STATIC AND DYNAMIC POSTURAL CONTROL IN SINGLE STANCE

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What is posture?
Posture is the prolonged keeping of a body position. In order to understand the meaning of posture it’s necessary to remember that man is an unstable structure, continuously fighting against the force of gravity not to fall. This situation of constant instability fosters a greater dynamism, as a subject with unstable balance can move much more easily than one in stable balance. In man and many other animals mobility has been favoured at the expense of stability.

In static conditions we can distinguish a few main postures:
- Standing up
- Sitting down (considered as a variation of the previous one)
- Horizontal

With the exception of the horizontal position, we therefore mean the way with which the body opposes the force of gravity in order to maintain a position and to interact with the surrounding.

What would happen if…..
….the afferent fibres that carry the proprioceptive signals from the knee to the spinal cord were cut? The standing subject would fall on the ground and he would fall forward as our centre of gravity is placed in front, so to foster dynamism.
Posture maintenance needs a continuous “tonic” contraction of antigravity muscles in order to oppose the action of the force of gravity. In fact these muscles contract and respond to the signals coming from the stretching of the neuromuscular spindles; if the afferent ways are interrupted, the reflex contraction would become impossible and the standing or sitting subject would fall on the ground.

In hominids (that is in primates that walk upright) some elaborate subcortical mechanisms provide for a continuous readjustment of the postural situation both in static and dynamic conditions.

Archeoproprioception and proprioception
In order to understand how these mechanisms take part in postural control, it’s necessary to shortly go over the evolution of the concept of proprioception. In 1906 Sherrington introduced the term “proprioception”, defining it as the flux of signals coming from the proprioceptors and reaching the spinal cord to give origin to reflexes. In the following decades, several authors have given the word proprioception more than one meaning, sometimes even contrasting ones; they always confine themselves to taking in consideration only the conscious component and they leave out the unconscious component, probably for the lack of means suited to the study and the understanding of it. Riva (2000) has introduced the concepts of archeoproprioception and proprioception, also with the terminological distinction between the conscious and unconscious component of the afferent proprioceptive flux. He also underlines the importance of the nervous areas, where the signals arrive. With the term “archeoproprioception” we refer to the flux of signals originating from the peripheral proprioceptors and reaching the most primitive structures of the nervous system: the spinal cord, the midbrain and the primitive part of the cerebellum (pic.1). Such structures are referred to as subcortical because they are not under the control of conscience.

On the other hand “proprioception” is the conscious representation of the sense of position and of joint movement. The signals that pass the subcortical filter and reach the cortex to originate proprioception are only one millionth part of the proprioceptive signals.
flux coming from the periphery. The conscious component has therefore a very small effect on movement quality and on joint functional stability.

The systems of postural control
Postural control and imbalance management, that is the skill to manage high instability situations close to the point where balance cannot be regained anymore, are based on the coordinated and synergic intervention of the archeoproprioceptive, visual and vestibular mechanisms (fig.2).

The **archeoproprioceptive** system is the “intelligence”, that is an information peripheric widespread service with several sensors in every muscular-tendineus-articular area, capable of transmitting informations to the nervous centres at spinal and midbrain level at very high speed (it uses the fastest and biggest nervous fibres: 80 –120 m/s). At the same time this system is involved in the effector response, as the fine muscular response modulation depends on the neuromuscular spindles. The earliest postural reactions are activated by the archeoproprioceptive afferences and they lack when these afferences are withdrawn.

The **visual system** is a proper system that allows to “secure” the body to fixation points, with the improvement of the precision of postural control, which is based on the archeoproprioceptive information only. In fact with open eyes the head lateral oscillations exceed just a few millimetres, whereas with closed eyes they increase in size and frequency.

The latero-lateral or antero-posterior oscillations of the head entail some representation micromovements of the visual fixation point on the retina. The visual system detects the micromovements and starts the postural adjustments in order to restore the image at the starting point.

The **vestibular system** is the most belated mechanism to come into play, as it has a higher activation threshold. The greater latency of this system allows the "precision system" (archeoproprioceptive + visual) to manage the postural situations in a most refined way. Therefore it represents an “emergency” means that surpasses the other two systems when the head movements exceed a certain range and speed.

Dynamic and postural control
With dynamic postural control we refer to an artificial condition that allows to evaluate the degree of postural control (dynamic posturometry) while the subject is in single stance on a support on the ground that moves continuously (pic.6) and which consists of a rocking-platform (pic.3) with visual feedback (pic.3a). This kind of condition doesn’t reproduce any kind of movement or human activity and is in reality highly specific in order to evaluate and to reprogram the functionality of the subcortical centres which are appointed to the movement and postural control in all conditions.

**Postural strategies**
If we confine ourselves to evaluating the postural behaviour in standing position and in static conditions we are like test drivers of cars in a courtyard. In fact it’s obvious that the “mission critical moments” of the postural control systems are the

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**POSTURAL CONTROL SYSTEMS**

- **Archeoproprioceptive**: the quickest
- **Visual**: the most precise
- **Vestibular** *: the most belated, violent and inaccurate

* Precision system
* Emergency system

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Picture 2  By Riva D., Trevisson P.: Sport&Medicina, 4, 2000 (modified).
POSTURAL CONTROL STRATEGIES

A. Archeoproprioceptive-visual
B. With upper limbs compensation
C. Vestibular

The archeproprioceptive strategy allows the most refined postural control. It’s a constant feature of the big champions of any sport, but it can be easily acquired by everyone.

The subject keeps his head and trunk almost still while the supporting lower limb moves with high frequency in order to manage the instability situation (pic. 7- A). This way the vestibular system is in a state of rest and doesn’t interfere with the refined management of motor behaviour, based on the consistency of the signals coming from the other two information systems.

With the fast position changes and the accelerations that the head undergoes, the vestibular strategy prevails and it becomes the main system to manage instability. It is an inaccurate control with higher latencies and is based on continuous movements and countermovements of the trunk, of the hips and upper limbs, that are always exaggerated in comparison with the biomechanical situation that has to be managed (pic. 7- B).

In the upper limb compensation strategy the subject keeps the trunk relatively still by using the arms as a rudder (pic. 7 – C). This strategy is used with an inadequate archeoproprioceptive strategy in order to stabilize the system and to limit the vestibular intervention.

Visual and subcortical feedback and tracking

At this point it’s advisable to explain the meaning of visual feedback in real time coming from the rocking-platform and from the “vertical controller”, during the management of instability situations.

The visual feedback remarkably increases the number the biomechanical situations that the supported subject has to manage in the unit of time. The inclination-translation of the platform that is conveyed by the track on the monitor every second “hooks” the subcortical centres to a new situation to be managed (pic. 3a and 6). A Freeman platform without visual feedback allows to work only at low frequencies. The consequence of high frequency translations management is the high flux of signals to the nervous centres that are trained to interpret them correctly and to give adequate answers in a faster and faster way. It is a very useful exercise of simultaneous translation of the proprioceptive signals for the nervous centres. It’s a real “full immersion” course. In a similar way, a pilot of an economy car for the low number of situations to manage in the unit of time.

In the past these postural strategies have been referred to as “ankle” or “hip”, according to the anatomical district that was involved most. Today we think it’s possible and above all more correct to distinguish them according to the involved functional systems. With the use of a system (Delos Postural System pic.3) consisting of a rocking Delos Equilibrium Board (DEB) and a postural control reader called “Delos Vertical Controller” (DVC), both with visual feedback in real time, it’s possible to discover the static and dynamic postural control of a subject and to quantify the functional stability degree of his lower limbs and system spine-pelvis. DVC is an instrument that records and shows the trunk angular movement in latero-lateral and antero-posterior direction in real time, and is placed in front on the sternum (pic.4) or at the back below the seventh cervical vertebra. Not only it gives typical information of the stabilometries that can be used in standing position and in static conditions; it also allows the analysis in single stance in a dynamic situation. The simultaneous monitoring in real time of the platform basculogram and the trunk posturogram allows to understand the system behaviour and to locate the lacking functional districts, with the chance to give the subjects one or more visual feedbacks related to the movement components that the operator believes more advisable to show.

A subject in single stance manages all instability situations by using the three following strategies (pic.5):
- Archeoproprioceptive-visual
- Upper limb compensation
- Vestibular

In a similar way, a pilot of an economy car for the low number of situations to manage in the unit of time.
The visual feedback “hooks” the subject to the subcortical centres, increasing the frequency and precision of the corrections. The high frequency of the fulcrum translations puts the postural control system in crisis and at the same time reprograms it.

The employment of a mirror as a visual feedback tool of the platform inclination-translations has no use, this being a complex information and not a punctiform one, and this requires the long time of the cortical elaboration before it can be used. In this condition there cannot be the subcortical link and the synchronization of the visual information with the proprioceptive information.

**Hypokinesis**

Studies by Riva et coll. at the Research Centre of Turin Interfaculty School of the University on Motor Sciences make us suppose that the progressive reduction of motor experiences (hypokinesis) that is typical of western people, can lead both to a progressive proprioceptive deficit with functional instability of the joints and to a reduced balance skill with consequent postural and movement uncertainty, also in the absence of ligamentous and joint damage. This situation leads to a choice of simplified motor tasks and a further deterioration of hypokinesis (pic.8). This “non-use” regression is confirmed by the fact that after very short training periods (just a few minutes for each leg in single stance) with an electronic rocking platform with visual feedback there is an improvement of the static and dynamic postural control, with an important recovery of movement self-sufficiency and

![Graphical representation](image-url)

*Image 6 The visual feedback “hooks” the subject to the subcortical centres, increasing the frequency and precision of the corrections. The high frequency of the fulcrum translations puts the postural control system in crisis and at the same time reprograms it.*

*Image 7 Postural control strategies. The blue track (dynamic posturogram) represents the trunk inclinations in the frontal plane recorded by DVC (30" trials: the windows represent 10"'). The subjects are in single stance on a DEB electronic rocking-platform (the platform basculegram is not shown but it’s always recorded by the system). The subject does the test with the only visual feedback related to the platform translations. A and B have their hands on their hips (by Riva D., Trevisson P.: Sport&Medicina, 4, 2000). The picture with the asterisk is enlarged in picture 6.*
The skill development to use the proprioceptive signals to an unconscious level represents an important tool not only of post-traumatic or post-operation rehabilitation type, but also as an effective means of prevention or restoration of motor skills with a non-use regression (a progressive reduction of movement self-sufficiency, choice of simplified motor tasks, risk of falls, osteoporosis).

**Athletes and functional regression**

A non-use regression with a choice of simplified motor tasks can also occur in high-standard athletes that train several hours every day. In a study presented at the III Congress on Medicine and Sciences on Figure Skating (March 2000), Riva et coll. have demonstrated how a simple change of the competition rules can lead the big champions of this sport to a functional regression, due to the lack of specific stimuli for the stress of the most refined postural control systems (Pic. 9). As a consequence, the athletes choose tasks that don’t involve the postural control systems in regression (the archeo-proprioceptive-visual ones) and they increase instead the difficulty level of the exercises that employ the roughest system (the vestibular one).

**Dynamic postural control and functional stability of the lower limb**

The degree of the dynamic postural control in single stance represents the *litmus paper* of the lower limb functional stability: in fact there cannot be a refined dynamic postural control with a compromission of the functional stability of the support limb. The functional instability in fact implies a regression of the postural control quality, with the use of “vestibular-type” strategies (Riva 2000).

At the same time, with a rough postural control, whatever the origin, there will be an inadequate functional stability of the lower limb. With rough postural strategies there cannot be a refined adjustment of the lower limb stabilizing mechanisms, even if it is anatomically healthy. Therefore an inadequate postural control is always a sign of functional instability of the lower limb even without a district pathology.

**Static posturometry**

In order to proceed in the evaluation and reprogrammation of the visual-archeoproprioceptive system it is very important to exclude the presence of faults of the visual pointing system or the vestibular system.

The test is defined as “static posturometry” and is carried out in single stance on a stable surface (Pic. 11) in three different conditions:

- with open eyes without visual feedback
- with shut eyes
- with open eyes with visual feedback

In normal conditions, with shut eyes the oscillations increase in frequency and extent (Pic. 12 – eyes shut x, y, 2D). The best performance as to an axis-target is generally achieved with visual feedback. On the other hand the best degree of postural stability can be found without visual feedback, when the subject can place...
himself on his usual postural axis and cling to a static fixation point.

**Exclusion of vestibular problems**
In these three conditions the normal stance test allows to point out any problems of vestibular type. In fact, in these cases the oscillations extent is bigger and it increases even more with shut eyes. The single stance test is even more responsive. It is performed with great difficulty by subjects with vestibular problems and with eyes shut.

In the dynamic posturometry test (DEB + DVC) these subjects can perform well, as they are trained not to use the vestibular system and its pathologic demands but to use spontaneously the archeoproprioceptive-visual system.

**Exclusion of visual problems**
Minor oscillations, that are recorded by the DVC with eyes shut indicate a possible situation of disturbance of the visual signals on the archeoproprioceptive control, with the worsening of the postural stability in static conditions, compared to the situation with open eyes. It’s in fact sufficient a reduction of the visual sharpness to increase the number of postural oscillations. In the elderly, sight problems can have a greater destabilizing effect than a concurrent degenerative pathology of the lower limb.

**Conclusions**
> The postural control depends on the coordinated intervention of archeoproprioceptive, visual and vestibular mechanisms.
> The postural analysis in normal stance and in a static situation doesn’t allow the evaluation of the archeoproprioceptive-visual control system.
> For a proper evaluation and an effective rehabilitative intervention it’s indispensable to present some instability situations in single stance and with visual feedback, meant as a high frequency functional activator of the involved systems (dynamic posturometry).
> The visual feedback can be about the postural control, the control of the causes of the instability situation, or both.
> In the archeoproprioceptive-visual system calibration, the platform feedback (task difficulty) is privileged; the DVC recording reads the postural dynamic control quality instead.
> In the subjects with a prevailing vestibular strategy, the postural control feedback (DVC) is proposed at first in order to reduce the vestibular system intervention; afterwards the DEB feedback is combined with the postural
one in order to increase the destabilising effect (task difficulty) and to refine the archeoproprioceptive visual system.

The several feedback combinations in dynamic and static conditions are an evaluative and rehabilitative tool, that is very powerful, adaptable and able to recalibrate the subcortical control mechanisms and those of articular stability.

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