

Posture and health, a fine balance.

Zbigniew KULIBERDA*, Edmond LE BORGNE**, Cécile VANDAME***

May 2020.

Authors information :

- * Z. Kuliberda (*67300 Schiltigheim-Strasbourg, France*), PT, Manual therapist, Postural imaging 4D, Postural biometry research and development.
- ** E. Le Borgne (*44000 Nantes, France*), Posturologist, Postural imaging 4D, Postural biometry.
- *** C. Vandame (*91370 Verrières-le-Buisson, France*), Podiatrist, Postural imaging 4D, Postural biometry.

This article is intended for all public health actors involved in the management of disorders affecting the musculoskeletal system.

Whatever the reader's specialist interest, from biomechanics to neuroscience, energetics to macrobiotics or ergology to ergonomics, this presentation aims to inform open and curious minds, minds that will advance knowledge on the functional capacity of the human being by challenging their own experiences.

Optical imaging is able to accurately reproduce the physiological functioning of the musculoskeletal system in upright standing position. It is therefore a useful tool for research and functional study. The latter specifically leading to the implementation of relevant care strategies. This article looks at video rasterstereography. This non-invasive, non-operator dependent optical imaging procedure guarantees reliable and reproducible results in accordance with the most stringent safety and objectivity criteria.

The temptation to classify remains at the core of our modern health system, but we must remember that there will always be cases that do not fit into any of these classifications. In the context of functional medicine, this temptation is currently a wasted effort. Many authors have proposed strategies that ultimately fail to satisfy the spirit of the healthcare system as every case is unique.

There is, however, a feature that is common to all individuals presenting with posturo-functional deficiency: pain.

If a balanced posture, harmonious chains and free-moving joints are key to normal mobility and anatomical and physiological integrity, the absence of pain will be the prerogative of those with this functional schema. Here we must fight against our tendency to classify the subject according to criteria or behaviours they do not have, with all due respect to those who do have them.

While it is true that everyone has the potential to trigger a symptomatic state, prevention is a matter of debate, probably due to lack of experience, evidence or conviction.

More attention has been given to deforming pathologies of the spine, but many still go undetected. This shows that it is difficult to establish a rule, and that the notion of harmony does not necessarily correspond to an orthonormal pattern but more likely comes from the notion of balance, both mechanical and functional, and therefore health balance.

As long as our functional capacities are able to respond to demands without excessive energy expenditure, the health balance is maintained as compensation is possible. It is the state of decompensation that becomes symptomatic and is not necessarily expressed by pain in the musculoskeletal system.

This is precisely what makes diagnosis and treatment proposals complicated, as, typically, the patient seeks help when the decompensation causes unbearable pain, often with mechanical impairment. The state of decompensation is characterised by recurrence of symptoms. The difficulty for the practitioner lies in the fact a multidisciplinary strategy is required to restore compensation rather than one single action.

Therefore, rather than attempting yet another classification of posturo-functional deficiency, this is an introduction to biometry using video rasterstereography. With its strict methodology, it opens up a new approach in health strategy. It focuses on health balance which, thanks to modern tools, can be measured objectively with reliable reproducibility. However, although optical imaging is proving a valuable addition, it is in no way a substitute for standard imaging techniques such as X-ray, CT scanning, magnetic resonance imaging,

etc., which are needed to diagnose structural abnormalities, osteoarthritis, slipped disc and spinal stenosis, or malignancies, rheumatic diseases, compression fractures, etc. Optical imaging could be useful in therapeutic decision-making aimed at reducing additional stresses related to existing pathologies and is particularly suited to non-specific or idiopathic pathologies.

Background

A functional organisation of the musculoskeletal system through optical imaging requires technological support that allows visualisation of all or part of a subject in all three planes of space obtained from a single recording. Conventional photography cannot meet this requirement as the images obtained are one-dimensional. That is why, with the advent of digital technology, 3D imaging first emerged in the 1960s.

- Hiroshi Takasaki (*Japan*) published his work at the summer session of the Massachusetts Institute of Technology in 1970 on 3D imaging using a Moiré topography system.
- W. Frobin, and E. Hierholzer (*FRG*) published their work at a NATO symposium held in Paris in 1978 on 3D imaging obtained using a stereo photogrammetric method for the measurement of body surfaces using a projected grid.
- M. Van Poucke, P. Boone and M. Vercauteren (*Belgium*) collaborated with the Oxford Metrics Institute Ltd and published their work in *SPIE* Vol. 672 in 1978 on 3D imaging obtained by an integrated shape imaging system (ISIS).
- Mr. Takeda and K. Mutoh (*Japan*) published their work in *Optical Society of America* in 1983 on 3D imaging obtained using a Fourier transform profilometry method.
- Lastly, W. Frobin, and E. Hierholzer (*FRG*) published their work in *American Society for Photogrammetry and Remote Sensing* in 1991 on 3D imaging obtained using video rasterstereography.

The prerequisite for obtaining reliable and reproducible measurements is the use of proven, non-operator dependent techniques such as photogrammetry and digital analysis in connection with morphological and skeletal constants.

The 21st century will see the use of photogrammetry in the biomedical field for the study of human anthropometry for the detection, monitoring and prevention of stress pathologies, in the same way that submarine sonar gave rise to ultrasound imaging.

In France, optical imaging is gradually establishing itself within functional medicine and the market is evolving with manufacturers such as SAM Instruments, DMS Imaging, Physical Tech and DIERS International. While the proposed topographic acquisitions are based on high-quality reflective or photogrammetric methods, the processing of morphometric data is highly questionable depending on the system used. Some have no automatic anatomical location or automatic calculation of morphological parameters, while others require simultaneous radiological photographs or specific positioning of the subject, etc.

Video rasterstereography is an optical acquisition method used for back surface measurement in which back shape analysis, reconstruction of the spinal shape and orthopaedic interpretation support are the most developed. The results, for scoliosis and kyphosis for example, show a good correspondence with radiographic images, and these methods of measurement, analysis and evaluation are at the heart of the Dicam system.

Dicam is a software programme that offers a fully automatic process and integrates the physiological oscillations of the natural upright standing position. It is currently the only software capable of analysing videogrammetric images, forcing its competitors to play catch-up. While 3D optical imaging has enabled observations of excellent quality, video rasterstereography integrates the time dimension and marks the era of 4D imaging which, when applied to functional medicine, undeniably meets the criteria for reproducibility, providing an objective way to monitor the organisation and functional therapies of the musculoskeletal system.

The scientific aspect

Video rasterstereography is an optical technique that enables the 3D reconstruction of the spinal shape of an observed subject. A regular grid (raster) - represented by alternating horizontal dark and light lines spaced 15 mm apart - is projected onto the subject's back and constitutes **image 1**.

An industrial IDS camera placed 80 cm above the projector - with an acquisition rate of 25 frames per second and an exposure time of 40 milliseconds - captures the distorted lines projected onto the subject's back at a convergence angle of 22° . The acquisition of the distorted raster lines constitutes **image 2** required for the principle of stereography for 3D reconstruction (*Frobin, Hierholzer 1981, 1983, 1985*) and allows you to obtain a series of images that make it possible to record a sequence of movements.

To date, the accuracy of 3D reconstruction is around of 1/10th of a millimetre and 1/10th of a degree thanks to the camera which uses a CMOS sensor with a resolution of 1280 X 1024 pixels (5:4 aspect ratio, 1.3 Megapixels) which offers a view of the reconstruction grid (Fig. 1) that accurately corresponds to the actual surface of the subject's back.

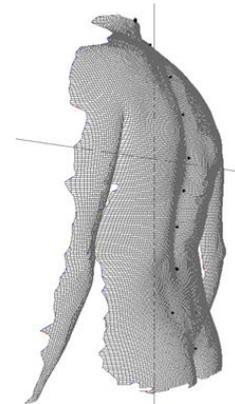


Fig.1

Analysis of characteristic shapes, such as arches (humps or concave surfaces) and depressions (planes or convex surfaces) on the posterior side of the trunk, makes it possible to identify anatomical landmarks using the mathematical principles of differential geometry which is applied to several thousand recorded points for each area studied.

The work of Frobin and Hierholzer made it possible to establish a symmetry line that divides the back into two halves with minimal asymmetry. In a subject presenting no deformities of the trunk, this symmetry line is vertical or quasi-vertical and closely corresponds to the line of spinous processes. In scoliosis, there is strong correlation between the symmetry line and the line of spinous processes (Drerup 1996).

By calculating the symmetry line and analysing characteristic shapes, the Dicam software automatically detects bony landmarks (Fig. 2): in the upper part of the symmetry line, the most pronounced concave surface corresponds to the most prominent part of the dorsal surface of the C7 spinous process, in the lower part of the symmetry line and laterally to it, the deepest convex surfaces, on the right and left, correspond to the sacral dimples that establish a link to the posterior superior iliac spines (Drerup and Hierholzer 1987).

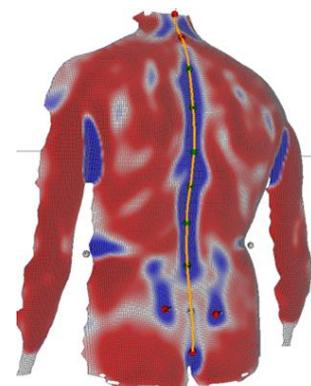


Fig.2

The various works of Turner-Smith form the basis for calculating a line that is more anterior to the symmetry line, called the line of vertebral centres. Its anterior position or depth relative to the surface of the back corresponds to a constant established on anatomical specimens.

The lateral position of the vertebral body line (Fig. 3) in the same study was estimated based on the following hypotheses:

- there is a concordance between surface rotation and vertebral rotation, the K-factor is very close to 1 (Turner-Smith and De Roguin 1984),
- the symmetry line follows the line of spinous processes,
- the vertebral bodies, for the most part, are not deformed by scoliosis,
- the distance P between the middle of a vertebral body and skin surface is a known anatomical constant (P varies according to the level at which the measurement is made on the spine and the size of the human body being measured).

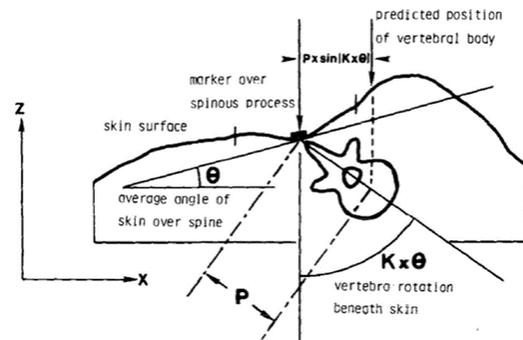


Fig. 3

If all these conditions are met, then the centre of the vertebral bodies is in the interval P from the skin surface and in the extension of the perpendicular to the surface rotation increased by the K-factor.

Therefore, Dicam is able to calculate and construct a vertebral model without the intervention of an operator. The plotting of the sagittal line (Fig. 4) from the centre of the vertebral bodies to each level of the horizontal plane and the calculation of the size of the vertebrae determined according to the distance between C7 and L4, enables the software to produce a final model of the vertebral volumes and their positioning in the space (Fig. 5).



Fig. 4

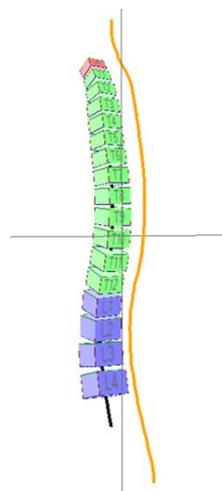


Fig. 5

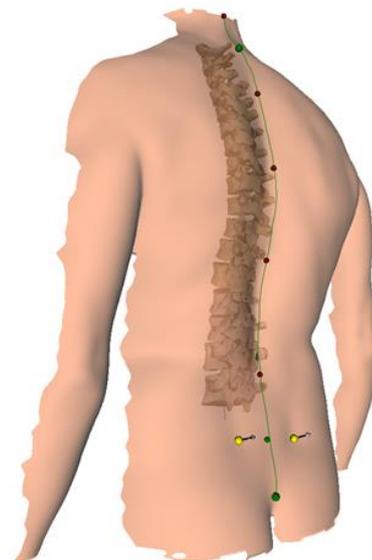


Fig. 6

The software selects typical vertebrae from a database containing thousands of 3D images of vertebrae, in order to propose matching relations (Fig. 6).

Methodology

The device equipped with an HD camera allows different types of measurements to be made and to date, European research engineers have proposed three types:

- The "Instantaneous" measurement. It is acquired in 40 milliseconds and is mainly used for tool/patient calibration (column height, patient/camera distance) with an almost instantaneous display of the reconstruction result and for checking the consistency of the proposed parameters.
- The "Average" measurement. This is the very essence of video rasterstereography. It is acquired in six seconds. The reconstruction proposed in quasi-real time is the image closest to the average calculated from 12 images acquired over a six second interval (one every half-second).

We prefer this measurement as, during the data acquisition period, it takes account of posture changes related to physiological oscillations in the upright standing position and trunk movements. Given the mathematical accuracy of optical imaging, this measurement is particularly valuable for the comparative analysis of postural changes, induced either physiologically or by various treatments. In fact, instantaneous measurements are of no benefit to functional medicine.

The natural upright standing position is also our preference as it does not introduce any additional bias unlike an orthonormal position which could generate adaptations. To quote David Gasq: "The placement of the feet does not seem to be a determining factor in the reproducibility of measurements. However, we believe that a position close to the natural position (17 cm - 14° position proposed by McIlroy et al. 1997, figure 5) is more suitable than a more unnatural position (McIlroy and Maki 1997)".

- The "Oscillations" measurement. Only video rasterstereography makes it possible to acquire in a 30 second time interval. The proposed reconstruction, in a time of about 20 seconds, is a video created by juxtaposing 30 images acquired at the beginning of each second.

This measurement is of the greatest benefit to functional medicine. It shows the active organization of the postural system.

Capturing the oscillatory signal makes it possible to evaluate disturbance in postural tone in collaboration with our various sensors - the oculomotor system, the auditory system, the manducateur system, the plantar sole, skin and scar sensitivity, the osteo-articular and organic proprioceptive system - which act as entry points to a change in tonic postural activity.

The "Oscillations" measurement therefore makes it possible to measure signal variations in tonic postural activity and from a biomechanical and biokinetic point of view, it allows the visualisation of inter-segmental movements of the trunk, thus constituting a major innovation. As a result, measuring the kinetic variations of trunk parameters offers a different approach to biomechanical synergy.

Recording times are offered as part of daily practice to limit computer storage. For study purposes, the recording time can be modified according to the operator's requirements.

The clinical support tool

The human being is an entity, which is why their health balance must be considered from a systemic perspective where the symptom itself is merely an expression of a loss of this balance.

Therefore, irrespective of a person's posturo-functional organisation, it should be qualified as correct if that person is pain-free. It is estimated that 10% of the world's population is pain-free and could therefore be referred to as the ideal posturo-functional class. These people have most likely found a relevant and lasting response to the "demands on functional capacities".

The slightest imbalance could generate stresses that will disturb tissue mobility to the point of jeopardising the anatomo-physiological integrity and leading to joint, capsular, ligament, muscle, and vascular pain and pathologies. These will have varied clinical presentations depending on the extent and origin of the stress but also on the "field" subjected to this stress.

By field, we mean biological possibilities of tolerance that allow a system to adapt to changes in the parameters under external conditions (stresses) and internal conditions (functional capacity). This adaptation is common to the species but includes features specific to each individual who, as a result of their experience and traumas, will learn to compensate for temporary or even permanent deficits via relevant solutions. This is why it is extremely difficult to attempt to classify stress pathologies as they are the result of a personal organisational imbalance.

Yet this is what authors at the top of their field are seeking to do, without demonstrating the veracity of their statements or providing objectively measured evidence. In their defence, the lack of accurate tools has meant they have only been able to make assumptions, but their approach makes them pioneers in holistic research and therapy.

It is not certain that the impairment schemas described as ascending or descending in the literature on posture make it possible to define an appropriate care strategy, as many of the people observed have a combination of these two schemas. Bias, which is likely to be present in all these studies, arises from the fact that there are very few observations of subjects in balance as they do not seek medical help. This is particularly the case for the majority of young adults in who are able to adapt enabling asymptomatic compensation of several posturo-functional imbalances.

It is possible that the collection of accurate clinical and posturometric data will provide a reliable timeline in the near future, but it is likely that each care strategy will have a timeline specific to the individual.

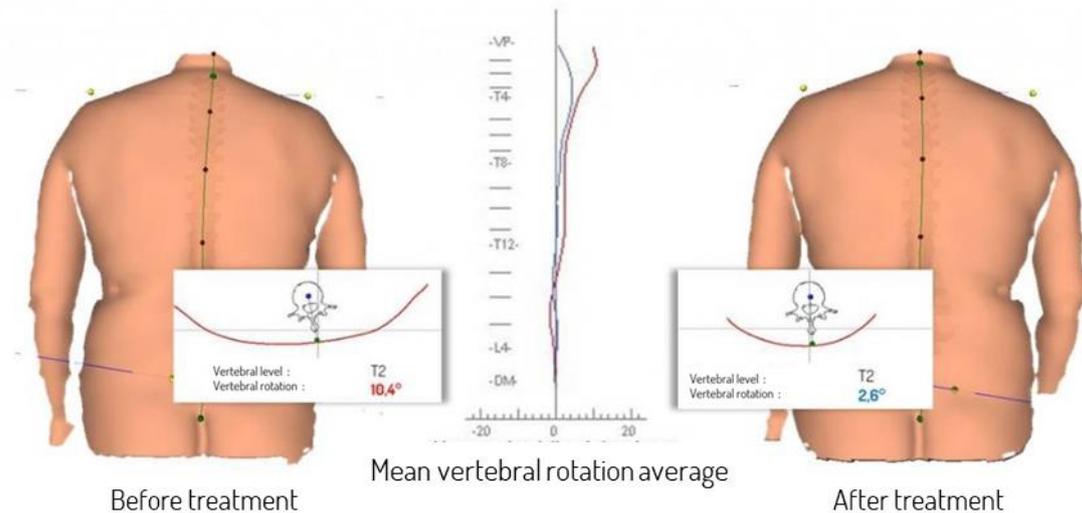
In any case, the management of stress pathologies requires a clear and simple visualisation of the current condition and, of course, of the impact of an applied treatment.

So that the reader is not lost by this presentation, the aim remains to discover the possibilities of video rasterstereography as a tool for visualizing tonic postural changes which is soon likely to become essential to the development of care strategies.

Firstly, we will discuss the possible visualization of average postural changes and, secondly, the visualization of oscillatory phenomena that animate the human being in upright standing position. So as not to leave anything out, we should also look at the evolution of the different parameters that can be measured when a subject is in motion, while walking or running, since video rasterstereography makes this possible. This topic will be addressed in another paper.

Here are a few comparative examples to help understand the changes generated by an action on postural inputs.

Influence of oculomotor therapy



This 60-year-old subject was seen for back pain and no longer feels upper back pain but still has intermittent lower back pain. Orthoptic care helped stabilize the physiotherapy treatment which, until that point, had been practised in isolation and had proved disappointing.

The decrease in rotations perfectly illustrates the reduction of stresses in this person.

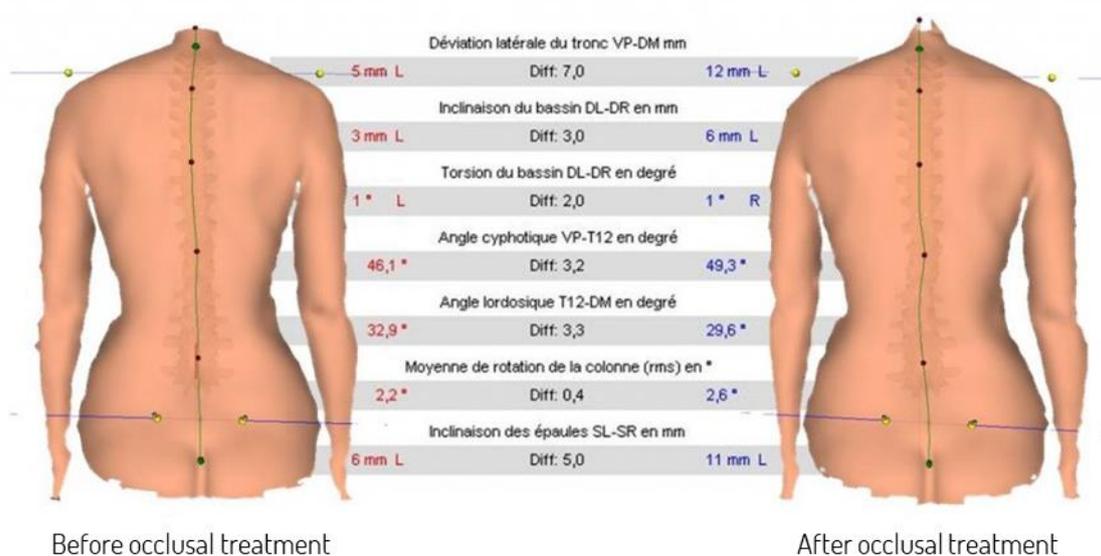
However, it has not yet been demonstrated that oculomotor imbalance is responsible for torsional stress, even though this is commonly seen.

It would appear that orthoptic treatment acts in a lasting way in the organization of the posturo-functional system, making it a treatment of choice. Moreover, it is not uncommon to observe disappearance of oculomotor imbalance after 3 to 4 sessions of orthoptic rehabilitation, which helps the tonic system expend less energy by reducing adjustment patterns which, in turn, favour exhausting mechanical stresses.

Tension asymmetry of the oculomotor muscles creates tension asymmetry in the neck and shoulder muscles that can extend to all the muscle chains. A failure of convergence never corrects itself, it generates a new body schema which will function with this imbalance but also with the posture disorders that accompany it and which, with time, will evolve into a stress pathology.

Oculomotor imbalance is often discovered during consultations for musculoskeletal-related pain (back pain, tendinitis, arthritis, etc.) when the practitioner is familiar with it, whereas convergence insufficiency manifests much earlier with multiple symptoms, such as tingling or burning of the eyes, the feeling of having sand in the eyes, difficulty focusing on an object for long periods of time, excessive fatigue, double vision, clumsiness, headaches, difficulty driving a vehicle at night or in semi-darkness, or learning disabilities in children.

Influence of oral dental system therapy



Here is the case of a young female subject seen for back pain that had not responded to symptomatic treatments. The origin of this pain was clearly established when taking her personal history -the pain started a few weeks after having a daytime mouthguard fitted. Comparative posturometry shows obvious changes in the posturo-functional organisation but these are barely perceptible to the naked eye.

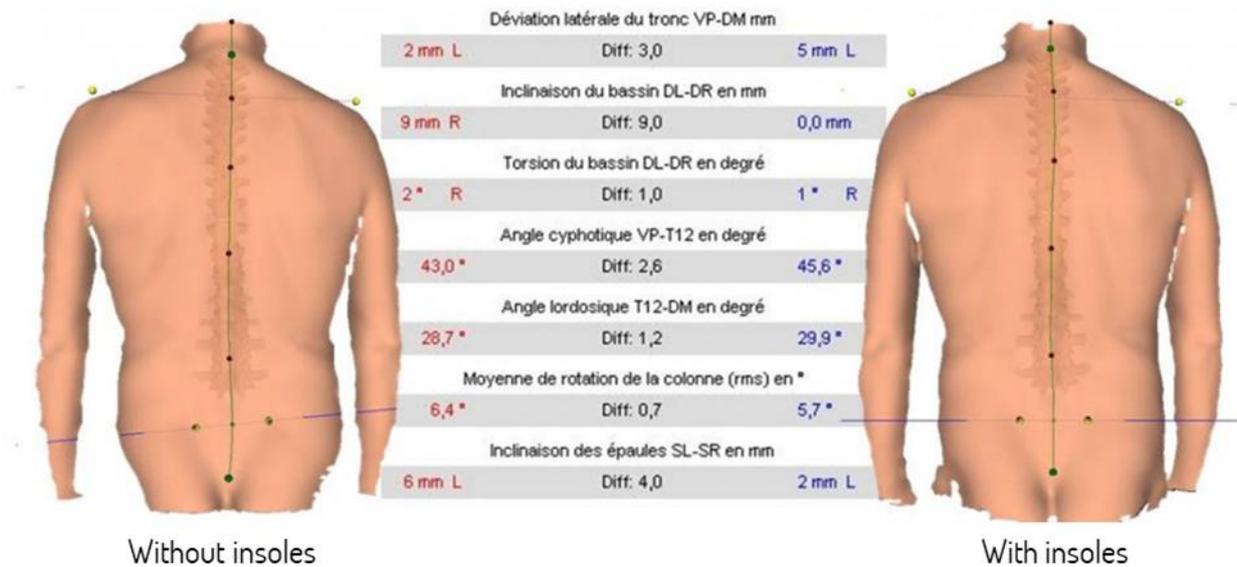
The role of the oral-dental system is considerably underestimated by practitioners. The jaw is an integral part of the tonic postural system. The integrity of the muscles of mastication ensures the right balance between the occiput and the cervical and dorsal vertebrae. This system is often neglected because of a lack of knowledge of how it interacts with the muscular system as a whole. Also, although an occlusal treatment can destabilise the posturo-functional system to the point of causing pain, as in the case above, it can also be very useful when it is performed well and for the right indication in order to alleviate a stress pathology. In many cases, occlusal treatment is performed for cosmetic reasons and the effects on the rest of the body are not monitored. This is a serious mistake, especially in adults, because the adaptation of tissue plasticity is less than in children.

Bruxism, jaw clenching, subluxations of the temporomandibular joints are all disorders that require occlusal treatment. Firstly, for direct reasons, such as maintaining the integrity of the temporo-mandibular joints, which can cause extremely debilitating degenerative pathologies over time. Secondly, for indirect reasons, experience and observations leading some authors to feel they are responsible for migraines, stiff neck, cervico-scapular neuralgia or speech, swallowing and digestion disorders.

It should also be noted that the study of microgalvanism, related to metals present in the mouth, is also an important development in the understanding of many pathologies. Its detrimental effect has been demonstrated using devices that are able to measure currents in the mouth (amalgams) but also between the mouth and its immediate environment (amalgam / earrings, necklaces, rings, bracelets, ...) that disrupt proper neuromuscular functioning.

Therefore, whatever treatments are undertaken on the manducatory apparatus, posturometric monitoring should be carried out. This helps prevent any long-term stresses. In the above case, the provision of insoles and physiotherapy or osteopathy on the central tendon would have avoided months of discomfort.

Influence of oculomotor therapy



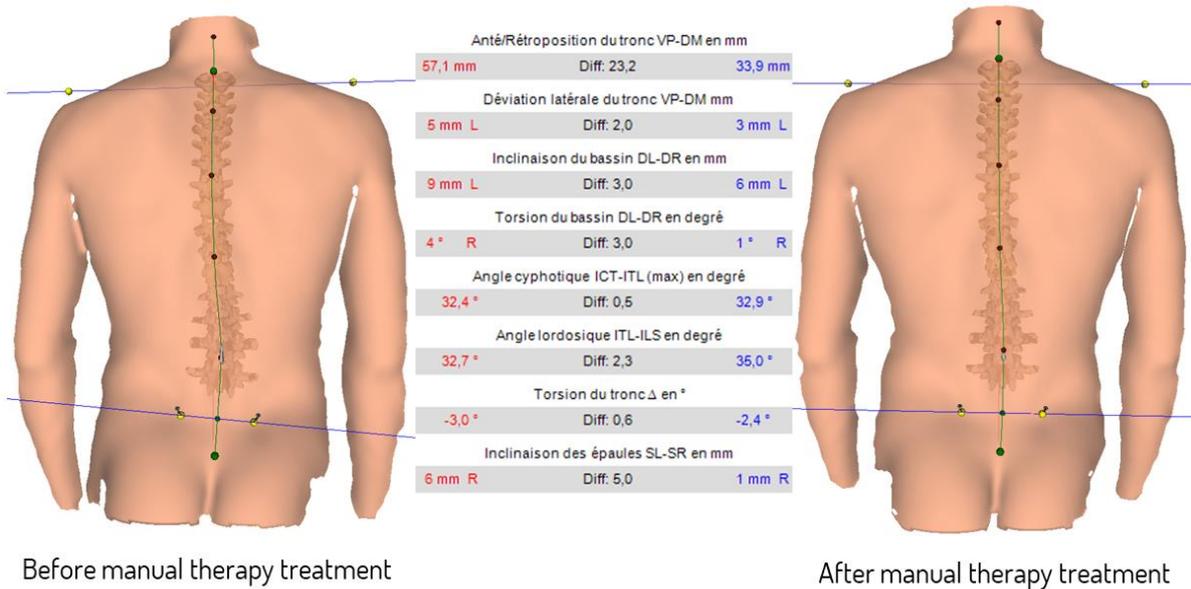
Here is the case of a 67-year-old subject suffering from neck pain and a feeling of torso twisting. Several types of insoles were manufactured and in the end, a pair of mixed, moulded, proprioceptive insoles provided him with the most comfort.

The effect of the podal system on the posturo-functional organization is such that, here again, it is not easy to define a rule. It is irresponsible to think that merely prescribing a pair of insoles is enough to eradicate recurrent low back pain.

Various posture research shows that our feet adapt to any overlying imbalance. The foot, including the ankle, will always adapt to harmonise support on the ground, but, over time, contact with the ground can become asymmetrical by fixing podal structures and generating a constraining overlying reorganisation. The foot-ankle pair therefore becomes a causative factor in posturo-functional imbalance that will require kinetics, physiotherapy or osteopathy to restore tissue amplitudes and proprioceptive reprogramming using thin insoles and not orthotics. Only a multidisciplinary approach will alleviate stresses, the effects of which can be objectively measured using comparative posturometry.

When the foot-ankle is free, the podal system does not cause painful stresses. In such cases, someone suffering from low back pain should not be given insoles as this is just adding to an already disturbed organisation.

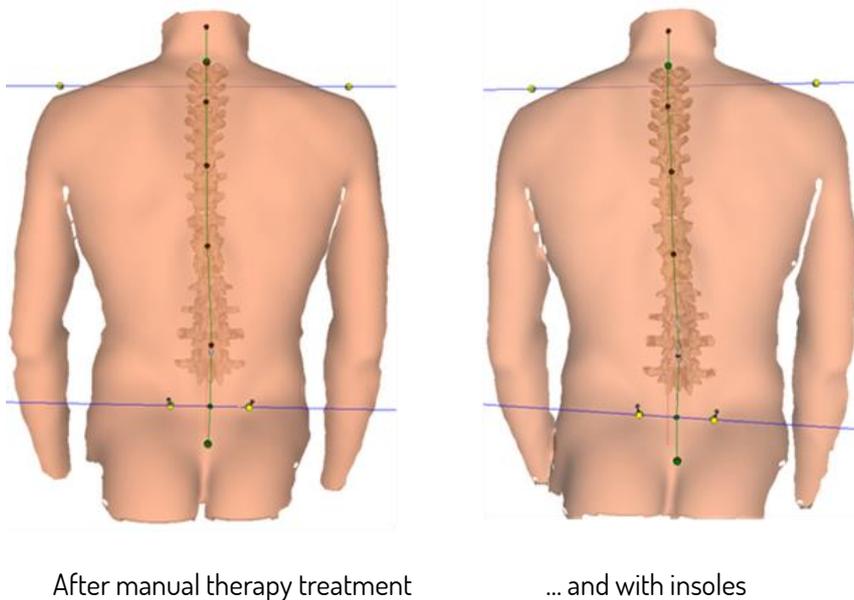
Follow-up of manual therapy treatment



Treatment given to a sportsman with lower back pain and pubalgia.

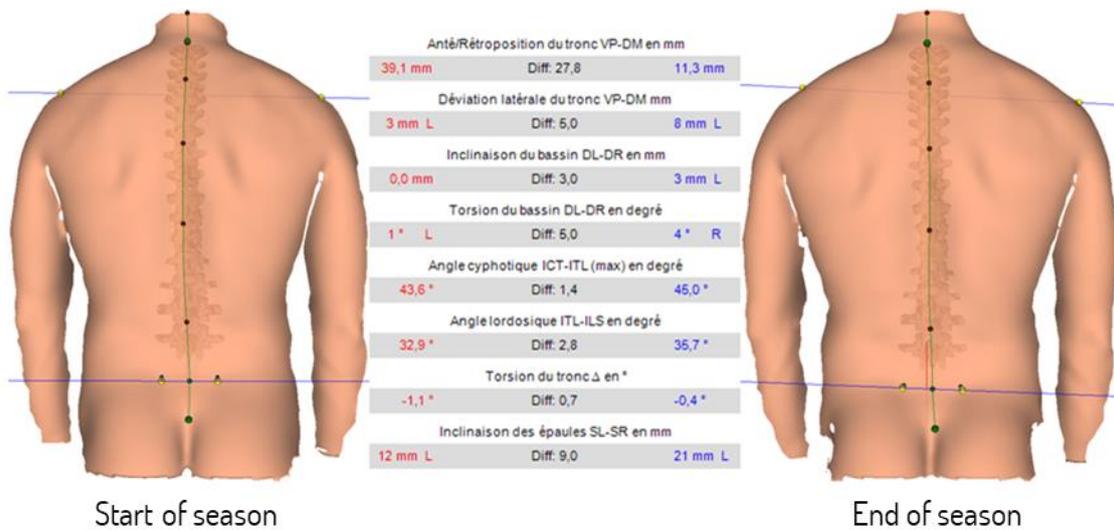
Even if the symptoms disappear following manual therapy treatment, the difficulty is maintaining the outcome obtained. The advantage of objective posturometric measurements is that you can react as soon as any imbalance appears.

Here is an example, seen too often, of treatment followed up with inappropriate tools.



Should we be concerned by the recurrence of symptoms in this sportsman? Is it always necessary to demonstrate the importance of the quality of a treatment or its relevance?

Follow up in sport



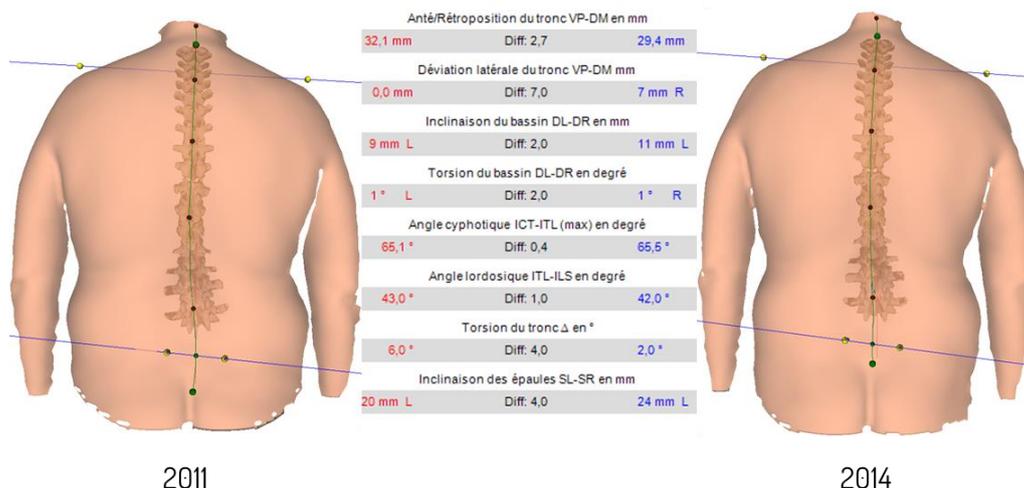
One of the things that makes the monitoring of sportsmen interesting is that this population constitutes a rather homogeneous group due to their work rate, life and proven stresses. Here is the case of a professional hockey player who was assessed at the beginning and end of the season.

Playing his sport, the successive training and physical preparation sessions cause obvious and measurable tonal and postural changes.

However, this case, which is not the only one in the team, challenges a widespread "belief" in the medical world. This athlete suffered from severe low back pain at the beginning of the season and continues to suffer in the same way at the end of the season. Wouldn't muscle strengthening resolve low back pain? Evidently not! And neither would the symptomatic treatments provided by the medical staff!

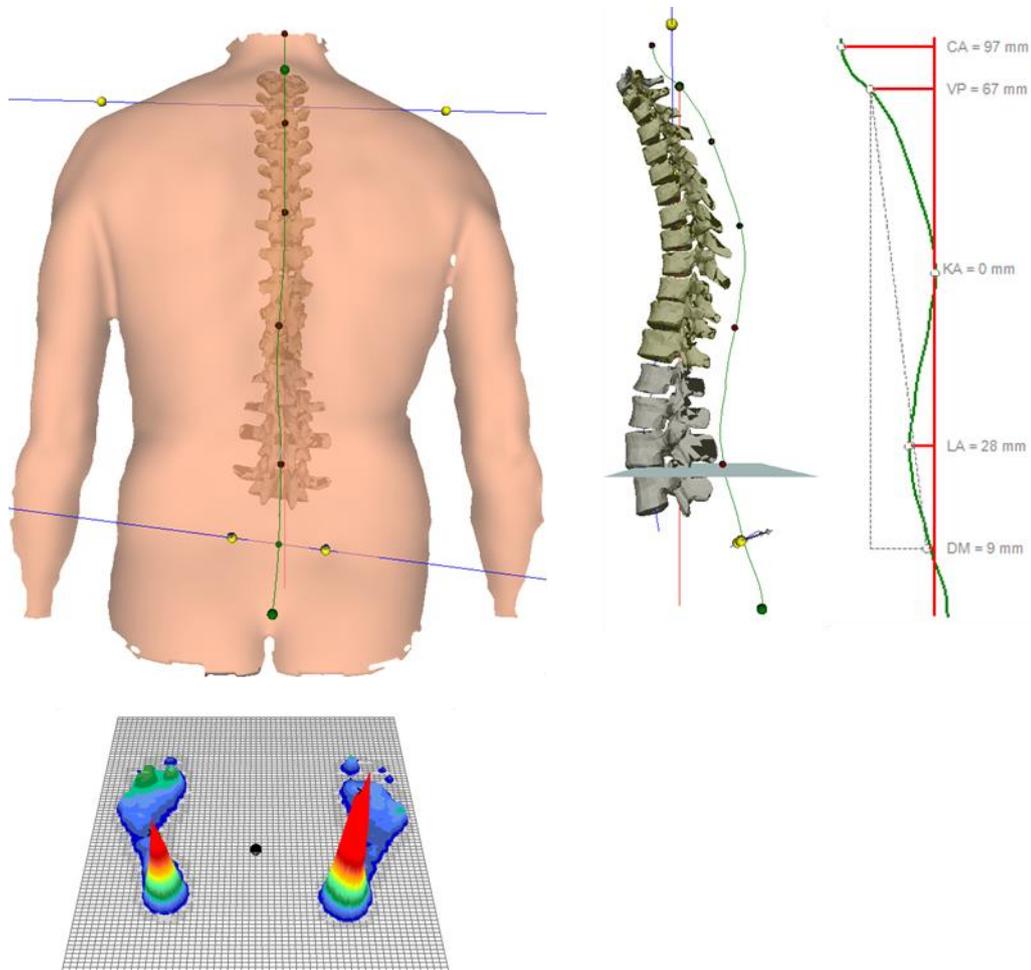
This example shows how important it is to individualise a care strategy but, above all, how important it is to consider a stress in a systemic and holistic way.

The example below demonstrates the absurdity of another dogma. Losing weight to get rid of back pain.



Orthoptic and podiatric care was suggested following the assessment in 2011. This was not followed up and the back pain is the same despite the weight loss, and the posturo-functional impairments are exactly the same after three years!

Finally, here is the case of a 43-year-old right-handed male subject measuring 178cm and weighing 74Kg.



The frontal plane shows a homolateral tilt of the girdles and a slight vertebral deformity.
The sagittal plane shows L3 in perfect horizontality, but on the other hand an anterior scapular plane with a rather weak lumbar arch.
The Pedoscan shows asymmetrical load distribution.

Despite a demanding professional life, the subject plays tennis regularly and does not suffer any pain! This example clearly demonstrates that posturo-functional organisation without stress is very far from an orthonormal state which is supposed to be a guarantee of no pain!

This example, which is far from unique, obviously raises questions.

What should the care strategy have been had this person been seen following a balance disturbance? It is likely that an over-correction would have been made, thereby generating further stresses. It is also likely that all those who have entered into medical nomadism have been victims of a blind "need to do something".

Oscillations in upright standing position

When man is standing at rest, the body is never immobile; it constantly oscillates according to particular and complex rhythms that place and maintain the gravitational centre inside the sustentation polygon in orthostatism.

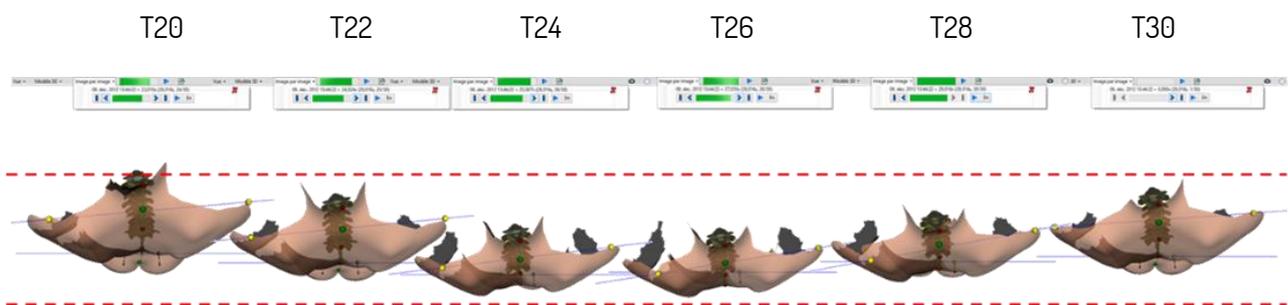
These movements, which reflect postural regulation, can be easily recorded by a statokinesimeter and derived techniques (J.B Baron).

Thus, for many years, physiologists and biophysicists have been working on elusive oscillatory information. It is silent, cannot be observed with the naked eye and is very important to analyse. It has been a focus of human biomechanics research since the dawn of time. How could we reasonably compare the oscillatory readings of two situations? We know of the important work carried out by Pierre Marie Gagey on stabilometry platforms that allowed him to evaluate biometry through the oscillations of humans.

Like DNA, an individual's biometrics are unique and characterise that person. However, we still need to be able to analyse them to provide answers on tonic postural activity. The stabilometry platform, widely used by chiropractors, is particularly valuable in the research and development sector. From Bell to Fournier, measurement tools have evolved thanks to new technologies and enable recordings as accurate as they are opaque and not of great use in daily practice. It is possible that the vision of the inverted pendulum, the basis of stabilometric analyses, is ultimately only useful to the researcher. In the curriculum for the Inter-university Diploma in Clinical Posturology in the module on stabilometry at the University of Toulouse led by David Gasq (MCU- PH), it is clearly stated that this medical device is still the subject of many publications, dissertations and theses.

We owe our teachers, who were pioneers in postural assessment and examination methodology, immense gratitude. Video rasterstereography is the only technique that allows us to measure oscillations. Without questioning the foundations of posturology, this technology makes it possible to draw conclusions on the subject's tonic postural activity. Visualization of inter-segmental movements enables analysis of the mechanical stresses involved. It is more understandable and directly useful to the practitioner, and therefore to the patient who is the main stakeholder in a care strategy.

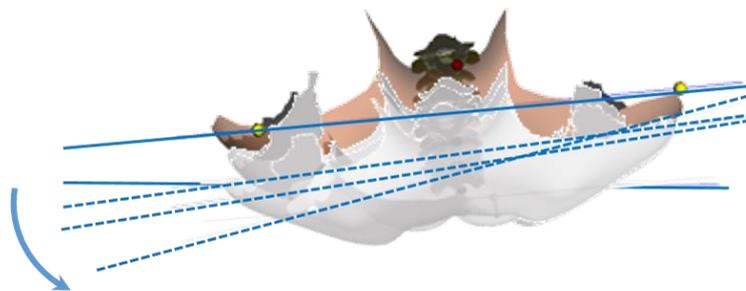
Oscillatory recordings are made on a 30-second cycle, allowing a good representation of the movement frequencies. Remember that in the context of studies, this cycle can be increased according to the operator's requirements.



Anterior-posterior oscillations (view from above).

The visualisation and measurement of various parameters in the three planes of space during trunk oscillations, simultaneously with the movements of the centre of pressure on the ground, are therefore now possible. While the frontal and sagittal planes have been the focus of much research, the horizontal plane remains the Achilles heel of postural studies, and for good reason - there are not many tools that provide reliable and non-operator dependent measurements. Back in 2010, Raimondi suggested that videogrammetry could be the solution offering excellent reliability. Therefore, there is no need to look for any standard, only videogrammetric-type examinations will fill the gap in the databases.

The mechanical stresses generated by vertebral rotations are feared because we do not know in concrete terms how a treatment affects their magnitude and, even less, the possible compensatory responses after correction. That is why some authors are cautious concerning the treatment of scoliosis, for example.



Variations in girdle rotation and trunk twisting, a visualization that opens up many options in terms of research.

Concerning the sagittal plane, it is not uncommon to discover that a person does not only oscillate on their ankles, an economical oscillation described in the research. In some cases, the movements in C7 are greater than in the pelvis, or even in the opposite direction, leading us to believe that a subject is more animated by undulations than oscillations. Future clinical studies will determine if this is the case for everyone, including healthy subjects, or if it is a sign of disturbance of the posturo-functional system.

As for the frontal plane, statokinesimetry enables observation of a lateral oscillation with no indication of the segments responsible for variations of the centre of pressure.

We therefore offer you a documented result which serves as an example.

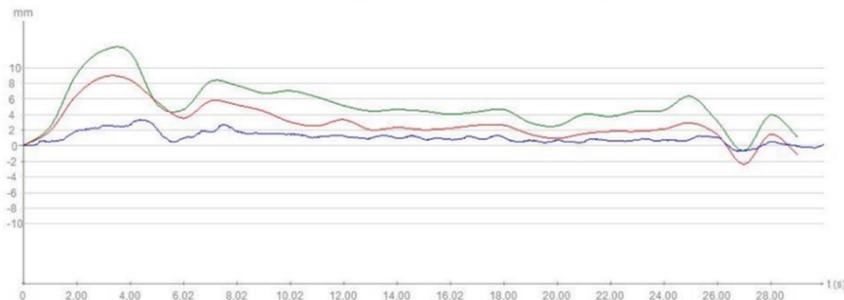
We recruited 2 subjects in their fifties, both in good physical shape with quite sedentary jobs and who take part in regular physical activity. The first, A, suffers regularly from back pain, while the second, B, has no pain. We asked each of them if we could take two measurements. The first measurement in the natural upright standing position and the second in the upright standing position with insoles.

Insoles were chosen as they are a stable object and are easy to use, unlike a pair of glasses or a mouthguard, both of which require adjustment. It should be noted that the insoles were industrially manufactured and the same pair of insoles were used in both subjects. Above all, it should be noted that the experiment is not intended to assess the effectiveness of the orthotic device, but to demonstrate any possible modification of tonic postural activity.

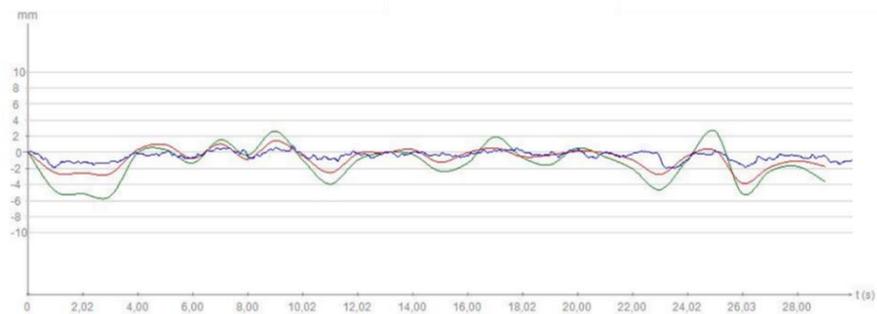
The parameters chosen for this presentation are the graphical visualization of the anteroposterior oscillations, movements of the line of the posterior superior iliac spines (PSIS) in the frontal plane and sagittal variation of the kyphosis angle and lordosis angle that allows us to observe movement of the trunk in its verticality.

Antero-posterior movements

The blue line represents movements of the body's centre of pressure on the ground, the red line represents movements at L5 and the green line represents movements at C7. Amplitude is on the Y-axis and time is the X-axis.



Subject A in natural upright standing position.

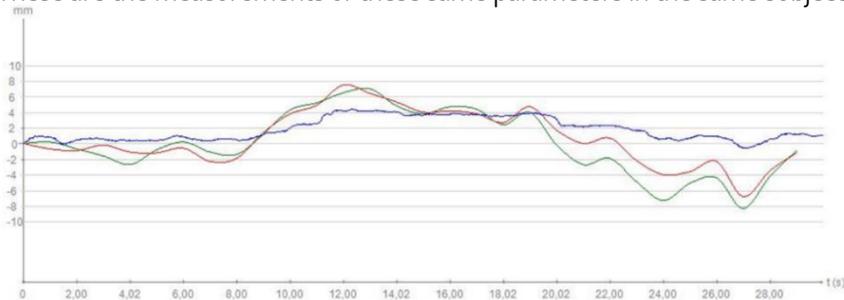


Subject B in natural upright standing position.

You can see that the signal is clearly present and represents the oscillations.

We all know that, in the anatomo-morphological analysis, tonic postural activity always varies between humans and it is now possible for us to measure it, which will inform the debate about the real or possible existence of a reference.

These are the measurements of these same parameters in the same subjects with insoles.



Subject A in upright standing position with insoles.

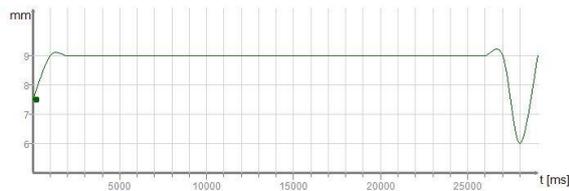


Subject B in upright standing position with insoles.

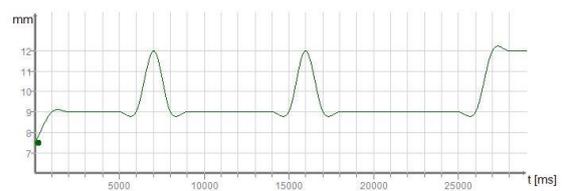
While interpretation of these graphs is not the purpose, the reader can easily see that there is difference in tonic activity between the two situations for each of the subjects.

Posterior superior iliac spine line (PSIS) movements

The line on the graph shows the movement of the most mobile PSIS relative to the other. In fact, a perfectly straight line represents a motionless pelvis, which could be described as stable even though the PSIS line may not be horizontal in average posture.

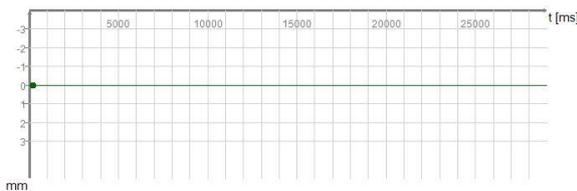


Subject A without insoles

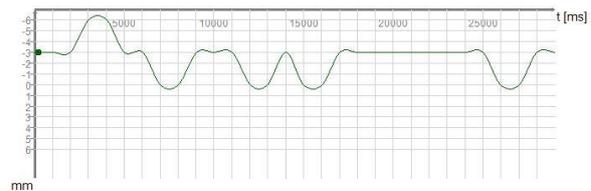


Subject A with insoles

For Subject A, the graph with insoles shows of elevations of the right PSIS in relation to the left PSIS every 10 seconds. The pelvis has become less stable.



Subject B without insoles



Subject B with insoles

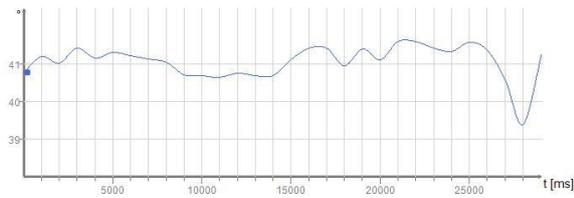
For Subject B, the graph with insoles shows fairly frequent elevations of the left PSIS in relation to the right PSIS. The pelvis has become unstable.

Note that the signal variations are around 6 millimetres and therefore imperceptible to the naked eye. Their presence, or absence, is an important factor in the personal organization of tonic postural activity and the response to stimuli.

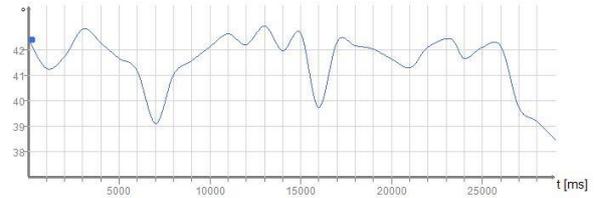
Movements of the sagittal curves

We have chosen to show you these parameters because we all know their importance and role during an activity in motion. During a clinical or radiological examination, the angular value of dorsal kyphosis and lumbar lordosis is only used for descriptive purposes as if it were fixed. Video rasterstereography brings a new dimension: variations in these parameters in the subject in upright standing position which can be compared to the vertical movements of the piston of a shock absorber. A disturbance of these parameters may, for example, direct the therapist towards the presence of intervertebral disturbances that will prevent effective action during treatment from other postural inputs.

Kyphosis variation

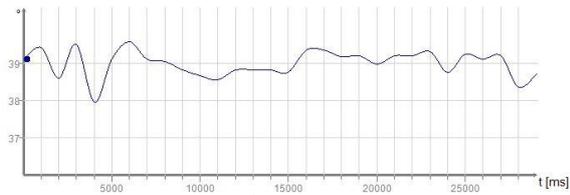


Subject A without insoles



Subject A with insoles

Lordosis variation

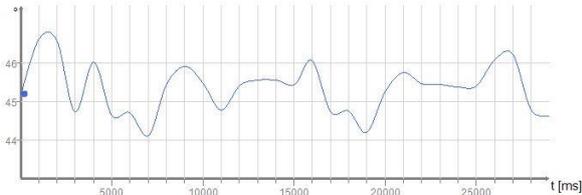


Subject A without insoles

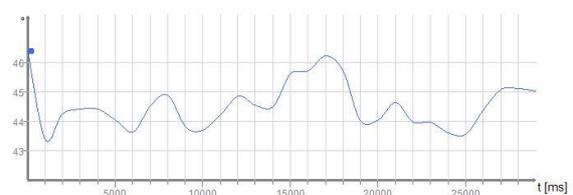


Subject A with insoles

Kyphosis variation

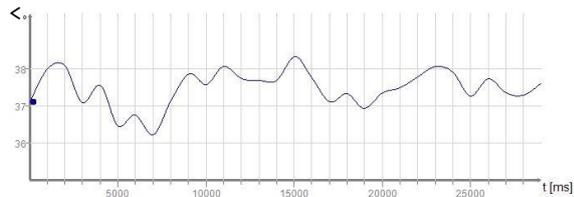


Subject B without insoles

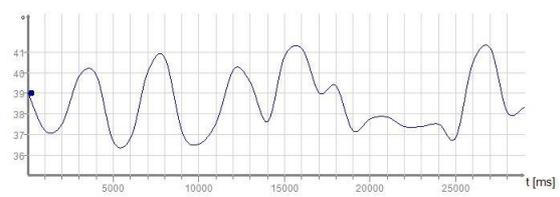


Subject B with insoles

Lordosis variation



Subject B without insoles



Subject B with insoles

Once again, the variations in frequency and amplitude are obvious. Above all, it should be noted that their rate is much higher than the respiratory rate and that it cannot be attributed to it. We should also note that might imagine there is a certain synchronicity in the kyphosis and lordosis variations. These recordings prove otherwise and show the individualised character of the organization of the tonic postural activity.

Conclusion.

Video rasterstereography, with its strict methodology, offers a new approach to health strategy and to the interpretation of health balance measured objectively with reliable reproducibility. This tool does not dispense with practitioners who have extensive knowledge in the fields of anatomy, biomechanics, neurosciences, biophysics, etc.

To offer a care strategy, the holistic approach requires a complete personal and family history as well as a controlled clinical examination. But any strategy requires control. And that is precisely why a tool is essential. But the reader should not be mistaken: a tool can only be qualified if it allows reliable comparison that is not operator-dependent. When an optical imaging device allows comparison based on the average calculation of two situations (videogrammetry) and not based on comparison of two instantaneous images taken randomly in the oscillatory cycle (photogrammetry), then it can be qualified as a tool.

The healthcare industry is gradually integrating it and, in 2019, teachers of the inter-university diploma in Clinical Posturology approved the first dissertation introducing 4D optical imaging as a relevant tool for this discipline (Edmond Le Borgne). Posturology is a multidisciplinary approach that will enrich our thinking. Neuroscience, a discipline that looks at postural changes according to different sensors, is at the heart of this presentation.

As in many fields, posturology needed to mark an evolution. Who could have predicted that one day a non-irradiating medical device would be able to capture reliable oscillations and angular values? And that from morphometric analysis we could obtain measurements that could be used in the field of biomechanics and neurosciences by various different healthcare professionals?

Video rasterstereography is in no way a substitute for radiographic imaging but it serves as a valuable complementary tool in the field of functional medicine. Whoever the healthcare player (functional medicine, physiotherapist, osteopath, posturologist, orthoptist, chiropract, dentist, orthodontist, occlusodontist, occupational therapist, ergonomist, sports specialist, neuroscientist, etc.), they all need objectivity. The patient requires an understanding, we must respond to this legitimate wish. Understanding strengthens adherence to the treatments offered and to medical follow-up, which is the key to the quality of future care.

Detection and better understanding also ensure well-being and avoid a downward spiral for individuals and the community. Postural biometry is an examination that helps control the social and financial cost of public health. It is a solution that finds its place in the context of preventive, corrective and/or curative medicine and can be used as an information and communication technology tool for the medicine of tomorrow.

We all have a role to play, not least sharing our technological developments.

Bibliography.

Literature on technology

- M. Betsch et al.: The rasterstereographic-dynamic analysis of posture in adolescents using a modified Matthiass test, in: *European Spine Journal* Nr. 43, 2005, S. 331–341.
- Carr, A.; Jefferson, R.; Turner-Smith, A. (1989). Surface stereophotogrammetry of thoracic kyphosis. *Acta Orthop Scand.* 04, 60(2), 177-180
- Conversation with Paolo Raimondi on vertebral rotation, recorded in October 2010. Faculty of Sports Sciences of the University of Aquila.
- Drerup, B. (1982). Measurement of kyphosis using moiré topography. *Biostereometrics '82 / SPIE* 361, 101-110
- Drerup, B. (1984). Principles of Measurement of Vertebral Rotation from Frontal Projections of Pedicles. *Journal of applied Biomechanics* 17, 923-935
- Drerup, B.; Hierholzer, E. (1987). Movement of the human pelvis and displacement of related anatomical landmarks on the body surface. *Journal of applied Biomechanics* 20, 971-977
- Drerup, B.; Hierholzer, E. (1996). Assessment of scoliotic deformity from back shape asymmetry using an improved mathematical model. *Clin. Biomech.* 11, 367-383
- Duval-Beaupère G, Schmitt C, Cosson Ph. A barycentremetric study of the sagittal shape of spine and pelvis. *Ann Biomed Engineer* 1992;20:451-62.
- Frobin, W.; Hierholzer, E. (1978). Rasterstereography: A stereophotogrammetric method for the measurement of body surfaces using a projected grid. *Proceedings of the society of photo-optical instrumentation engineers* 166, 39-44
- Frobin, W.; Hierholzer, E. (1981). Rasterstereography: A photographic method for measurement of body surfaces. *Photogrammetric Engineering & Remote Sensing* Nr 47, S. 1717-1724 PMC 6853417
- Frobin, W.; Hierholzer, E. (1982). Calibration and model reconstruction in analytical close-range stereophotogrammetry. Part I: Mathematical fundamentals. *Photogrammetric Engineering & Remote Sensing* 48, 67-72
- Frobin, W.; Hierholzer, E. (1983). Automatic measurement of body surfaces using rasterstereography. Part II: Analysis of the rasterstereographic line pattern and 3-D surface reconstruction. *Photogrammetric Engineering & Remote Sensing* 50, 1443-1452
- Frobin, W.; Hierholzer, E. (1986). Mathematical representation and shape analysis of irregular body surfaces. *Biostereometrics '82 / SPIE* 361, 132-139
- Frerich J, Hertzler K, Knott P, Mardjetko S. Comparison of Radiographic and Surface Topography Measurements in Adolescents with Idiopathic Scoliosis. *Open Orthop J.* 2012;6:261-265.
- Graf H, Hecquet J, Dubouset J. Three-dimensional approach to spinal deformations [3-dimensional approach to spinal deformities]. *Rev Chir Orthop* 1983; 69: 4074-416.
- Guigui P, Levassor N, Rillardon L, Wodecki P, Cardinne L. Physiological value of pelvic and spinal parameters of sagittal balance: analysis of 250 healthy volunteers. *Rev Chir Orthop* 2003 ; 89 : 496-506.
- L. Hackenberg et al.: Rasterstereographic back shape analysis in idiopathic scoliosis after posterior correction and fusion, in: *Clinical Biomechanics* Nr. 18, 2003, S. 883–889
- Hierholzer, E.; Lüxmann, G. (1982). Three-dimensional shape analysis of the scoliotic spine using invariant parameters. *Journal of applied Biomechanics* 15, 595-598
- Patrick Knott, PhD, PA-Ca, *, Peter Sturm, MDb, Baron Lonner, MDc, Patrick Cahill, MDd,1, Marcel Betsch, MDe,2, Richard McCarthy, MDF, Michael Kelly, MDg, Lawrence Lenke, MDh,3, Randal Betz, MD, Multicenter Comparison of 3D Spinal Measurements Using Surface Topography With Those From Conventional Radiography *Spine Deformity* 4 (2016) 98e103, USA.
- Legaye J, Duval-Beaupère G, Hecquet J, Marty C. Pelvic Incidence: a fundamental pelvic parameter for three dimensional regulation of spinal sagittal curves. *Eur Spine J* 1998;7:99-103.
- Liljenqvist, U.; Halm, H.; Hierholzer, E.; Drerup, B.; Weiland, M. (1998). 3- dimensional surface measurement of spinal deformities with video rasterstereography. *Z Orthop Ihre Grenzgeb.*;136(1), 57-64
- M Mangone, P Raimondi, M Paoloni. Vertebral rotation in adolescent idiopathic scoliosis calculated by radiograph and back surface analysis-based methods: correlation between the Raimondi method and rasterstereography. *Eur Spine J* 2013;22:367-71.

- Mardjetko S, Knott P, Rollet M, Baute S, Riemenschneider M, Muncie L. Evaluating the reproducibility of the formetric 4D measurements for scoliosis. *Eur Spine J.* 2010;19:241-242.
- Schulte TL, Hierholzer E, Boerke A, Lerner T, Liljengvist U, Bullmann V, Hackenberg L. Raster stereography versus radiography in the long-term follow-up of idiopathic scoliosis. *J Spinal Disord Tech.* 2008;21(1):23-28.
- Tabard-Fougère A, Bonnefoy-Mazure A, Hanquinet S, Lascombes P, Armand S, Dayer R. Validity and Reliability of Spine Rasterstereography in Patients With Adolescent Idiopathic Scoliosis. *SPINE.* 2016;42(2):98-105.
- Takasaki, H. (1970). Moiré topography. *Appl Opt.* 1970 06 1;9 (6), 1467-1472.
- Turner-Smith, A.; Harris, J.; Houghton, G.; Jefferson, R. (1988). A method for analysis of back shape in scoliosis. *Journal of applied Biomechanics* 21 (6), 497- 509
- Vaz G, Roussouly P, Berthonnaud E, Dimnet J. Sagittal morphology and equilibrium of pelvis and spine. *Eur Spine J.* 2002;11:80-87.
- Weiss HR., Seibel S. Can surface topography replace radiography in the management of patients with scoliosis ? *Hard Tissue* 2013 Mar 22;2(2):19.
- Xenofoss, S.; Jones, C. (1979). Theoretical aspects and practical applications of moiré topography. *Phys. Med Biol.* 03; 24(2), 250-261

Literature on posture

- BARON J.B statokinesimetry (study of human vertical posture) *Ann.Kinésithér.*1982, 9,377,388
- Gagey P.M. Baron J.B., Ushio N. (1980) Introduction to Clinical Posturology. *Agressology*, 21, E, 119-124
- Gagey ABC of Stabilometry
- Gagey, P.M., and B. Weber. 2004. Posturology. Standing regulation and disturbances. editing. Paris: Masson.
- Gagey PM (2016) Specifications of the Clinical Stabilometry Platform « ADAP_Normes13 ». *MTPRehabJournal*, 14: 332-341
- GASQ David How is stabilometric data used in clinical practice? *ADP 2015 Review*
- Hamaoui Alain Posture, balance, movement: role of trunk mobility on posturokinetic capacity November 2016 *Neurophysiologie Clinique/Clinical Neurophysiology* 46(4-5):237 DOI: 10.1016/j.neucli.2016.09.004
- McIlroy, W.E., et B.E. Maki. 1997. Preferred placement of the feet during quiet stance: development of a standardized foot placement for balance testing. *Clin Biomech (Bristol, Avon)* 12 (1): 66-70.
- Le Borgne Edmond Posturologie-Imagerie Optique Posturale IUD in *Clinical Posturology* 2019
- Thoumie Philippe role of peripheral afferents of the lower limbs in balance recovery. *Experimental and clinical study /; under the direction of Simon Bouisset / [s.l.] : s.n.*, 1993
- *Pratiques en posturologie clinique*, Book originally designed by B. Weber † (1927 - 2013) coordinated by A Scheibel, Françoise Zamfirescu, PM Gagey and Ph Villeneuve.