar abduction, radial abduction; forearm supination, pronation.
- *Passive joint mobility (joint resistance) under given external torque*:
  Thumb abduction; spread 1–3, 1–4, 1–5, 2–3, 3–4, 4–5, 2–4, 3–5, 2–5; extension MCP joints II–V; forearm supination, pronation.
- *Muscle strength*:
  Force of flexion fingers 1, 2, 3, 4, 5.

As can be seen, we are not dealing here with an anthropometrical or biomechanical investigation as usual. Characteristics were selected with regard to their potential function in playing specific instruments. It was clear from beginning that the examination would have to be completed and specialized in the future.[23]

Limits of Generalization

In instrumental training, general rules of course are needed. But the old question is: How far are they valid in the individual

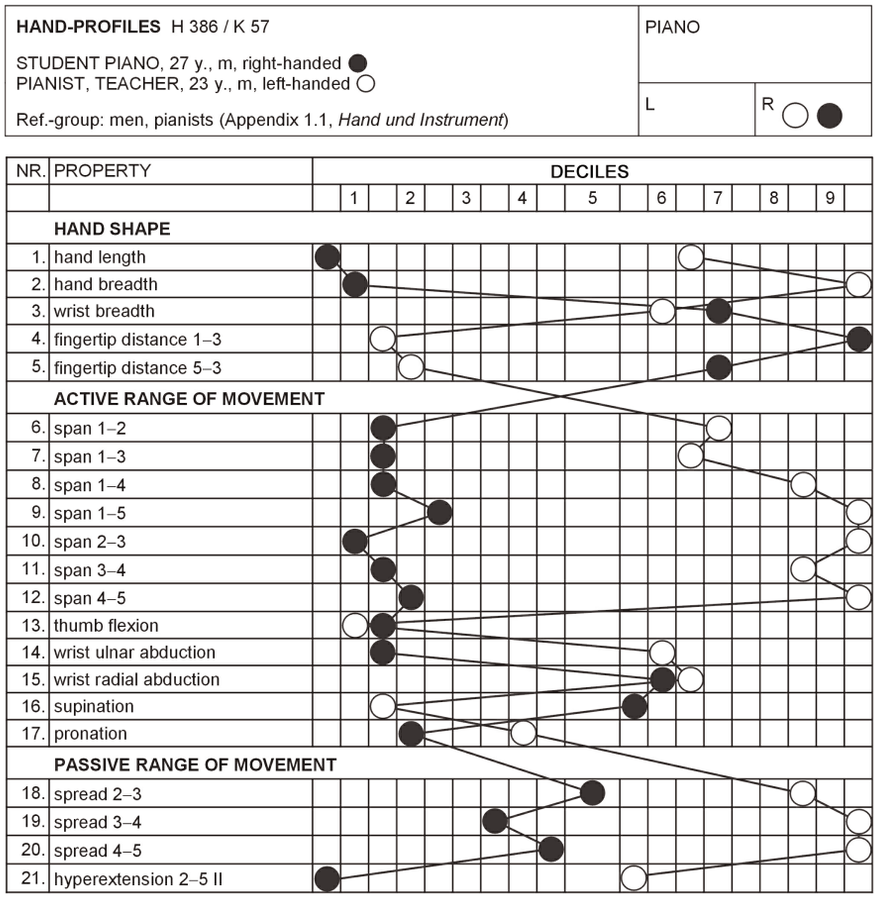

FIGURE 5. Subjects H 386 / K 57: *Student and teacher:* The problem to understand each other due to different hands. Comment of the teacher to the student: "You should practice more!" From Wagner Ch. *Hand und Instrument: Musikphysiologische Grundlagen, praktische Konsequenzen*. Wiesbaden: Breitkopf & Härtel; 2005; with permission.[22, 226]

case? Knowledge of the extent of variation of biomechanical components may facilitate the decision: Hand length, hand breadth, hand span and other comparable parameters are found at the bottom of the list of ranked variabilities (5–6%), and passive mobility factors are on top of the list (up to 70%).[22(pp323)] It is worthwhile, therefore, to pay attention here to possible extremes, because they may influence individual technique, consciously or unconsciously, and sometimes are hard to perceive from outside. Who, for example, would believe that finger span 3–4 may differ from 4.2 cm to 11.2 cm (1.65 to 4.41 inches) in professional pianists,[22(p282)] or active supination of violinists/violists would range from 65° to 120°?[22(p291)]

Furthermore, the rather weak intra-individual correlation of manual factors[24,22(pp328)] may complicate the evaluation of the musician's hand. It would be unreliable to assume a closer connection between e.g. hand size and finger span widths, etc. At present, there is no choice than to include all of the factors to recognize freedom or limitation of an individual's hand.

Passive Mobility—The Invisible Factor

Particular attention should be paid to the factor of passive mobility. Though awkward to measure, we need to know the levels of resistance against which the instrumentalist is working—and we of course need to know the level of available muscle strength. The measure of active range of movement may give an orientation, but it covers up to which extent muscle strength and joint resistance as independent variables contribute to the result. The extremely low resistance in supination in elite violinists, for example, may illustrate the importance of separate measurements.[11]

"Critical Factors?"

Which of the parameters of the BHM could be seen as "critical factors?" There are only a few small-sized pilot studies comparing violinists/violists versus non-musicians,[9] healthy violinists/violists versus violinists/violists with playing-related pain,[10] and successful musicians (pianists and violinists) versus musicians showing serious difficulties with their instrument.[11] These studies are not sufficient to give a final answer, but it is conspicuous that most of the joint resistance factors are significantly different between the two corresponding groups. Furthermore, "successful pianists" showed significant differences with all of the active ten finger spans, compared with "problem pianists," and "successful violinists"

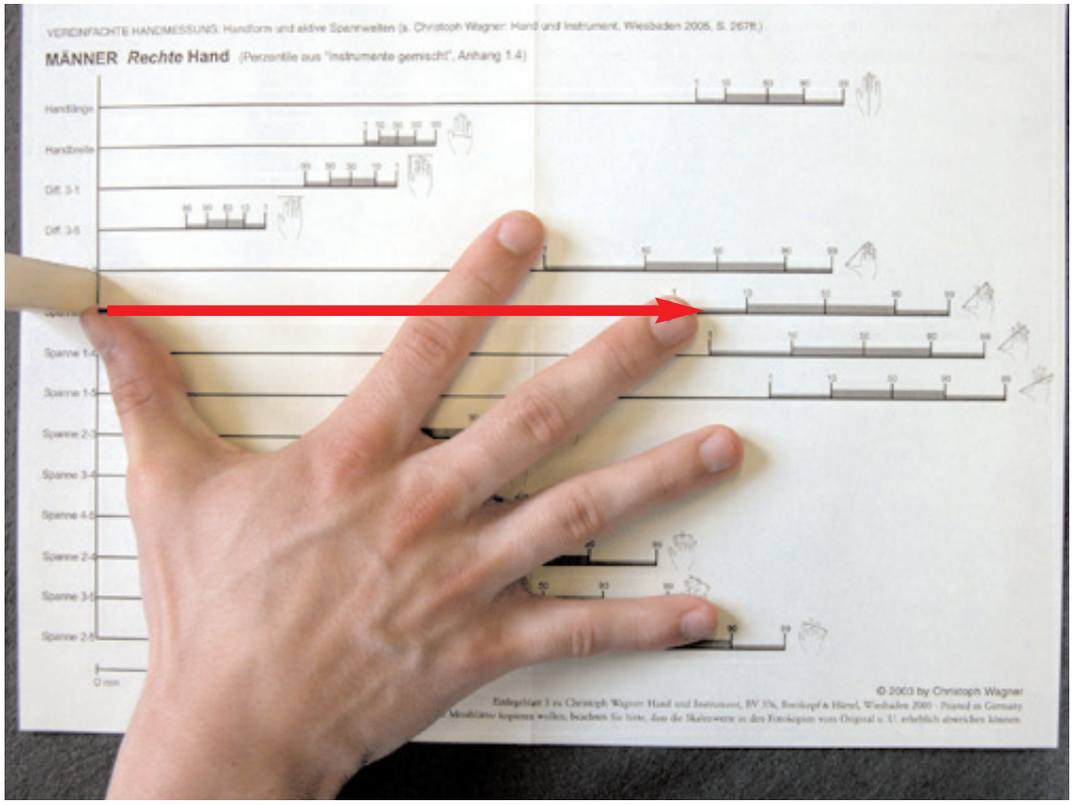

FIGURE 6. Pragmatic Hand Evaluation (PHE): Comparing the span width 1–3 with the percentile scale derived from the reference group of "mixed instruments." (Photo reprinted courtesy of the author.)

showed a significantly higher active range of supination range as the "problem violinists." Morphological data as a whole seem to be less characteristic.

The Hand Profile

The results of an individual biomechanical hand measurement can be depicted as a "Hand Profile" (Figs. 2–4). It shows an individual's constellation of measured values as compared to the decile or percentile values of a reference group of professional instrumentalists. Thus, Hand Profiles direct the observer's attention to marked deviations from the mean (left or right margin). It must be avoided however to derive any practical decision from single values. From the beginning, we should keep in view the permanent interaction of manual components with regard to possible compensation. Furthermore, profiles should always be seen in context of the instrumentalist's situation, his or her musical goal, the current repertoire, musical requirements, technique and technical difficulties, general complaints (e.g., neck, shoulder, back), working method and habits, special ergonomics of the instrument, workplace, and psychological background. This strategy is the only one leading to adequate decisions. It is clear that professional knowledge of the special instrument, its technique, and a wide pedagogical experience is indispensible to anyone who is making use of the Hand Profile, whether a musician, a teacher or a health care personnel.

Frank Wilson[25] was the first to use the program "Hand Diagnostics for Instrumentalists" in his studies on focal dystonia. He emphasized that particular biomechanics of the hand might contribute to the disorder. Our own data underline this assumption.[22(p241)] A few examples may illustrate the experience with Hand Profiles (Figs. 2–5).

In 2009, the program "Hand Diagnostics for Instrumentalists" was transferred to the *Zurich University of the Arts* (ZHdK). A special center forming part of the musicians' medicine section, the *Zürcher Zentrum Musikerhand* (ZZM, www.zzm.ch), was founded to develop and complete the methodology and to establish extensive cooperation at any level of music performance and education. It should be emphasized that at present, the ZZM is the only place in the world where the BHM technology is available and the test can be carried out.

What, however, can be done for instrumentalists who cannot profit directly from the Biomechanical Hand Measurement (BHM) in Zurich?

Pragmatic Hand Evaluation (PHE)

We decided to develop a strongly simplified hand evaluation procedure, derived from the results of hand research with musicians. It should be available to anyone, everywhere, and be carried out by musicians and teachers themselves. As experience has shown, even distinctive biomechanical limitations in the upper extremity sometimes escape the instrumental-

ist's (and the teacher's) attention. Above all, it is the music teacher who is able to set the course of an individual technique for his or her students, thus caring for prevention. Movements of both arms in piano playing, for example, should consider the individually very different range of pronation, from the beginning.

The PHE at present contains:

1. the measurement of hand size and all finger spans by means of distribution scales (Fig. 6) taken from the reference group of mixed instruments.[22(pp301)]
2. a rough estimate of certain ranges of movement (thumb, wrist, elbow, MCP joints II–V), finger strength, and finger independence.

The selection of the single tests must correspond to the instrument played.[22(pp263)]

The PHE is done without technical apparatuses and is easy to learn. However, it has to be trained thoroughly until a high level of precision is reached. After some routine, not more than 15 minutes per hand are needed. The interpretation of results needs the same background of knowledge and experience as with the Biomechanical Hand Measurement. The handling of the PHE is described in detail in *Hand und Instrument.*[22(pp263-270)] The papers for the examination are attached to the book.

Finally, health care personnel also may profit from the PHE if they are instrumentalists themselves. They may have the chance to understand the interaction of general complaints as a possible consequence of local problems with the hand in their patients. First experiences in using the PHE in music practice are encouraging.[26]

Goodbye to "Normality"

In his editorial to *MPPA* in March 2006, Ralph Manchester remarked: "The role of technique and the interaction between technique and various characteristics of the human body remain a mystery."[27] Perhaps we may have a certain chance to at least diminish the "mystery" if we say goodbye to "normality," i.e., if we look at these "various characteristics" as singular solutions of nature each time anew. Tailoring playing technique, prevention, and therapy should be the answer to this individuality.

I would like to thank Ulrike Wohlwender, Professor of piano pedagogy at the State University of Music and Performing Arts Stuttgart (Germany) and Dr. med. Horst Hildebrandt, Professor of music physiology, head of the musicians' medicine section at Zurich University of the Arts (ZHdK, Switzerland), for their constructive discussions of the manuscript and their valuable suggestions. Also, I am very grateful to Oliver Margulies, MA, MAS (ZHdK) for improving the English manuscript.

REFERENCES

1. Brandfonbrener AG. Epidemiology of the medical problems of performing artists. In Sataloff RT, Brandfonbrener AG, Lederman RJ (eds): *Textbook of Performing Arts Medicine.* New York: Raven Press; 1991; pp25–69.
2. Bragge P, Bialocerkowski A, McMeeken J. A systematic review of prevalence and risk factors associated with playing-related musculoskeletal disorders in pianists. *Occup Med* 2006; 56:28–38.
3. Pak C, Chesky K. Prevalence of hand, finger, and wrist musculoskeletal problems in keyboard instrumentalists: The University of North Texas Musician. *Med Probl Perform Art* 2001; 16(1):17–23.
4. Sakai N. Hand pain related to keyboard techniques in pianists. *Med Probl Perform Art* 1992; 7(2):63–65.
5. Sakai N. Hand pain attributed to overuse among professional pianists: A study of 200 pianists. *Med Probl Perform Art* 2002; 17(4):178–180.
6. Donison C. Hand size versus the standard keyboard. *Med Probl Perform Art* 2000; 15(3):111–114.
7. Wristen BG, Jung M-C, Wismer AKG, Hallbeck MS. Assessment of muscle activity and joint angles in small-handed pianists: A pilot study on the 7/8-sized keyboard versus the full-sized keyboard. *Med Probl Perform Art* 2006; 21(1):3–9.
8. Yoshimura E, Paul PM, Aerts C, Chesky K. Risk factors for piano-related pain among college students. *Med Probl Perform Art* 2006; 21(3):118–125.
9. Wagner Ch. Physiologische Voraussetzungen für das Geigenspiel. In Schwarz V (ed): *Violinspiel und Violinmusik in Geschichte und Gegenwart*. Bericht vom internationalen Kongress Graz 1972. Wien: Universal Edition A.G.; 1975; pp196–210.
10. Wagner Ch. The evaluation of the musician's hand: An approach to prevention of occupational disease. In Spintge R, Droh R (eds): *Music in Medicine: Neurophysiological Basis, Clinical Applications, Aspects in the Humanities*. Heidelberg: Springer-Verlag; 1987; pp333–341.
11. Wagner Ch. Success and failure in musical performance—Biomechanics of the hand. In Roehmann FL, Wilson FR (eds): *The Biology of Music Making, Proceedings of the 1984 Denver Conference*. St. Louis, Missouri: MMB Music, Inc; 1988; pp154–179.
12. Yoshimura E, Chesky K. The application of an ergonomically modified keyboard. *MTNA e-journal* November 2009; pp2–13.
13. Boyle B, Boyle RG. Hand size and the piano keyboard. An introduction to the technical and musical benefits for pianists using reduced-size keyboards. *Piano Professional, EPTA (UK)* 2010; Spring, pp18–23.
14. Sakai N. Keyboard span in old musical instruments: Concerning hand span and overuse problems in pianists. *Med Probl Perform Art* 2008; 23(4):169–171.
15. Markison RE. Adjustment of the musical interface. In Winspur I, CB Wynn Parry (eds): *The Musician's Hand–A Clinical Guide*. London: Martin Dunitz Ltd; 1998; pp149-159.
16. Arrau C. *Leben mit der Musik. Aufgezeichnet von Joseph Horowitz.* (Original: "Conversations with Arrau" 1982). Bern, München, Wien: Scherz Verlag; 1984.
17. Markus A. *Great Pianists Speak with Adele Markus*. Neptune, NJ: Paganiana Publications, Inc; 1979.
18. Chung I-S, Ryu J, Ohnishi N, et al. Wrist motion analysis in pianists. *Med Probl Perform Art* 1992; 7(1):1–5.
19. Ferrario VF, Macrì C, Biffi E, et al. Three-dimensional analysisof hand and finger movements during piano playing. *Med Probl Perform Art* 2007; 22(1):18–23.
20. Cardinal GD. Analysis of wrist flexion and extension in piano performance Biomechanical and anthropometrical perspectives. Dissertation Indiana University, Dec 2009.
21. Lee S-H. Hand biomechanics in skilled pianists playing a scale in thirds. *Med Probl Perform Art* 2010; 25(4):167–174.
22. Wagner Ch. *Hand und Instrument: Musikphysiologische Grundlagen, praktische Konsequenzen*. Wiesbaden: Breitkopf & Härtel; 2005.
23. Schuppert M, Wagner Ch. Wrist symptoms in instrumental musicians: Due to biomechanical restrictions? *Med Probl Perform Art* 1996; 11(2):37–42.
24. Wagner Ch. The pianist's hand: anthropometry and biomechanics. *Ergonomics* 1988; 31(1):97–131.
25. Wilson FR, Wagner Ch, Hömberg V. Biomechanical abnormalities in musicians with occupational cramp/focal dystonia. *J Hand Ther* 1993 Oct.-Dec.; pp298–307.
26. Wohlwender U. *Was heisst hier "kleine Hand"?–Spannweiten und andere Handeigenschaften realistisch einschätzen*. Üben & Musizieren 2009/2: 30–35.
27. Manchester RA. Toward better prevention of injuries among performing artists (editorial). *Med Probl Perform Art* 2006; 21(1):1–2.