New Diagnostic Methods in Biomechanics, Sports, Rehabilitation and Automotive Engineering

---

Neue Diagnoseverfahren für Biomechanik, Sport, Rehabilitation und Fahrzeugentwicklung

Dissertation

zur Erlangung des akademischen Grades

doctor philosophiae (Dr. phil.)

vorgelegt dem Rat der Fakultät für Sozial- und Verhaltenswissenschaften

der Friedrich-Schiller-Universität Jena

von Dipl. Ing. Arnd Friedrichs

geboren am 17.11.1968 in Friedrichroda

Gutachter

1. Prof. Dr. R. Blickhan

2. Prof. Dr. K. Zimmermann

Tag des Kolloquiums: 28. 07. 2000

A new ultrasonic method for measuring joint angles

Chapter 3

Abstract

The detection of body movements/positions and joint angles is a fundamental part in biomechanic, orthopedic and ergonomic analysis. A new method is proposed which estimate continuos joint motions based on ultrasonic runtime measurements.
A transmitter and a receiver channel are attached to the skin surface. Thereby the ultrasound is coupled on the body under a flat angle with respect to the skin surface. The distance is measured using the almost constant propagation velocity of ultrasound in body tissue. Knee angle with respect to skin distance was calibrated using a third order polynomial. Measurements showing large inter individual differences but good intra individual conformity. With the advantages of long term storage an the lack of mechanical parts the method is suitable for application under field conditions.

Symbols

l	length of the measured skin deformation
l_{fem}	length of the femural part
l_{tib}	length of the tibial part
ag	distance to the center of rotation
a	angle
$x_{0..4}$	„Points of support“

Introduction

Several methods are known to measure joint angles from external and internal data. Since decades goniometers have been widely used to determine joint angles and the range of motion in clinical tests, ergonomic studies and biomechanic analysis (Gerhardt and Rippstein, 1989). In order to measure the range of motion (ROM) universal 360° degree manual goniometers (Riddle et al.; 1986) and inclinometers are mostly used by physical therapists (two armed goniometer, transparent goniometer, fluid inclinometer). Improved versions are electronic inclinometers with easily readable displays and simple procedures to set the start value to zero. Furthermore data can be transferred to the computer. The advantage of the described systems are that they are easy to handle, lightweight and inexpensive. Problems of those systems are short device-arms in relation to long segments of the subjects for the goniometers and the large space necessary for inclinometer measurements. A measurement under clothed conditions is almost impossible ((Eckhouse et al., 1996). For a continuous measurement of joint angles electrogoniometers (potentiometers and strain gauge transducer) are used. The electrogoniometer is easy to apply and the data can be transferred online to the computer. Main problems of those systems are the relative high sensitivity to various loads especially overload of the spring. Furthermore exoskeletons are used to determine joint angles based on a number of stiff rods which are connected to the body segments over spherical joints at the joint center. Thereby angles are determined with a potentiometer. Disadvantage of those systems are the shell over the human body and the lack of comfort hampering long term applications (Kupfer et al., 1999). The weight amounted to more than 2 kg.

All the described systems come calibrated and most of them like electrogoniometers, exoskeletons, and electronic inclinometers are partly useful for long term applications. Transducers fixed to the joint transmit the data to a remote system or to a local storage device and have a high resolution independent of the movement of the object.

Another group of devices - video, infrared, ultrasound, and magnetic- need a calibrated room for 2D or 3D measurements. Joint angles are determined by placing markers on the body segments for tracking of the markers by the optical system. The markers must be visible during the whole time of measurement (Eckhouse et al., 1996). The advantage of those systems are the availability of 3D coordinates and spatial angles. Furthermore, video systems provide redundant information of the body segments (Seyfarth et al., 1999). The problems of those systems are that the markers must be placed visibly to the camera (chapter 2), movements of the cloths produce errors of the marker distances, and the measurement is only possible in the calibrated range. Furthermore the limited resolution of the system makes it impossible to achieve high resolutions within a large area of observation. A long-term application is nearly impossible with to the present storage and analysis technology.

Only a few systems are known based on the skin movements during human motion. Well known are range of movement measurements as part of clinical test based on Schober and Ott. Here two markers are placed on the back in the upright standing position (Fig.1). The change of the marker distances during maximum flexion is an indicator for the range of movement of the patients spine. The distance between two markers is a correlated with the joint angle (Mayer et al. 1984). Increasing the joint angle the skin stretches and while decreasing the joint angle the skin will be compressed. Therefore the actual distance of the two markers can be used as a measure for the flexion of the body (Macrae and Wrigth, 1969) especially in back movements. After calibration the relation between skin distance and joint angle can be determined (Snijder et al., 1987).

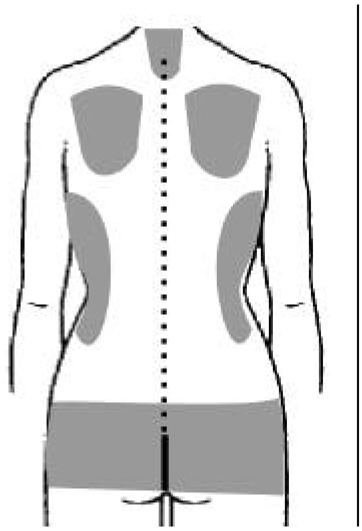


Fig.1: Shaded regions are bad applications to measure posture alterations at the human spine. (modified from Snijders et. al., 1987)

Due to stretching and shortening of the skin, the flexion-angle is estimated based on a helical spring connected to a force transducer (Snijder et al., 1987). Limitation for this system is the sensitivity to physical stress. The presented studies combine the idea of goniometer measurements with new methods of skin distance measurement based on ultrasonic runtime measurements under the skin. A calibration procedure has been developed allowing for reliable measurement of the knee angle.

Material and methods

Measurement principle The new ultrasonic measurement device from the hardware supplier orthoson® (Jena) is based on the ultrasonic distance measurement principle. Two sensors for one input-channel are placed at the skin in order to measure the contraction and dilatation of the skin. The velocity of the ultrasound in soft tissue is almost constant and within the range of 1400 - 1650 m/s. The influence of the temperature can be neglected, changes in body temperature amount only to about 2 C° which effects the sound speed only by less than 1%. The sensors should not be placed across bones (patella, elbow) because the velocity of the signal is about three times faster in bone material than in soft tissue and the relative error of measurement will increase. Moreover the strong absorption of the ultrasound in bones will decrease the amplitude of the ultrasonic waves which decreases the measurable distance to only a few centimeters. For the measurement the ultrasound is coupled to the skin surface under an angle of 20 - 30°. Thereby the upper skin layer is the preferred path way of the ultrasound. The signal propagates almost directly from one sensor to the other. Skin tissue and lower skin layers represent biological borders with different acoustical impedance's. Estimations show that for ultrasound sent under a flat angle into layered tissue even small impedance differences produce a great amount of reflection increasing the length of the acoustic pathway. Furthermore, a certain part of the signal spreads parallel to the skin surface. For the run-time measurement the first peak of the arriving wave is measured. Later waves, which follow longer path ways (reflection in the body) are insignificant for the measurement procedure. The influence of the transversal waves is also unimportant for the measurement because the velocity is low (about 1 - 100 m/s) (Sarrazyan, 1986). Transversal waves will reach the receiver later than the longitudinal waves. Furthermore transversal waves are strongly damped by the surrounding tissue and the propagation distance is only a fraction of the wavelength (0.3 mm; Andrew et al. 1974).

Protocol

As a first example the human knee joint was selected. Five female and five male subjects (65 kg, ± 12 SD kg) participated on a passive flexion extension experiment. We chose a randomized selection of the subjects in order to achieve a great variety in the body dimensions. All subjects performed passive flexion/extension movements and for one subject we determine the reattachment effects of the sensors. Here, we applied the sensors for one session and the subject performed 3 trials. Then we removed the sensors and reattached the sensors again. This procedure was repeated 10 times.

To determine a general transfer function between skin marker distance and knee angle ten subjects performed the knee flexion/extension movement 3 times without reattachment of the sensors.

To determine the optimum placements for the sensors a sensitivity study was performed. Because of the measurement principle the quality of the signal differs for different body regions. Thereby we attached the sensors at various parts around the knee joint to find an optimum area. We scan the knee in 30 degree steps (Fig 2). The optimisation criterias are a large range of measurement and a high accuracy. A further important criterion was the reproduction of the application place. Furthermore the sensors should not touch each other during maximum flexion or extension.

During the experiment all subjects where laying prone at a fitness machine (Techno Gym). Thereby the hip was fixed with a belt to the device (Fig 1). The center of rotation of the knee joint was positioned close to the rotation axis of the machine. With a fixed goniometer the actual knee angle was determined for ten positions. The ultrasonic devices was connected online to a laptop (586 IBM) via the RS232 interface. For a certain angle value the ultrasonic data were transferred to the computer by pressing a key at the keyboard. Skin distance data where collected from 180 degree (fully stretched leg) to 80 degree knee-flexion angle (maximum flexed leg in this position). Because of the number of data and the kind of movement a sampling rate of 10 Hz was selected.

Fig. 2: Experimental set-up for the flexion extension experiment consists of the fixed goniometer (a) and the ultrasonic distance measurement device (b) and the laptop-computer for online data transfer

Biomechanical Model

A simple model gives the basic relation between the skin deformation and the rotation of the joint. The proposed model consists of two segments l_{fem} and l_{tib} (Fig. 3). The femural part of model is attached at a distance of 10 cm from the center of rotation of the knee joint in the direction of the *Musculus vastus lateralis*. The second part describes the connection between the proximal part of the *M. gastrocnemius* and the attachment point of the tendon of the *Musclulus gastrocnemius* at the thigh. As resulting skin distance we understand the length of the two model parts (Fig. 3). The sensor application for the geometrical model was estimated based on the optimal position of the sensitivity analysis.

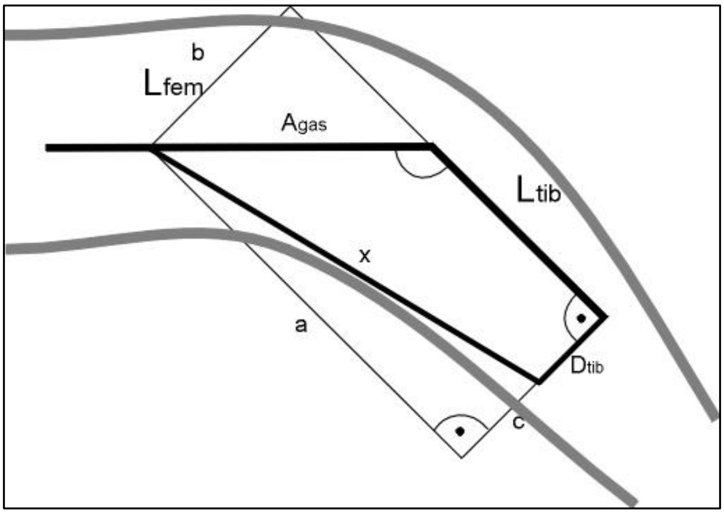


Fig. 3: The kinematic model of the resultant skin distance x with the femural and tibial part.

The resulting length of the two parts can be described by equation (1)

$$l = \sqrt{(l_{tib} - a_G \cdot \cos(\alpha))^2 + (a_G \cdot \sin(\alpha) - d_{tib})^2} + l_{fem} - a_G \tag{1}$$

Statistical analysis and polynomial fit

To develop a calibration function which transfers the flexion-angle into the distance of the sensors different polynomial fits were investigated. Based on a lagrangian interpolation algorithm (equation 2) it was determined the points of support for the calibration function.

Lagrangian interpolation method:

$$\begin{aligned} Y &= f(x) = a_0x^3+a_1x^2+a_2x+a_3 \\ &= \frac{y_0\,(x-x_1)\,(x-x_2)\,(x-x_3)}{(x_0-x_1)\,(x_0-x_2)\,(x_0-x_3)} + \frac{y_1\,(x-x_0)\,(x-x_2)\,(x-x_3)}{(x_1-x_0)\,(x_1-x_2)\,(x_1-x_3)} \\ &\quad + \frac{y_2\,(x-x_0)\,(x-x_1)\,(x-x_3)}{(x_2-x_0)\,(x_2-x_1)\,(x_2-x_3)} + \frac{y_3\,(x-x_0)\,(x-x_1)\,(x-x_2)}{(x_3-x_0)\,(x_3-x_1)\,(x_3-x_2)} \end{aligned} \tag{2}$$

measurement points are: $x_0 = 80$; $x_1 = 110$; $x_2 = 150$; $x_3 = 180$.

A descriptive statistical test was performed to determine inter and intra individual parameters (SPSS, SPPS Inc. and Excel 97, Microsoft). Significance was assumed at $p < 0.05$.

Results

Sensitivity analysis: The quality of the calibration differs in dependence of the site of application. The measurement across the patella (bone) shows a high non-linearity and irreproducibility of the signal. Applications at the medial side of the knee show a very irregular course with high standard deviation. The ventral path shows a rough course and the sensors are in contact at the maximum knee flexion. A measurements at the lateral side of the knee shows a smooth steady course and a large measurable range of motion (Fig. 4). All application points at the lateral side of the knee joint give nearly the same good results. A standard application for the best results are the proximal end *of the musculus gastrocnemius* and a place two centimeters below the distal end of *the musculus vastus lateralis* (fig. 3).

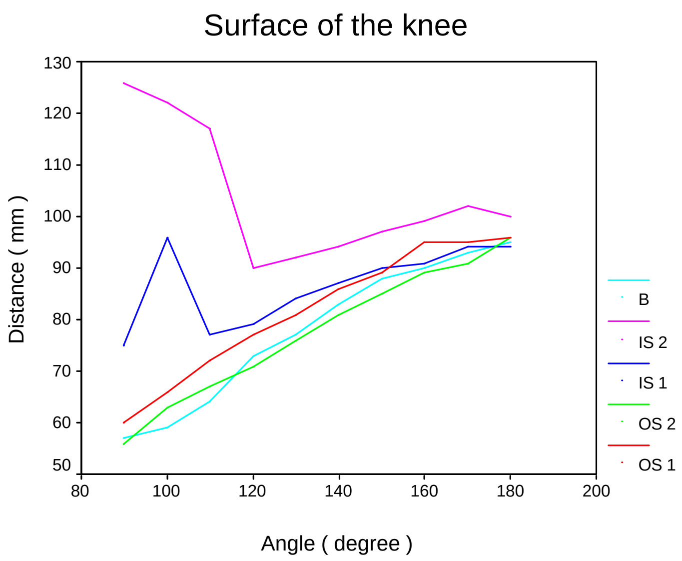


Fig. 4 : Influence of the application point for the relation between skin movement and angle . For pathways with a high amount of soft tissue (OS1, OS2 outside) the relationship is smooth. Characteristics obtained at the inner side of the knee (IS1, IS2) are not monotonous.

Statistical results Using the attachment points for optimum application of the sensors an individual calibration function was determined.

The maximal amount of skin dilatation from flexion to extension ranges from 60 to 70 mm (Fig4). For the selected sensor set-up this signal is more than 40 percent of the maximum signal of the measurement. The resultant graph for the passive joint movement shows a non-linear course with three different segments. Between 180° (full extension) and 160° (part A) the relationship is flat. Part B has a nearly linear course and ends at about 100°. Below 100° up to a fully flexed leg (part C) the course is nonlinear (Fig 5, a).

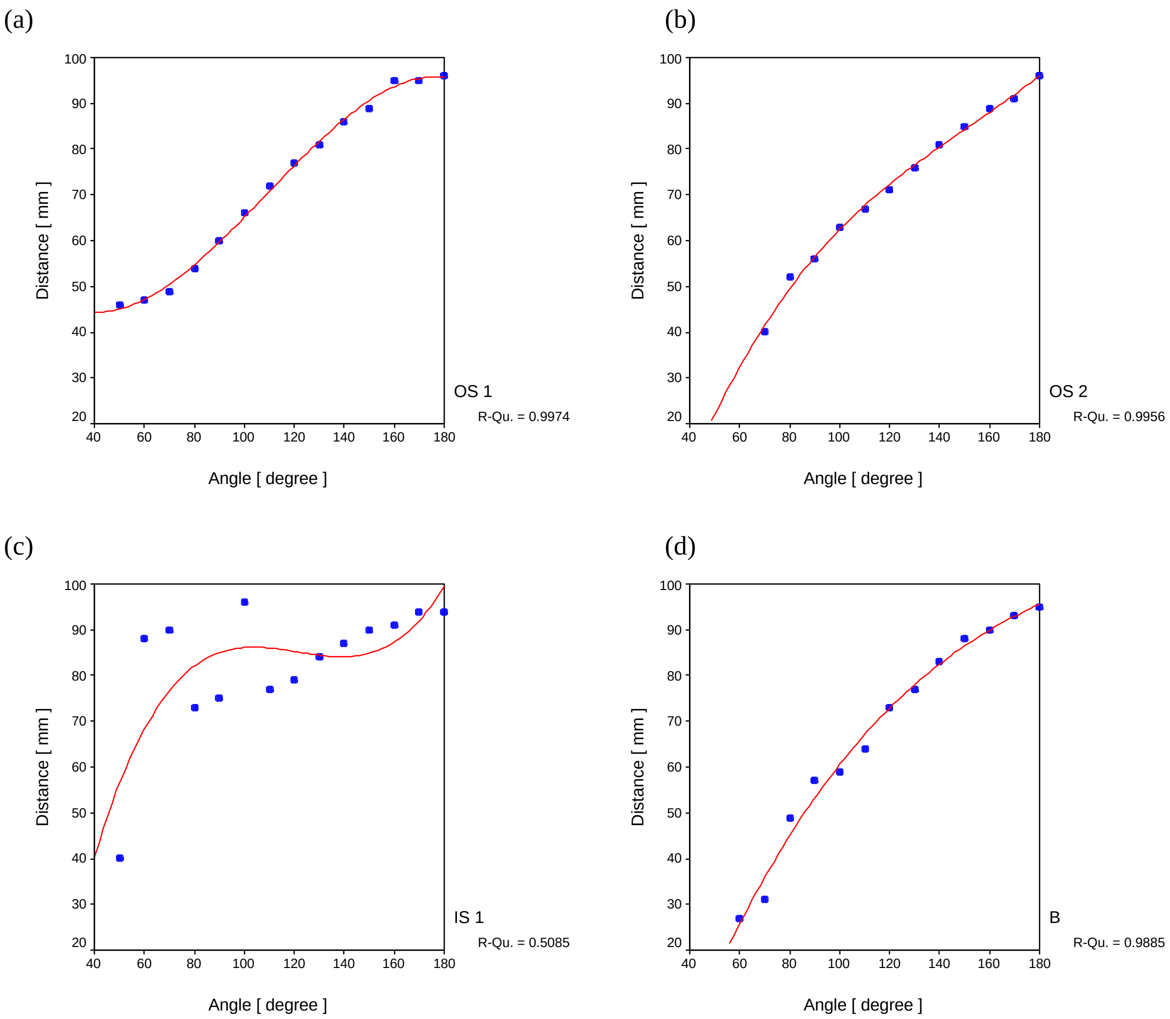


Fig. 5: Third order polynomial fit to the distance-angle measurements for all selected application points. At the outside of the knee (a, b) maximum measurable ranges combined with smallest deviation can be achieved. Greatest deviations occur at the inner side of the knee (c).

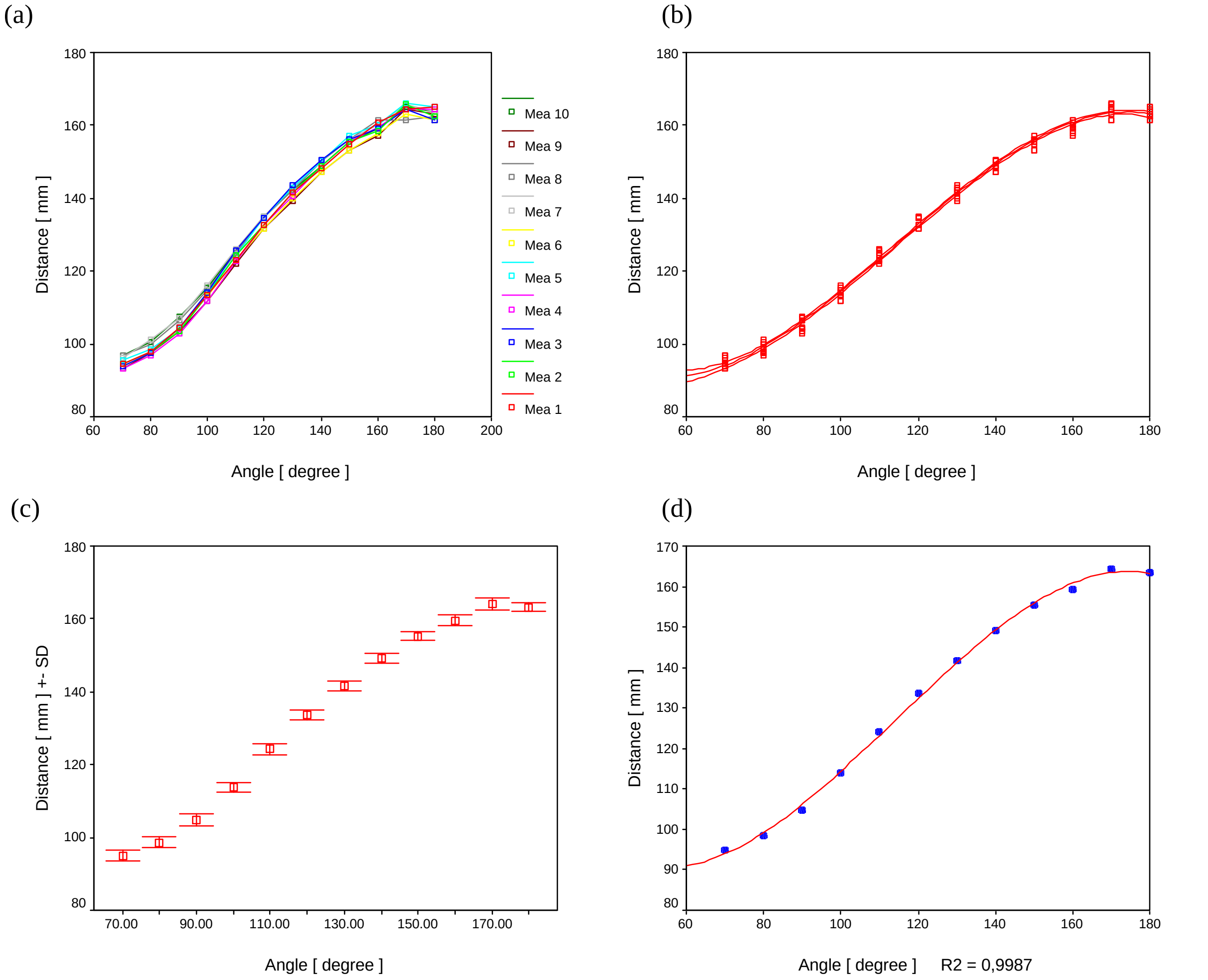


Fig. 6: Intraindividual variability. Calibration for 10 repeated applications at one subject. a) Measurements, b,c) Mean and SD, d) Third order polynomial fit. data**.**

Reproducibility after new application: In ten trials for one subject the course of the graph changes only insignificantly. The highest relative error shows the measurement at about 160° (almost full stretched leg) with less than 1.6 percent which corresponds to an angle of 4 degree (Fig. 6).

After a new application of the sensors the course of the graph changes only insignificantly. The highest relative error is at the touching point of shank and thigh and is less than 1.8 percent which corresponds to an angle of 4 degree. In this situation the skin will be extremely deformed by touching of body parts. Furthermore, at 170° the error is of similar magnitude.

Reproducibility of the graph at various subjects The course of the graph is reproducible for each subject within an angle of three degrees at each part of the graph (Fig 7). For all subjects the graph has a rather similar course and shows the three parts. The absolute error of all measurement points is about 1,6 mm and the relative error is less than 2 percent with respect to the total distance. The SD of all experiments increased with increasing flexion movements. The highest SD is observed at the touching point of tight and shank(Fig. 7, c).

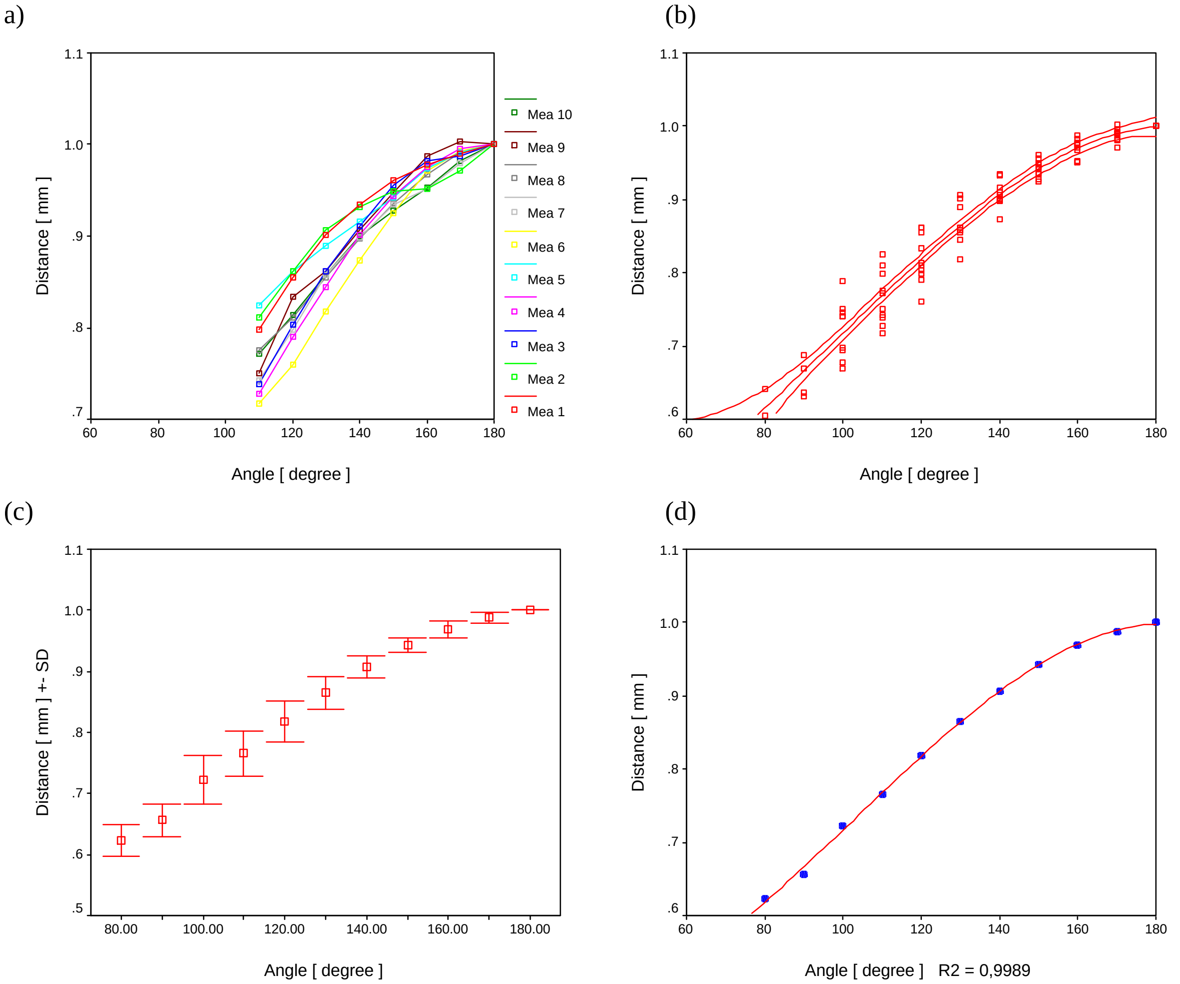


Fig. 7: Interindividual variability. The measured distances at the starting point were scaled to 1 for all subject graph. a) Measurements. b,c) Mean and standard deviation with the reatest Highest deviations occur between 110° and 130°. d) Third order polynomial fit to the total mean.

Polynomial fit: A linear and a quadratic fit to the measured data results in a large standard deviation for the whole range of motion. Within the range of 160° - 110° the linear fit results in an acceptable small error. Maximum deviations for the linear and quadratic fit occur at the transition between part A to B and part B to C.

	linear fit	quadratic fit	cubic fit
correlation	0.96 – 0.98	0.98-0.99	> 0.99

Tab.1: Correlation between the fits and the measured graphs.

Since the standard deviations between the third and fourth order polynomial were not significantly different we used the lagrangiuan interpolation method with a third order polynomial. Therefore, a minimum number of 4 values is necessary for calibration.. As calibration angles for the function we used 180° (full extension), 150°, 110°, and 80° (full flexion). The standard deviation of the fit is less than 1.3 degrees (Fig.8).

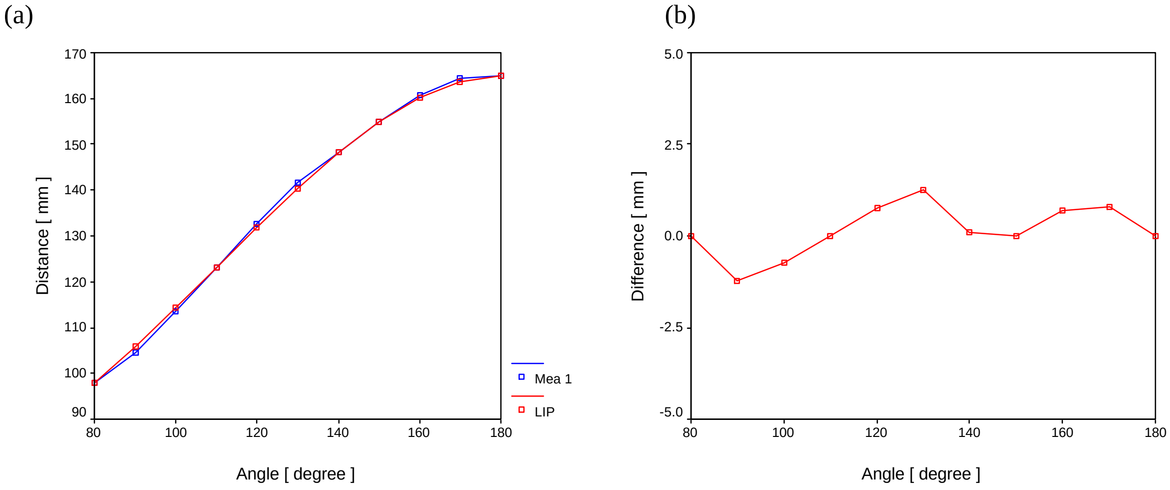


Fig. 8: Fit of a third order polynomial (red) to the measured data (blue) (a) and the residuals (b). The mean residual is less than 1 mm.

Modeling Results: Fitting a simple mechanical model to the measured data resulted in small deviations (SD = 2.0°). Input parameters are anatomical data like length of the tibia distance, distance to the centre of rotation and femur length. The simulated results are in good agreement with the lagrangiuan interpolation method. The model works precise in all three parts of the graph. However, the time to estimate the measurement points for the model is much higher than using the polynomial fit method.

Discussion

It was investigated a new method to measure knee angles. The described method is non-invasive and can be used for long term analysis (more then 50 hours). Maximum sampling rates are 100 Hz necessary for dynamic problems. The application points for the sensors are easily detectable using anatomical landmarks. It developed a statistical and a kinematic model in order to describe the skin deformation in relation to flexion - extension movement of the knee. Greatest tolerances of the kinematic model occur at the end points of the range of movement (maximum flexion and maximum extension) because the system does not entail tissue deformation. For the statistical model errors are larger at the flexion of the knee. These errors can be reduced using a higher order polynomial (4. or 5. order) requiring more points of support for the calibration. The points of support for the lagrangian interpolation method are selected based on the shape of the graph. Thereby the beginning, end and inflection are important for the course of the graph. The advantage of the kinematical model is the use of physiological parameters like femural distance , tibial distance and the distance to the center of rotation but with a higher experimental expenditure. The measurable range of motion is about 100°. For some subjects it was observed more than 110° which depends on the behavior of soft tissue, the flexibility, and the body type of the subject. The analyzed movements shows standard deviations of less than 2 % for each subject. The largest errors occur at the contact point of the thigh and the shank because at this point the skin is strongly deformed by the sudden swelling of the muscle belly in all directions. However this effect is observed only in extreme flexion movements which are rarely used in normal tasks like working, dancing, chair rising, and so one. The measured data are showing two points of inflection like a third order polynomial. So the use of a third order polynomial fit for describing the movement was useful for all subjects. For some tasks like rising from a chair the linear fit is useful because the range of movement of the maneuver is less than 90°.

A standard transfer function will produce great deviations for different individuals since the skin elasticity and geometric conditions differ for each subject. Like other biomechanical analysis systems the „ultrasonic goniometer“ must be calibrated newly for each subject. But for each individual the transfer function is still the same after removing and replacing the sensors at the equal skin area.

Literature

Andrew, K., Chan, Rubens A. Sigelmann, Arthur, W. Guy. (1974) Calculations of Therapeutic Heat Generated by Ultrasound in Fat-Muscle-Bone Layers. IEEE Transactions on *Biomedical Ingenieering*. **Vol 21(4)**.

Chan, Andrew K., Sigelmann, Rubens A., Guy, Arthur W. (1974) Calculations of Therapeutic Heat Generated by Ultrasound in Fat-Muscle-Bone Layers, IEEE Transactions on Biomedical Ingenieering, Vol. BME-21, No. 4, g am.

Eckhouse, RH, Penny, MA, Maulucci, RA (1996) A comparison of kinematic recording instruments. *J Med Syst*. **20(6)** 439-56.

Gerhard, J.J., Rippstein, J. (1992) “Gelenk und Bewegung, Neutral-0-Methode, SFTR-Protokollierung, Rationelle Meßtechnik, Moderne Goniometrie; Verlag Hans Huber, Bern, Göttingen, Seattle, Toronto.

Gerhard, J.J., Rippstein, J. (1990) “Measuring and Recording of Joint Motion”; Hogrefe & Huber, med. pub.

Kupfer, J., Zach, H.G., Ellegast, R.P. (1999) Wirbelsäulenbelastung – Arbeitswissenschaftliche Instrumentarien der Belastungsermittlung für die Prävention.; Berufsgenossenschaftliches Institut für Arbeitssicherheit – BIA; In: Prävention von arbeitsbedingten Gesundheitsgefahren und Erkrankungen des Stütz- und Bewegungsapparat. Leipzig.

Macrae, I.F., Wright, V. (1969) Measurement of forecastle Movement. *Annals of the Rheumatic Diseases* **29**, S. 584-558.

Riddle, D.L., Rothstin, J.M., Lamb, R.L. (1968)Goniometric Relability in a clinical setting. *Physical Therapy* **67**(5), 668-673.

Sarvazyan, UBIOMED VII, Eisenach 1986

Seyfarth, A., Friedrichs, A., Wank, V., Blickhan, R. (1999) Dynamics of the long jump. *J Biomech*.;**32** (12) S.1259-67.

Snijders, C. J., van Riel, M. P. J. M. (1987) Continuous Measurements of The Spine Movements in Normal Working Situations Over Periods of 8 Hours Or More. *Ergonomics* **30** (4), S. 639-653.

Biomechanical analysis of the spinal column at music-students during several-hour piano-game

Chapter 4

Abstract

The most frequent ailments with occupation-musicians are illnesses of the whole muscle-skeletal system and particular that of the spinal column. To improve the abilities and skills of music-students and occupation-musicians it is necessary to rehearse music-pieces over a long time period with high intensity. Monotonous loads of the spinal column occur during a rehearse-session of approximately 3 to 4 hours during the day. Consequently, piano players frequently complain about muscle-aching and joint-problems. Especially extremely tall and very small pianists are forced to take compensatory movements.

By means of a new ultrasonic skin-distance-measurement posture changes of the spinal column were measured during several-hour piano-play. Alterations of the geometry of the spinal column only appear after approximately 2 to 3 hours rehearse-time, without interruption. This observation can be attributed to a reinforced chest kyphosis as well as a height-decrease of the inter-vertebral-disks.

Introduction

Professional piano-playing represents a complex physical and great sensomotorical task for music-students or occupation-musicians. Different factors influence the ability to play music-pieces with high perfection:

1) To learn a music-piece as virtuous as possible, it must be practiced over long time periods. This comes along with a monotonous posture maintained for hours. Consequently, the degree of movement of the spinal column is much reduced during large parts of the day. Another influencing factor on the playing time in music-students is the reduced availability of instruments at German conservatories.

2) In order to manage complicated music-pieces a proper finger-mobility is demanded. In this case a predisposition is desirable in the sense of a weak hyper-mobility, on the other hand exactly this quality of experienced musicians of higher causes troubles of the muscle-skeletal system (Grahame, 1993; Larsson et al., 1993; Larsson et al., 1987; Nef et al., 1998). The different anthropometrical lengths and ranges of the musicians at one hand and the rigid geometry of the instruments at the other hand force the artists in compensatory movements. Over years faulty positions lead to posture-pain and to muscle problems. Studies of German insurances shows that 70% to 80% of the professional-musicians perform music mostly under pain. These examinations are supported by different other authors in various studies (Hoppmann et al., 1989; Mandel, 1990; Rozmaryn, 1993; Schlaug et al., 1995; Wilson et al., 1993).

The listed physical components form one side of professional piano-playing. Many musicians stand under an extreme high psychic pressure, which is expressed in muscle-skeletal dysbalances.

A new ultrasonic skin distance measurement informs about the temporal course of the posture-alteration during the piano-play in music students. In difference to known posture analysis systems (IR-systems, video-systems), where musicians must usually rehearse under laboratory-conditions, our experimental-design allows an investigation during normal playing. This can be done directly on the body of the pianist for several hours.

Furthermore, rehearse-play and public appearance are compared using an example of a solo-concert.

Symbols

B,C	left and right channel at the neck region
D,E	left and right channel at the neck region
F,G	left and right channel at the neck region
LF	lateral flexion
FE	flexion/extension

Theory of ultrasonic skin-distance-measurement

In general and in particular across joints the skin has an elastic behaviour. With an alteration of the joint angle, the skin changes it length at certain positions near the joint (Derksen, 1996; Macrae and Wight, 1969; Mellin, 1989; Snijders et al., 1987; Uhlmann 1986). The change of the tension of the skin is directly related to the angle-alteration between the underlying structures (Macrae and Wight, 1969; Snijders et al., 1987). This quality was described for the lumbar-region with a linear approximation (Macrae 1969). Ultrasound-waves transmitted into the upper skin-layer spreads with a speed of approximately 1450 m/s in spherical-waves. The measurement system Orthoson (Fig.1) estimates the time between wave transmission and reception of the first wave-impulse and calculates the distance between the two crystals.

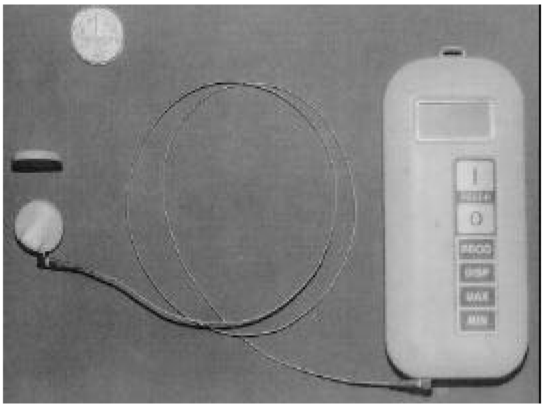


Fig: 1 The picture shows the measurement device Orthoson with one pair of sensors

Protocol

Over a period of 10 days and during continuos 4 hours rehearse sessions, the movement was monitored with an ultrasonic distance measurement system. The daily schedules on the piano was recorded by the pianist. The student rehearsed daily the same music-pieces during this time period with playing breaks and two sessions without interruption.

In addition, movement-data of the student were recorded during an one-hour piano-concert. For the analysis of the flexion/extension as well as lateral- flexion, 8 ultrasound-sensors were placed (Fig. 2) at the spinal column (lumbar, chest and neck area). Each sensor was attached to the left and right side of the spine in a distance of 2.5 cm of the body-longitudinal-axis. The vertical measurement distance in the lumbar range amounted to 160 mm, in the chest area 300 mm, and in the neck area 110 mm. As a measure for the lateral flexion the difference between the signals of the left and right channel of a sensor pair was calculated:

$$A - B = LF_1 \quad (1)$$

$$C - D = LF_2 \quad (2)$$

$$E - F = LF_3 \quad (3)$$

$$LF_{Sum} = LF_1 + LF_2 + LF_3 \quad (4)$$

The dorsal flexion/extension of the spinal column was estimated as the mean value from the signal indicated by the left and the right:

$$(A+B)/2 = FE1 \quad (5)$$

$$(C+D)/2 = FE2 \quad (6)$$

$$(E+F)/2 = FE3 \quad (7)$$

$$FE_{Sum} = FE_1 + FE_2 + FE_3 \quad (8)$$

This procedure was proceeded for the lumbar chest and neck region. All data were sampled with 1Hz and stored at the measuring instrument (Orthoson) and transferred later to a PC. Statistical analysis took place with Microsoft EXCEL (Microsoft) and the statistical tool SPSS 8.0 SPSS Inc.

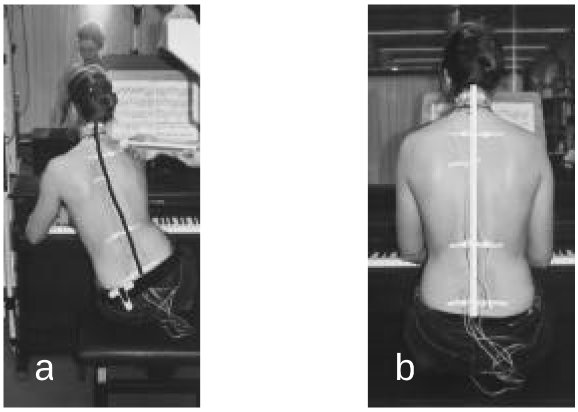


Fig 2: placement of the sensors (a) during maximum lateral flexion (black line spine); (b) upright seats (white line spine).

Results

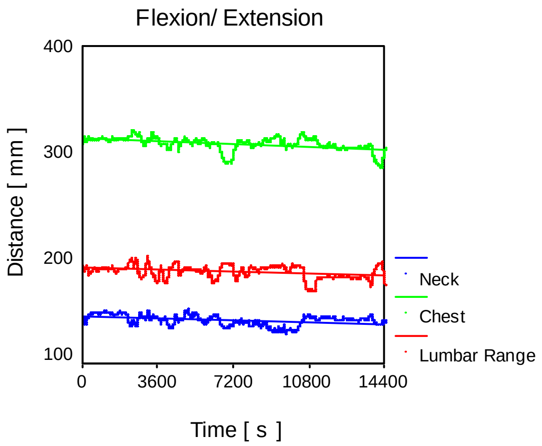
Clear changes in average posture could be observed during daily rehearse sessions. The small device was comfortable to wear. It did not influence the performance of the piano player.

Rehearse-days

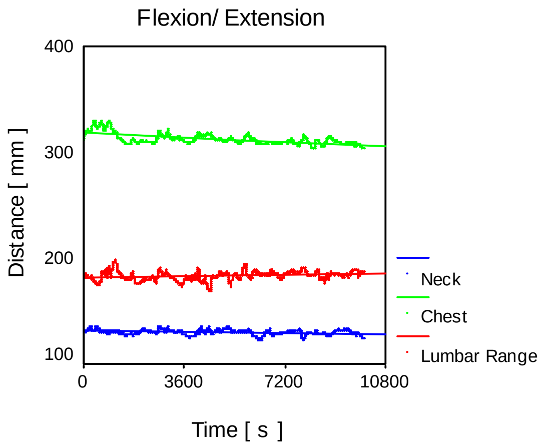
No change in average posture (displacement amplitudes) has been observed within the first hour playing. This was found both at rehearse days with and without breaks.

After 2 to 3 hours posture changes could be observed in the dorso-ventral plane along the whole spinal column (Fig. 3, Fig. 4). These changes increased on days with uninterrupted rehearse-play. The mean value of the spine length decreased from (mean = 648mm ± 13 SD)at the beginning to (mean = 627 mm ± 10 mm SD) at the end of the play on days with short breaks. At days with longer breaks the distance decreased only from (mean = 636 mm ± 15 mm SD) to (mean = 627 mm ± 10 mm SD). After approximately 2 to 3 hours, the movement-amplitude of the lateral flexion increased. The lateral flexion for the observed days shows various patterns during the course of a day. It could be observed increased lateral amplitudes (a) at the end of the rehearse-time for days with shorter breaks and unchanged lateral amplitudes with stronger lateralisation for days with longer breaks.

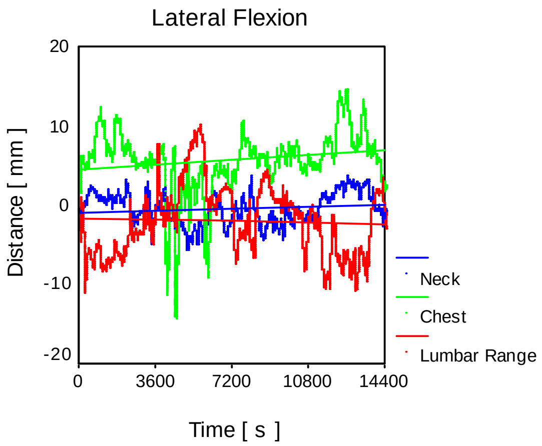
a)



b)



c)



d)

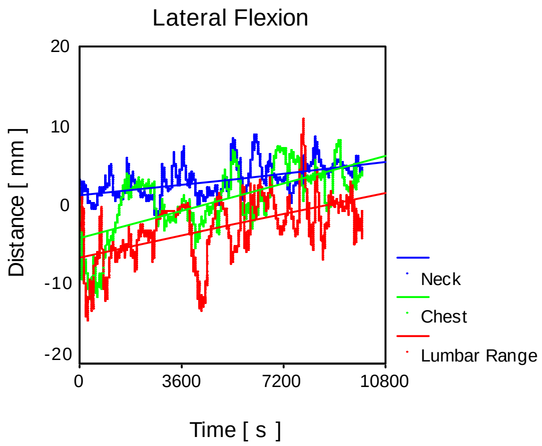


Fig 3: a) Sensor distances of the thoratic (red) the lumbar (green) and neck region during rehearsal. At about 3 hours rehearse time all regions have about the same slope. b) Playing with longer rehearse breaks shows the same trend for the chest region but the slope of the neck and lumbar region is about zero. The lateral flexions are different between both rehearse days. c) Increased lateral amplitudes at the end of the period and an out of phase behaviour of the chest and lumbar region. d) General trend to lateralisation of the of the whole spinal column with decreased amplitudes

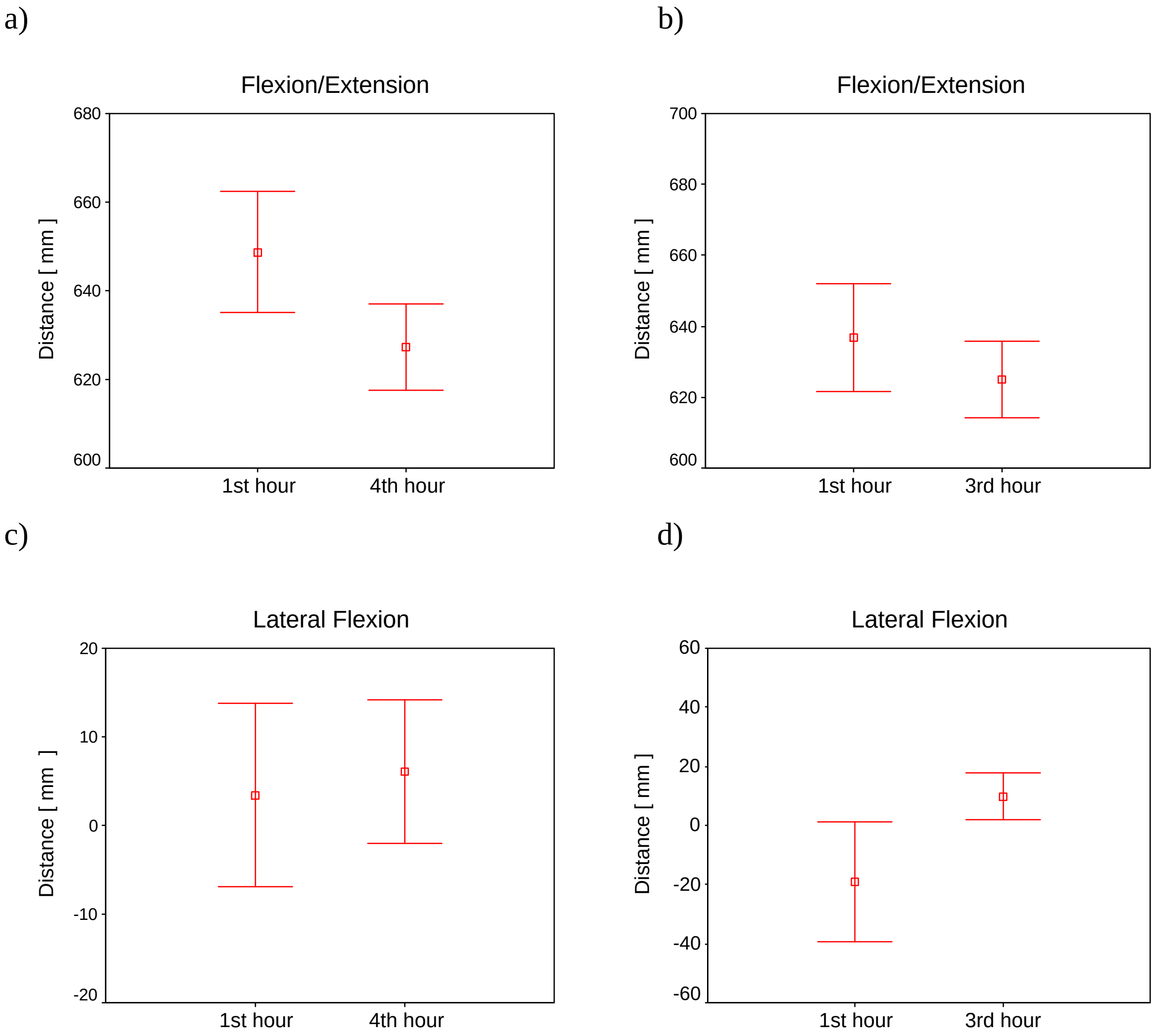


Fig 4: Mean sensor distance (from lumbar till neck region) during the first and the third hour of playing for a day with shorter (a) and for a day with longer breaks (b). Changes in lateral flexion are showing only a trend for a letralisation during the day with shorter (c) and longer breaks (d).

A trend to a height-decrease of the spinal column-length over the measurement duration of 10 days could not be observed.

Concert

The device was well accepted by the pianist during the concert. The time course of posture was similar to that observed during the one-hour rehearsal. There was no difference in flexion/extension and also lateral flexion during this period. Also, a trend of an increased lateral amplitude was not to be seen.

Discussion

The present examination was enforced to examine changes of the geometry of the spinal column during several-hour piano-play. Advantage of these new experimental set-up in comparison to conventional movement analysis systems (3D-ultrasound-analysis, video-analysis, IR-systems) is the possibility to analyse the posture of pianists under everyday-conditions. This can be done at the music-instrument and during the performance. The observed decreased length of the spinal column (sum of all sections neck, chest and lumbar area) might be due to a reduction of the height of the inter-vertebral-disks or to an increased kyphosis in the chest range. An increasing lateralisation during several-hour play of all analysed spinal regions can be the result of a compensation-posture due to fatigued muscles. The higher amplitudes in lateral corresponds to the behaviour of small school students which also tend to have higher lateral amplitudes at the end of the day (chapter 5). Both longitudinal-decrease of the spinal column as well as the lateralisation are reduced during rehearsals with longer breaks between the practice-sections.

To investigate the influence of the fatigued muscles to the stabilisation of posture the measurements will have to be combined with EMG analysis of the back muscles. The findings of this study are in agreement with other authors of work-related musculo skeletal disorders in professional musicians (Revak, 1989; Zaza, 1998).

Our pilot-study gives first hints for programs specifically developed to improve posture-stabilisation and performance. Our study can help to organise rest, relaxation, and stretching periods.

Literature

Derksen J. C., van Riel, M. P., Snijders, C.J. (1996) A New Method for Continuous Recording of trunk postures while playing golf. *Journal of Applied Biomechanics.* **12**, 116-129.

Dupuis, M. (1993) Pathologies of the musculo-skeletal system in musicians. *Union Med Can*. **122(6),** 432-436.

Grahame, R., (1993) Joint hypermobility and the performing musician. *N Engl J Med.* **329(15),** 1120-1121.

Hoppmann, RA. Patrone NA. (1989) A review of musculoskeletal problems in instrumental musicians. *Semin Arthritis Rheum*. **19(2),** 117-126.

Larsson, LG. Baum, J., Mudholaker GS., Kollia GD(1993) Benefits and disadvantages of joint hypermobility among musicians. *N Engl J Med*. **329(15),** 1079-1082.

Larsson, LG. Baum, J., Mudholaker GS., (1987) Hypermobility: features and differential incidence between the sexes. *Arthritis Rheum*. **30(12),** 1426-1430.

Mandel, S. (1990) Overuse syndrome in musicians. When playing an instrument hurts. *Postgrad Med*. **88(2),** 111-114.

Macrae, I.F., Wright, V. (1969) Measurement of forecastle Movement. *Annals of the Rheumatic Diseases* **29**, 584-558.

Mellin, G.P. (1989) Comparison between tape measurements of forward and lateral flexion of the spine. *Clinical Biomechanics* . **4**, 121-123.

Snijders, C.J., van Riel, M.P.J.M. (1987) Continuous Measurements of The Spine Movements in Normal Working Situations Over Periods of 8 Hours Or More. *Ergonomics*. **30(4)**, 639-653.

Nef, W, et al. (1998) [Hypermobility syndrome. When too much activity causes pain]. *Schweiz Med Wochenschr*. **128(8),** 302-310.

Revak, J. M. (1989) Incidence of upper extremity discomfort among piano students. *Am. J. Occup. Ther*. **43(3)**, 149-54.

Rozmaryn, L. M. (1993) Upper extremity disorders in performing artists. *Md Med J*. **42(3),** 255-60.

Uhlmann, K. (1986) Textbook of the anatomy of the movement-apparatus, sources & Meyer publishing house Ltd. &Co, Wiesbaden.

Schlaug, G. et al. (1995) Increased corpus callosum size in musicians. Neuropsychologia. **33(8),** 1047-1055.

Wilson, F.R. et al. (1993) Biomechanical abnormalities in musicians with occupational cramp/focal dystonia. *J Hand Ther*. **6(4),** 298-307.

Zaza, C. (1998) Playing-related musculoskeletal disorders in musicians: a systematic review of incidence and prevalence. *CMAJ*. **158(8),** 1019-25.

.

Continuos monitoring of spine movements during school

Chapter 5

Abstract

The trend to the mental and light physical work in the society of the adult has also an effect on our children. Learning at and playing takes place almost without any motion. The working conditions at school often resemble those of a desk-job. Sitting at the school desk becomes the main task. We investigate a test battery consisting of various biomechanical and medical tests to quantify the impact of this behavior and of lessons stressing the possibility of movement onto the posture of students. Thereby we employed a new method which allows to continuously monitor posture at normal school conditions. Our findings document significant changes during the school day. Furthermore, we detected posture stereotypes.

Introduction

Just like the mental development is connected with the acquisition of knowledge the physical development of the child depends on movement. It is no surprise that physical dysbalances, overload-syndromes and posture-problems appear because of lacking movement. These symptoms are increasingly observed among school children. The foundation for the general social trend of decreased movement ability is laid at school. To prevent lack of movement and problems of posture, alternative concepts which connects movement and knowledge reception during the lessons are necessary. This problem was recognized in various European countries which test new school concepts since approximately 10 years (Holzer et al., 1998). These studies were supported by questionnaires and interviews establishing a connection between backache problems and everyday school life (Olsen et al., 1984; Balagues et al., 1988). The studies revealed that more than fifty percent of the new school children have posture weaknesses (Holzer et al., 1998). Swiss scientists point out that approximately thirty percent of the 7 to 17 year old children complain about back-troubles (Fleiß et al., 1996). Back problems increase with the age of students (Holzer et al., 1998). Harreby (1997) assumes that backaches in young children result in posture problems for the adults. Some experimental set-ups documented the general posture condition from preschool and school students based on video screening experiments (Höllinger et al., 1996). Here a middle scoliosis was found for over sixteen percent and a strong hollow back for ten percent of the examined students. However according to the author an objective analysis would demand laboratory-conditions.

In general three different approaches are known for analysis of posture during the day. 1) qualitative methods: here one ore more observer are reporting the work or school day based on predefined criteria’s (e.g. forward bending, backward leaning, sitting position and lifting task).

This type of analysis can be supported by video and picture documentation. An improved version is the system APALYS (ILMCAD) where a certain number of photographs is used to fit a geometrical model to the human body. Based on body measures (segment lengths, joint angle and body mass) the loads in the lumbar spine can be calculated for static conditions. More detailed informations can be obtained by using 3D-systems with high spatial and time resolution. Thereby a subject is attached with a number of markers to calculate joint angles and segment parameters (see chapter 2). For every day task sample frequencies of 100 frames/s are recommended. Those systems can be separated in online (ultrasonic, IR, magnetic) or offline systems. A requirement of both types are the availability of a calibrated frame. Often, an EMG analysis is proceeded in parallel. To calculate the torques and forces in the human body simultaneously to the recorded movements all external forces must be measured with a 3D-force plate. Due to the actual state of computer technology and analysis methods the described biomechanical methods are only suitable if the analysis sequence is rather short (less than 2 min). For direct measurements at the human body various sensors types (angle sensors, acceleration sensor, inclinometer, pressure insole mates and exoskeleton) are known. A main requirement of those systems is not to interfere with daily activities. Systems are known which are applied above and under clothing. For systems which are used above clothing, a small movement of the sensors in relation to the real human motion is required.

The mentioned video analysis method was invented as a unique method which tries to analyse behaviour spinal column of young school students (Holzer et al., 1998). Up to now there existed no tool which allowed a continuous monitoring of posture during the school day. Within the scope of prevention for diseases of the posture- and movement system (especially spinal column) a new intervention program with the name “school in motion " has been established. In the present study a new tool is presented which allows to quantify the influence of such instruction-concepts on the physical constitution of school students. For the first time the instrument allows to monitor continuously posture during normal schooldays and thus to quantify the effects of alternative teaching method.

Symbols

A,B	left and right channel at the neck region
C,D	left and right channel at the neck region
E,F	left and right channel at the neck region
LF	lateral flexion
FE	flexion/extension

Material and Methods

Construction and operation of the measurement device. The instrument Orthoson® consists of a flat (120mmx50mmx12mm), very light weight (85 gr) electronics-unit with foil-keyboard, display and one to six ultrasound transmitter-sensor (Fig. 1). The instrument can be carried in the trouser pocket of the schoolchildren. The one channel device has an internal memory with a statistic tool which

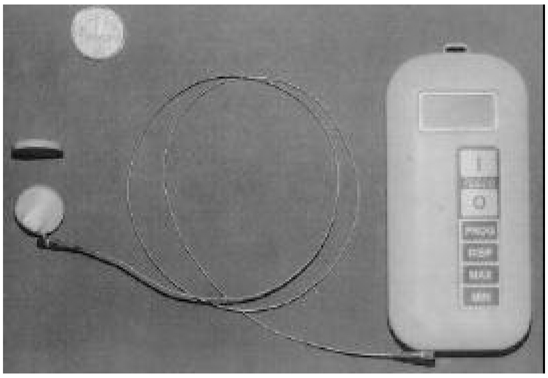


Fig.1: Orthoson instrument with one measuring channel.

allows classification of the posture during the school day. The six channel instrument can store data on- or offline without statistical classification but with a time scale. Each ultrasound-sensor contains a piezo oscillator. For fixation at the skin customary adhesive-rings for ECG-electrodes are used The system measures the constant velocity of ultrasound underneath the skin which enables the calculation of the skin distance. (For details see chapter 3).

The deformation of the skin is proportional to changes in posture. The device allows continuous monitoring of the posture for about four hours with a sample rate of 1 to 10 samples/sec.

Protocol

20 school students took part at the posture experiments. In two second classes 10 students per class were involved. One group had an one hour intervention weekly the other class took part in normal frontal lessons and was compared as the control-class. The total intervention period was 3 months. Both classes never had an intervention before and the concept was also new for the teachers.

Data were recorded at the beginning, in the middle, and at the end of the intervention period each during four consecutive days (Monday - Thursday). In each session three students received the one channel Orthoson® and two students the six channel instrument. Immediately after the lessons the data-acquisition ended.

One channel measurement The sensors were applied to the lumbar region. The spacing of the sensors in the lumbar-region was about 15 cm. Posture was classified in 7 steps (A [smallest deflection],F [largest deflection]). Upright sitting is to be found between C and D and is marked as gP (good position) (Fig. 2). The instrument counted the relative frequency of each posture class during the school day. The two outer regions stretch up to minimal spacing (maximal extension) and to maximum spacing (maximum flexion). The measurements were calibrated individually by filming the school students in front of a wall during maximum flexion and extension.

Fig.2: Sitting Positions a: Extension (A, B, C); b: upright(gP); c: Flexion (D, E; F)

Six channel measurement: The six channel measurement enables a simultaneous distance-measurement in the neck -, breast - and lumbar-region. The application of the sensor pairs begun with the lower pair on height L5/S1, the second on Th12/L1, the third on height C7/Th1 and the last on C1. Each sensor was attached to the left and right side of the spine in a distance of 2.5 cm of the body-longitudinal-axis (Fig. 3). The measurement distance in the lumbar range amounted to 110 mm, in the chest area 200 mm and in the neck area 110 mm. Movement-data and posture-data of the schoolchildren were recorded during the lessons and the breaks (rest) over a time period of 5 hours.

As a measure for the lateral flexion, the difference between the signals of the left and right channel of a sensor pair was calculated:

$$A - B = LF_1 \quad (1)$$

$$C - D = LF_2 \quad (2)$$

$$E - F = LF_3 \quad (3)$$

$$LF_{Sum} = LF_1 + LF_2 + LF_3 \quad (4)$$

The dorsal flexion/extension of the spinal column was estimated as the mean value from the signal indicated by the left and the right:

$$(A+B)/2 = FE1 \quad (5)$$

$$(C+D)/2 = FE2 \quad (6)$$

$$(E+F)/2 = FE3 \quad (7)$$

$$FE_{Sum} = FE_1 + FE_2 + FE_3 \quad (8)$$

All data were acquired with 1 sample/s and stored in the measuring instrument (Orthoson) and transferred later to a PC. Statistical analysis took place with EXCEL (Microsoft) and the statistical tool SPSS 8.0 (SPSS Inc).

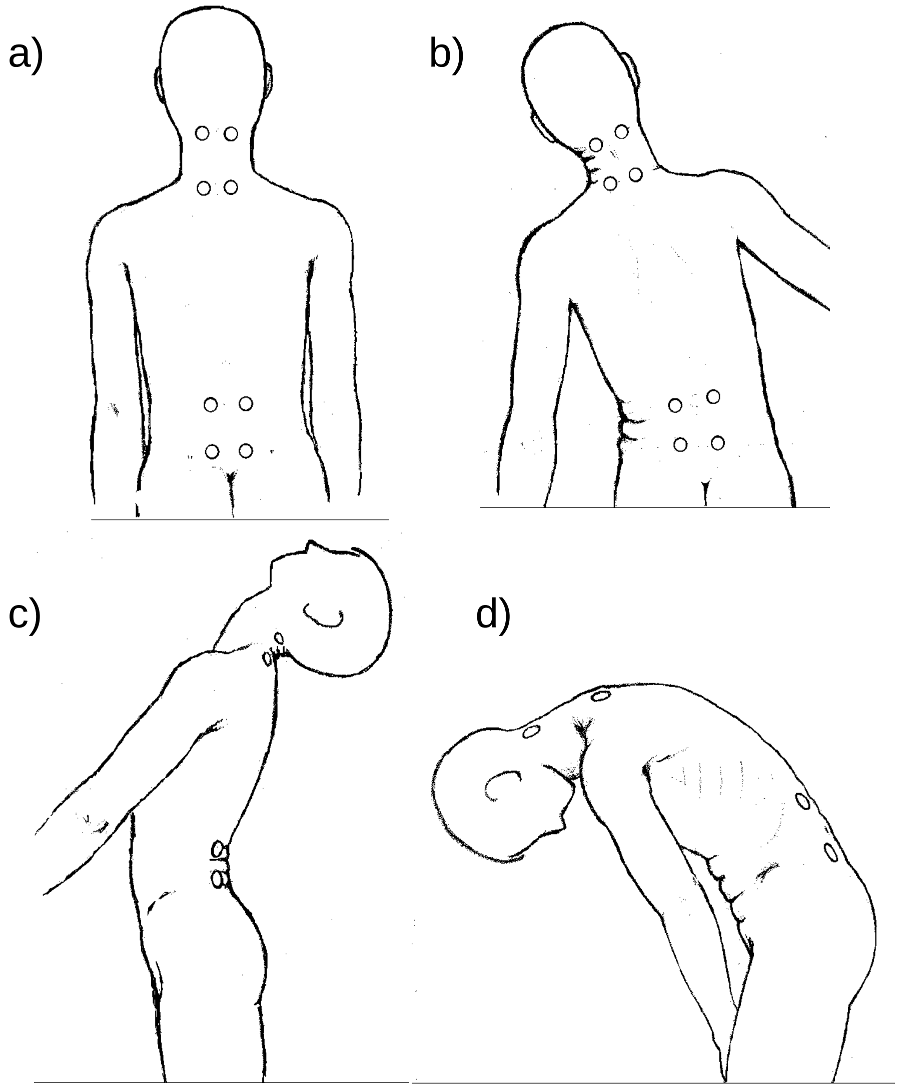


Fig. 3: Position of the sensors for six channel application with a) upright position; b) lateral flexion; c) extension and d) flexion movement.

Results

One channel registrations The observation are showing general posture profiles for both classes and interindividual posture stereotypes for selected students. We have met four different statements within the results: 1.The general posture-profiles of all students are not in preferred posture areas, 2. interindividual differences between different students are significant, 3. the change of the posture profile over the time varied from student to student, 4. the posture-profiles of the class in motion and the motionless classes are not no significantly different.

General posture profile: The posture-profile across all subjects shows a Gauss distribution of the posture pattern during the day (Tab. 1, Tab. 2, Fig. 4).

	A	GP	F
Mean (mm)	77-83	95-101	113-119
SD(mm)	8	8	9

Tab. 1: Mean and SD of the maximum extension (A), neutral position (GP) and the maximum flexion (F) of all students.

	A	B	C	GP	E	F	G
Mean (duration)	2.1	11.0	28.1	31.2	17.8	6.9	0.3
SD(duration)	2.8	6.4	8.4	7.2	5.9	6.1	0.6

Tab. 2: Mean and SD of the preselected posture of all Students

On average the participants preferred to sit in an upright (gP) position. Only 2.4 % of the total counts could be found in extreme positions (A and F).

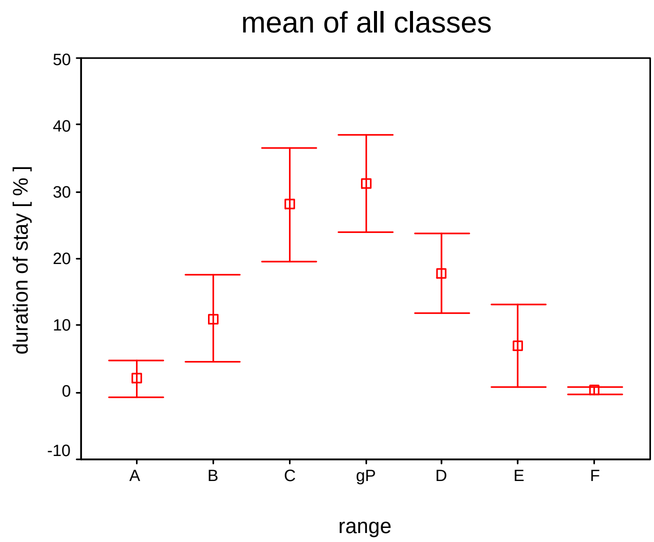


Fig. 4: Posture-profile from the lumbar range over all subjects shows the relative frequency of posture in the selected positions (A maximum extension and F maximum flexion).

Interindividuel differences: Individuals can have their own patterns. They differ in the mean position and in the distribution. For example some subjects prefer upright sitting (subject S) while others (subject R) use a wider posture-spectrum. Both children are students from a class in motion (Tab. 3, Fig. 5). Significant differences in those students are in the areas A, C and gP (p<0.05). The difference between the relative frequency of student R and student S is significant (p<0.05).

subject		A	GP	F
R	Mean(mm)	76-82	94-100	112-118
	SD(mm)	8	8	8
S	Mean(mm)	75-81	93-98	110-116
	SD(mm)	14	14	15

Tab. 3: Mean and SD of the maximum extension (A), neutral position (GP) and the maximum flexion of subject R and subject S

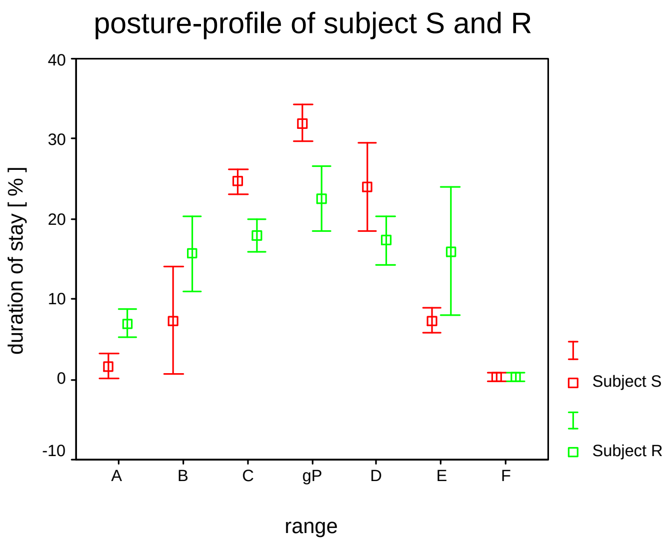


Fig. 5: Individual posture distribution of two subjects of the same class with significant differences in the areas A, B, C and gP.

Changes during the intervention: The pattern remained rather constant for a single individual. There was no tendency for a change of the pattern during the intervention (Fig. 6). Also no significant changes of the posture patter was to be seen for the whole class (Fig. 7).

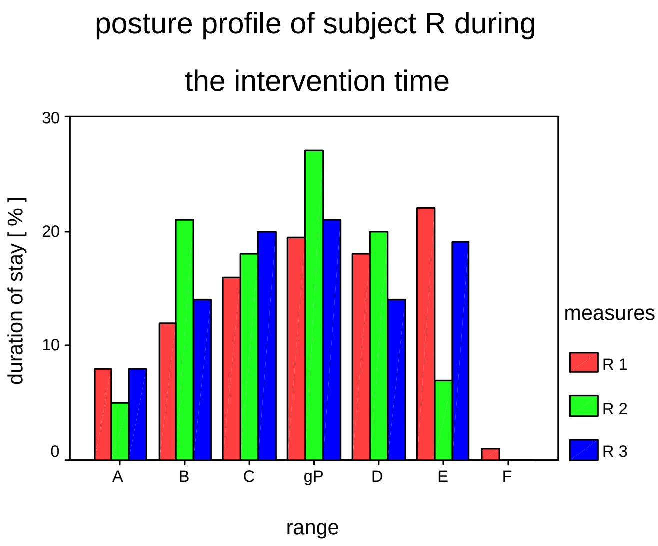


Fig. 6 During the intervention time the posture pattern remained nearly constant for a single subject. Merely at one measurement day a more frequent duration in range B and range gP was to be seen(r1=first, r2=intermediate, r3=end of the intervention periode).

Comparison class in motion and control: No difference exists between the class in motion and the control. The results in the context of our study did not deliver significant differences between the two groups. The mean of the two groups and the posture-profiles are very similar (Tab. 4, Fig. 8).

	A	B	C	D	E	F	G
Mean moved	2.3	11.8	25.2	32.5	18.3	6.9	0.1
SD	2.9	5.9	5.4	6.9	5.1	6.3	0.3
Mean unmoved	2.0	10.5	29.9	30.4	17.5	7.0	0.4
SD	2.7	6.7	9.4	7.3	6.4	5.9	0.7

Tab 4: No significant differences for Mean and SD of moved and unmoved class were observed.

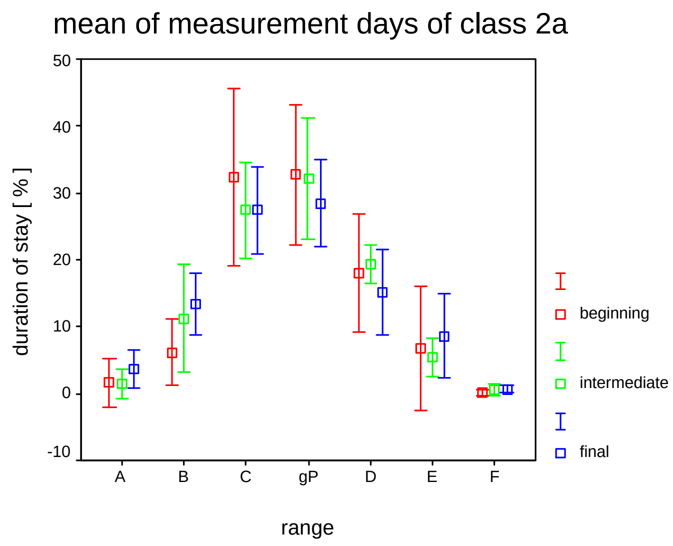


Fig. 7: Distribution of posture at the beginning (dark red), intermediate (green), and the final (blue) investigation. The distributions do not differ

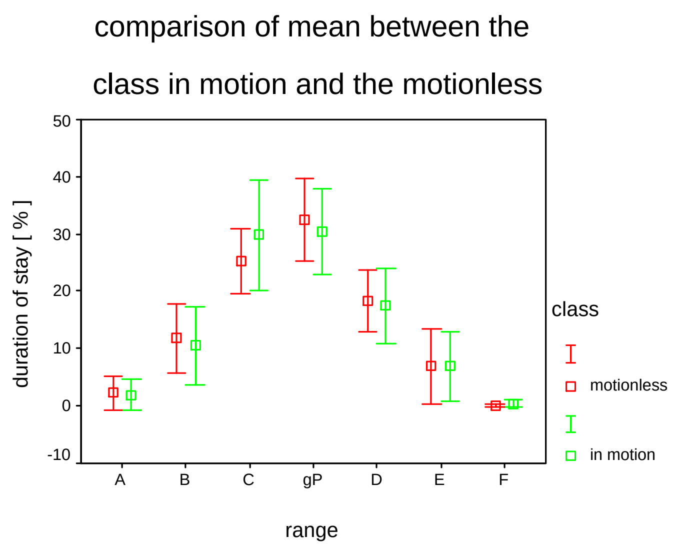


Fig. 8: No significant changes are to be seen between the class with (green) and without (red) intervention .

Six channel design and continuous monitoring of the time series

The analyses with the six channel device delivered detailed information about different regions of the spinal column. In addition it is possible to monitor flexion/extension and lateral flexion movements. The application did not influence the daily activities of the schoolchildren. Between the first and final measurement date no alteration of the posture-profile was estimated in the group of control students (Fig. 10).

Flexion/Extension: In the chest region of a selected student the distances of the sensors showed significant changes from the first up to the fifth lesson (Fig. 8). The mean value was in the middle of the first period (20 min) 200 mm ± 5 mm SD and in the last period (20 min) 195 mm ± 6 mm SD). Alterations of the sensor-distance between breaks and lessons were not significant. The observed distance decreased continuously from the first to the fifth lesson for student A and continuously increased for student B. This individual pattern did not change during the intervention.

In contrast to the chest region, a clear posture pattern could be observed in lumbar region mirroring the time course of events during a school day. The sensor distance at the lumbar regions increased at the beginning of the instruction (increased flexion) and from approximately middle of the lesson the value was reduced to an increasing extension.

During the breaks an extremely reduced distance could be observed (upright standing). A general trend to the change of the maximum and minimum of this posture-pattern over the schooldays could not be observed.

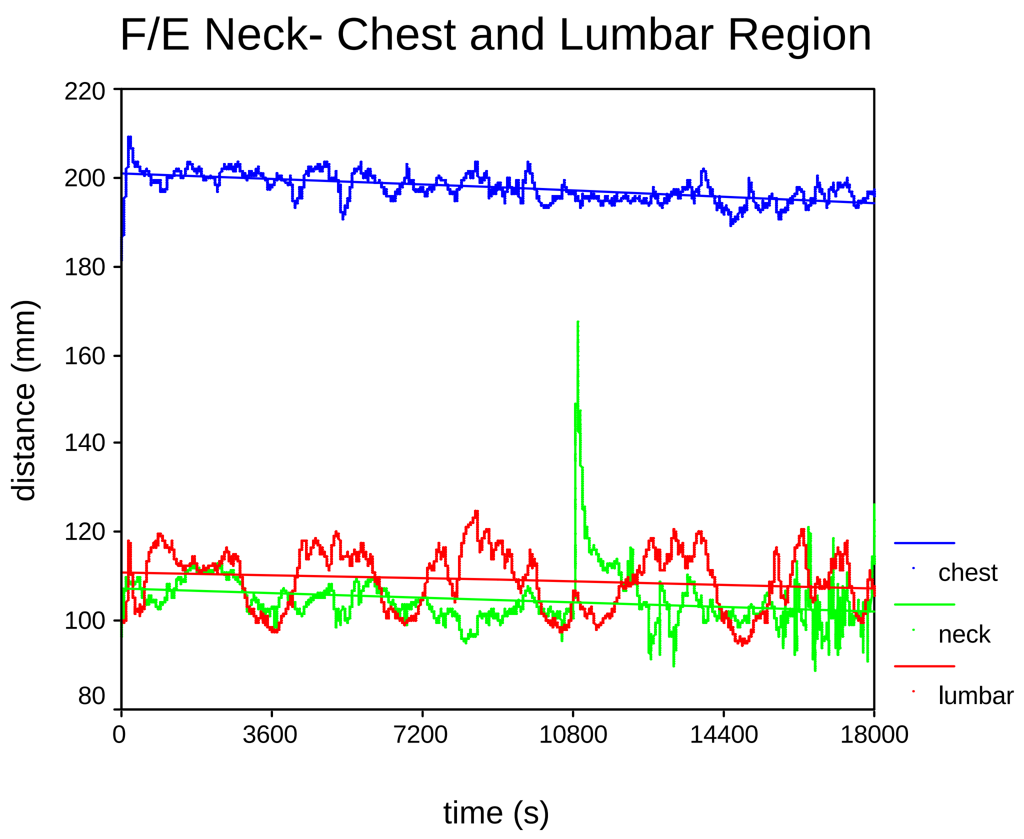


Fig 9: The graph shows a decreased mean value for the chest region(blue) and a weak decrease for the neck range with greater oscillations at the end of the day. The lumbar region shows unique pattern for lesson and breaks (great sensor distances sitting during lesson and small distance standing during break).

The neck range showed a reduction of the base line with coupled movements to the lumbar range. The distances of the neck sensors were reduced while simultaneously the distances increased at the lumbar region. From pelvis to neck the total-length of the spinal column reduces from 421 mm ± 10 mm SD at the beginning to 410 mm ± 20 mm SD at the fifth hour for one student and was enlarged for the second student. The whole profile is dominated mainly by the movement of the lumbar region.

Lateralflexion: In the chest region, it comes to an increased lateralisation from the first up to the fifth lesson. This observation is enforced during the breaks. The opposite lateralisation is to be seen at the lumbar region (Fig. 10). The lumbar region pattern of the instruction and break can be identified like in the Flexion/Extension movement for the lateral flexion. After the break, the flexion reaches a maximum value. From approximately middle of the lesson the student returns to his starting point. These oscillations increase during the day. No significant changes of the posture-profile are measured in the neck area. These findings were observed for both students (Fig. 11, Fig .12).

During the schooldays the sum of all spinal column-sections shows an increase lateralisation which was dominated by the lumbar region.

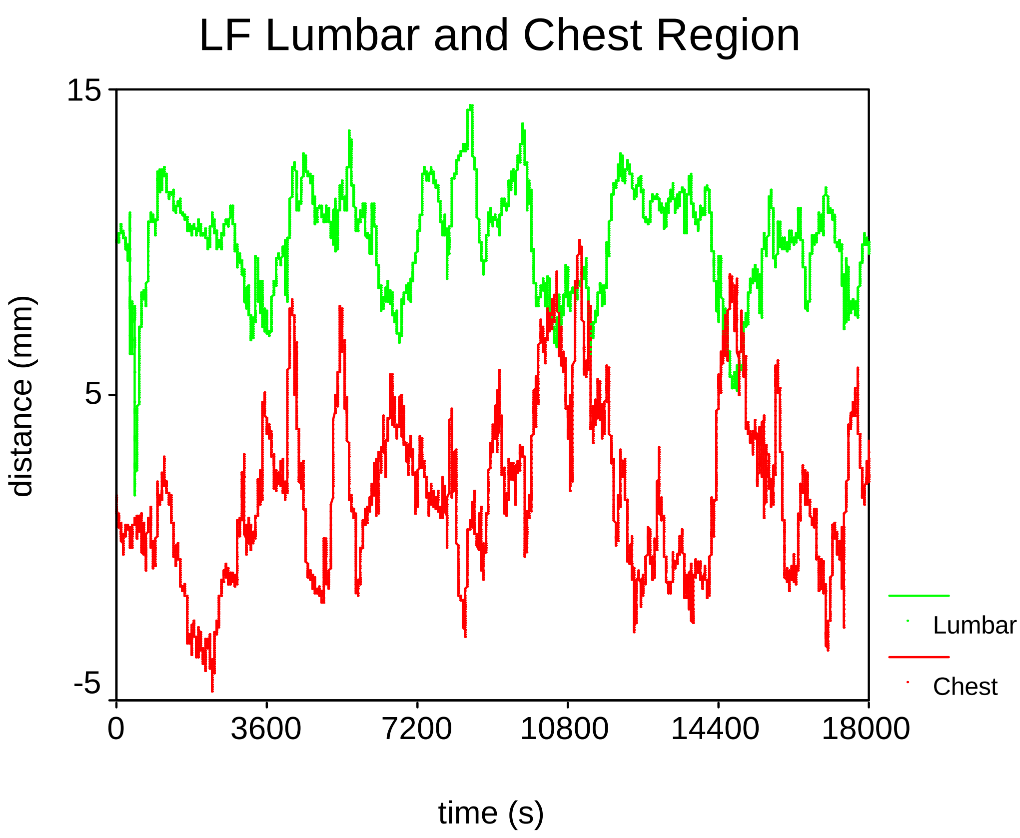


Fig 10: During breaks the distances in the lumbar and the chest regions increase from the first to the last lesson. The breaks were marked as the grey areas. Also the amplitudes of the fluctuations are higher at the end of the school day.

The lateralisation is also expressed as an increase of amplitudes and frequencies. The FFT analysis showed significant differences for both students during the day but was constant during the intervention time.

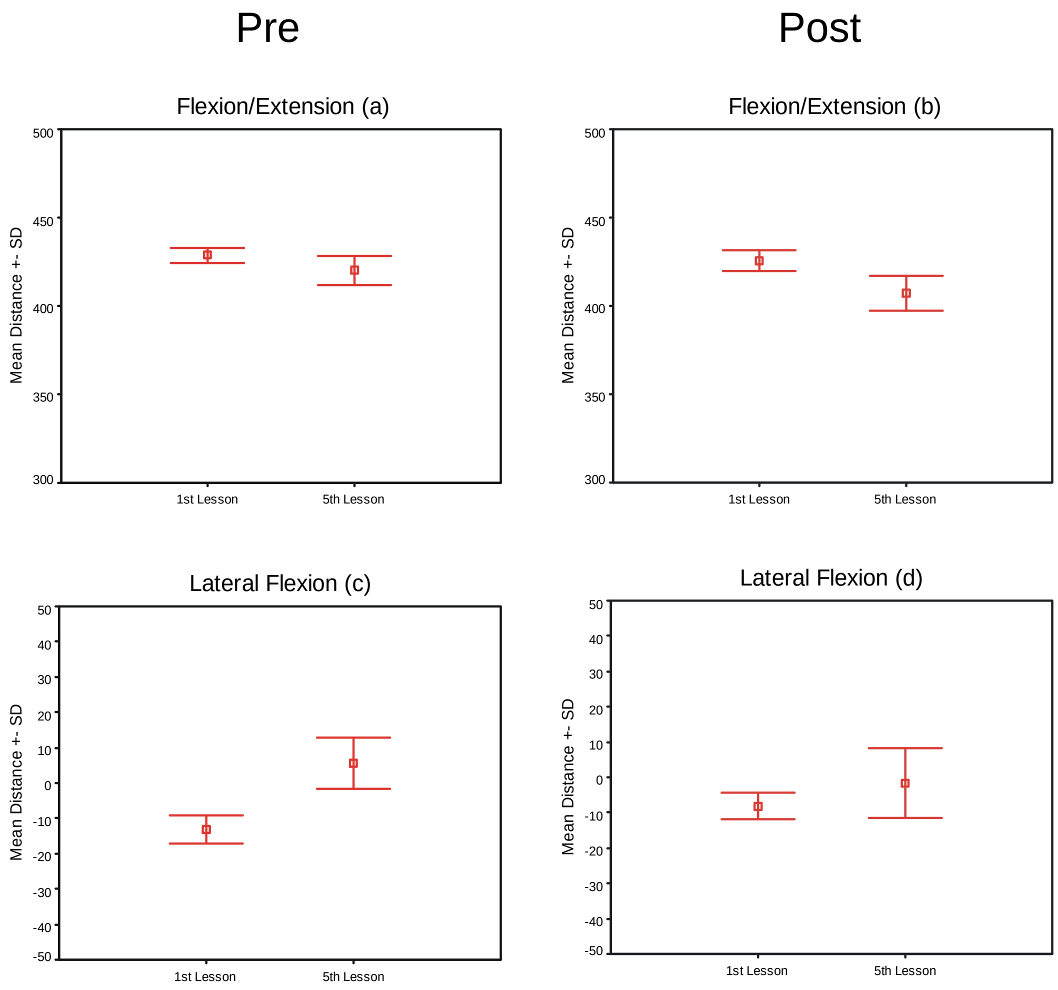


Fig 11: student A) Average (mean, SD) posture left (a,c) before (pre) and (b,d) after the intervention. a,b) The sensor distance decreases significantly ($p < 0.05$) from the first to the fifth lesson. c,d) The lateral flexion shows also changes significantly ($p < 0.05$) during the day.

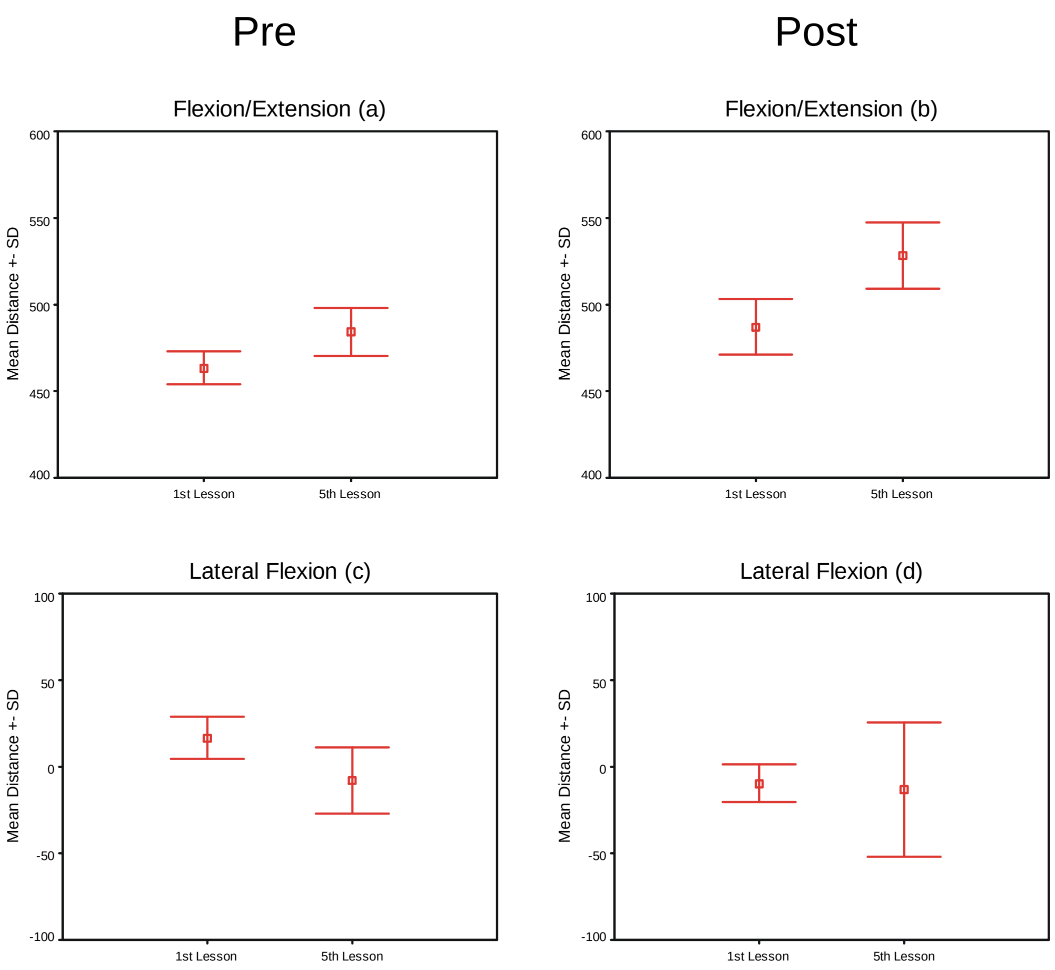


Fig 12: student b) Average (mean, SD) posture left (a,c) before (pre) and (b,d) after the intervention. a,b) The sensor distance increases significantly ($p < 0.05$) from the first to the fifth lesson. c,d) The lateral flexion shows also changes significantly ($p < 0.05$) during the day.

Moved class and unmoved classes The large deviations between individual posture-types admits no statement about the change in posture during the intervention period. The determined posture-stereotypes remain constant during the intervention period.

Discussion

The instrument: The purpose of this study was to develop a tool which allows to measure posture profiles. The tool was tested using an example of an intervention in a primarly school. Thereby, continuos monitoring of posture during the day in young school students was the central goal of our investigation. With the used method we were able to quantify posture over time periods of several hours. The application did not hamper movements during the lesson and turned out to be extremely robust (the devices survived crashes on the ground without essential damage). The application of the devices required little organisation and the system could be used easily in field-experiments. Advantage of these new experimental set-up in comparison to conventional movement analysis systems (3D-ultrasound-analysis, video-screening, IR-systems) is the possibility to measure posture without interference and during the whole day under everyday-conditions.

In contrast to laboratory set-ups which primarily allow to analyse artificial situations (for example before, and after the instruction) our method can be used to monitor the movements of the spinal column over the schooldays continuously. Those investigations are possible also with conventional video-systems located in a class room with the observed students in the visible area. One disadvantage of this method is difficulty to analyses body movements through the overlying cloths. For continuous recording it is necessary to use a large analysis window (3 m x 3 m x 3 m). However this requirement comes along with an increased error of the measurement. Our results show that the changes in posture during the day are within a very small range which are close to the resolution of such video systems (reduction of spinal length by about 15 mm). Another advantage of direct measurement with local sensors is the mass of data in video analysis which are hardly to handle even with extreme fast computers. Furthermore, markers used to increase accuracy of digitisation (see chapter 2) or allow for online infrared registration and reduced data streams hamper normal behaviour. In addition, they must be reapplied from day to day increasing the error of digitisation. Electrogoniometers (such as penny & Giles Biometrics) used for direct measurements are either bulky or very sensitive to disturbances. Also systems like Kupfer et al. 1999 (exoskeletons which enables the measurement of spine movements) influences the student in his natural movement-behaviour through a high organisational expenditure, albeit the possibility exists to give statements about posture-changes during long time periods.

One channel experiments All students preferred most of the time a neutral posture. In the course of the day merely a small trend to a reinforced extended posture was to be seen. By comparing the intervention-class with the control-class no significant differences appeared. This result is supported by the finding of different and conservative posture-stereotypes which were not influenced by the intervention. It can be concluded that simple averaging will blur these results. Intervention studies must monitor individual changes. The observations agree with empirical studies which report that troubles with the spinal column originate in early childhood (Harreby, 1997). Posture-stereotypes established in early childhood and not corrected during ageing result in problems of the spinal column in the older population.

Six-channel-experiments: Since installation of the 6 canal-devices was much more expensive only two students were equipped with the measuring instrument. This example set-up allowed a complex examination of the neck, breast and lumbar region. Similar to the one-channel system this design (mass 120 gr) was carried easily by the student and did not impair instruction. The general statement for a changed behaviour in the course of a day can be confirmed in all areas of the spinal column. The power of the observed trends is limited through the low number of the subjects, however it can be strengthened by the results of the one channel design. The observed height-decrease of the breast-region indicates a compression of the breast-spinal column and increased extensions during the day for one group and the opposite behaviour were found with fatigue induced flexion movements in the other group. It is to be suspected, that metabolic and neural causes play a major role. The movement-pattern of the lumbar range for the dorso-ventral axis shows a behaviour which concurs with psychological examinations with school students. At the beginning high interest, reduced capacity (massive flexion) to the middle of the lesson, and against the end of the lesson positive impulses due to the approaching break. An observed increase of the distances in the neck region can be interpreted as reduced ability to keep the head upright. Starting with the upright stand during the break the upper body drifted more and more to the anterior directions.

Intervention

The intervention did not result in any significant change in posture. Reasons for this might be:

- the intervention-time period is to short,
- the number of subjects is to low,
- the difference between the moved and unmoved group with respect to motor demands is not sufficient ,
- or changes in the moved group are in an early-stage, i.e. movement has not been manifested in the examination period.

The lack of significant alteration should not discourage us to proceed on the way towards a "healthy school". Obviously, short-term changes can be found in social parameters. First examinations has yielded for example that

- the "school-fun" of the teachers climbs (86% of the questioned teachers),

- moved instruction are fun for students (76%),
- the students are able to study and even more intense (88%)
- -many aspects of the intervention-measure (relaxation-phases, kind of the furnitures, new methodical principles.) are maintained to a high percentage even after months .

Based on the results the biomechanical significance of this studies is high. Posture alterations cannot be estimated within a time of 3 months with an one hour weekly intervention. Beside the positive social aspects the program results not in a posture improvement.

The reason for this finding is a high postural variability in young school students. Further studies which focus in postural alterations must be adapted to the specific posture and movement profiles of the single subject otherwise the inter individual differences will mask the results. In addition, a longer intervention time with higher intervention frequency will enforce the findings.

Perspective

The proposed study allows the estimation of flexion/extension and lateral flexion movements at different spinal column regions. By means of a cross application of the sensor pairs also torsion movements can be quantify. Pre test with sales persons at a supermarket are showing a maintained increase of the torsion value if the subjects works the whole day at the same cash box. Combining the flexion/extension, lateral flexion and torsion we are able to describe the degree of freedom of the spinal column during longer time periods.

Literature

Alleread, W.G., Marras, W.S., Parnianpour, M. (1996) Trunk kinematics of one-handed lifting, and the effects of asymmetry and load weight. *Ergonomics*. **39**, 322- 324.

Balagues, F., Dutroid, GG; Walburger, M. (1988) Low back pain in school children. *Scan. J. Reabil. Med*. **20**, 175-179.

Boocock, M.G., Jackson, J.A., Burton, A.K. Tillotson, K.M. (1994) Continuous measurement of lumbar posture using flexible electrogoniometers. *Ergonomics*. **37**, 175- 185.

Brüggemann, G.-P., Gao, J., Kersting. (1995) Biomechanische Untersuchungen wirbelsäulenbelastender Tätigkeiten in Mitgliedsbetrieben der Berufsgenossenschaften. Prävention von berufs- und arbeitsbedingten Gesundheitsstörungen und Erkrankungen. 2. Erfurter Tage. Radandt, S., Grieshaber, R., Schneider. (Hrsg.) 195- 214.

Ellegast, R.-P. Kupfer, J. Reinert, D. (1997) Personengebundenes Meßsystem zur Registrierung äußerer Belastungsgrößen bei beruflichen Hebe- und Tragetätigkeiten. Internationales Symposium Berufsbedingte Wirbelsäulenerkrankungen. 8. Wirbelsäulen- Workshop Wirbelsäulenverletzungen. Hamburg (in Druck).

Ellegast, R.-P., Kupfer, J., Busse, S., Reinert, D., Reis, W. (1996) A concept for recording stress parameters during the performance of occupational task. To appere in Proceedings of the Canadian Society for Biomechanics, IXth Biennial Conference, Buraby, Canada. Hoffer, J. A., Chapmann, A., Eng, J.J., Hodgson, A., Milner, T. E., Sanderson, D. (Eds.), 326- 327.

Fleiß, O., Fleiß, H.., Holzer, P., Ritter, G. (1996) Rückenschulprojekt Steiermark für BerufsschülerInnen. Projektbericht Steirische Gesellschaft f. Wirbelsäulenforschung.

Hansson, P.-A., Öberg, K.E.T. (1996) A method for computerized three-dimensional analysis of biomechanical load on seated tractor driver. *Int. J. Ind. Ergonomics* . **18**, 261- 268.

Harreby, M., Hesselsoe, G., Kjer, J., Neergaard, K. (1997) Low back pain and physical exercise in leisure time in 38- year- old men and woman. A 25- year prospective cohort study of 640 school children. *J. Eur. Spine*. **6(3)**, 181-186.

Hölinger, R., Klöckner, W., Pussert, E., Schneider, S. (1996) Gesunde Haltung. Hartung – Gorre Verlag Konstanz.

Holzer P., Fleiß, O., Fleiß, H., Ritter, G. (1998) (in prep.) Computerunterstützte Haltungsuntersuchung bei Schulkindern. . Kongressbericht 4. Biomechanik – Symposium der DVS. Oldenburg.

Holzer, P., Fleiß, O., Fleiß, H., Ritter, G. (1997) Videoscreening of the Spine – an easy to use, computer aided method for posture control and Spine analysis. J.A.Sevastik, K.M. Diab (Hrsg).Research into Spinal Deformi ties 1, ISO Press Amsterdam. 185-187.

Jäger, M. Luttmann, A. (1989) Biomechanical analysis and assessment of lumbar stress during load lifting using a dynamic 19-segment human model. *Ergonomics*. **32**, 93- 112.

Karhu, O. Kansi, P. Kuorinka, I. (1977) Correcting working postures in industry: A practical method for analysis. *Appl. Ergon*. **8**, 199- 201.

Kivi, P., Mattila, M. (1991) Analysis and improvement of work postures in the building industry: Application of computerized OWAS method. *Appl. Ergon*. **22**, 43- 48.

LeBlanc, R., Labelle, H., Rivard, CH., Poitras, B., Kratzenberg, J. (1997) Three – dimensional (3D) postural evaluation of normal human Subjects. Sevastik JA., Diab KM. (Hrsg): Research into spinal deformities 1. IOS Press, 293-296.