The postural system as a functional venous pump

V.I. Usachev
Institute of Osteopathic Medicine named after V.L. Andrianov, St. Petersburg

In 1990, Inamura K and Coll. [1] published an article on the relationship of venous return to the heart with slow postural sway with a period of 0.012-0.022 Hz (83.3-45.5 seconds). The result was obtained using the plethysmography technique. In 1999, the same authors wrote about the role of Postural Sway as a compensatory Mechanism for Gravitational Stress on the Cardiovascular system [2].

We tried to clarify the functional role of the postural system as venous pump, using the technique of duplex ultrasonic scanning of crural veins.

Methodology.

During the experiment, the venous blood flow of two healthy subjects was studied at the V. poplitea level which collects blood from almost the entire shin, including M. gastrocnemius, and the soleal sinuses. These muscles form the triceps muscle of the shin, which is the main one in the function of the venous pump.

The diameter of veins in mm, the linear velocity of blood flow in cm/s, and the volume velocity of blood flow in ml/s were studied. The comparative characteristic of the volumetric flow velocity in the performance of eight tests was analyzed.

Sequence of tests:

1) ***Lying*** - lying on the back, on a table with legs on the back of the chair for the convenience of installing the sensor. The gravitational vector acted transversely to the body.

2) ***Sitting*** - sitting on the table, shanks hanging from the table, the feet did not touch the floor. The gravity vector acted in the longitudinal direction relative to the body and legs.

3) ***« Sitting fingers »*** plantar flexion of the toes

4) ***« Sitting foot »*** plantar flexion of the foot (one movement in 3 seconds);

5) ***Standing*** - standing with closed eyes to increase the amplitude of the postural sway.

6) ***Standing Forward*** - tilt the body forward to the limit of stability.

7) ***Standing Left*** - tilt the body to the left to the limit of stability in 3 seconds;

8) ***Walking*** - is an imitation of walking on the spot lifting the heel and supporting on the toes.

The study was conducted in a highly qualified center for radiation diagnosis in St. Petersburg.

Results.

First, we looked at the volumetric velocity of blood flow in all tests of V. poplitea (Fig.1) and soleal sinuses (Fig. 2).

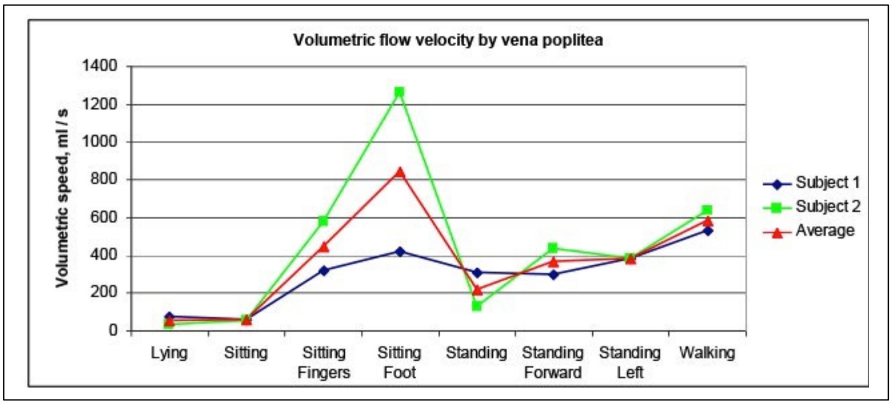

Fig. 1. Volumetric flow velocity by vena poplitea.

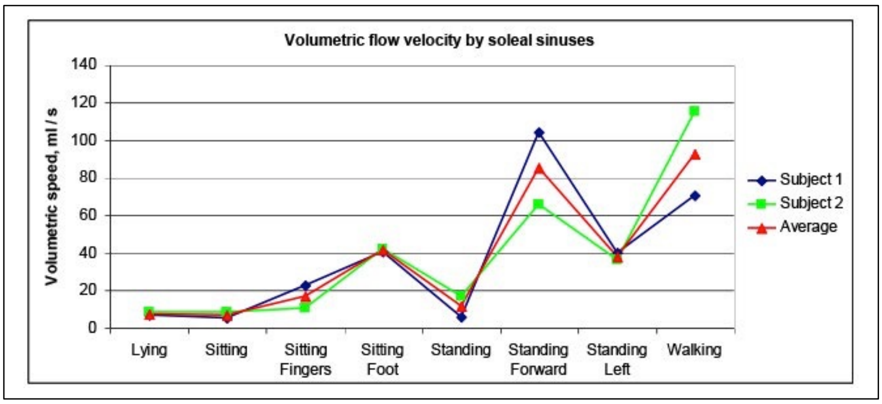

Fig. 2. Volumetric flow velocity by soleal sinuses.

Despite the differences in the values of the velocity of volumetric blood flow in different veins and in different subjects, the blood flow in the corresponding tests is almost identical.

The main objective of the experiment was to compare the blood flow in various tests in percent relative to its values during imitation walking. Therefore, we analyzed the relative mean values for both veins in the two subjects.

In the standing position with closed eyes, the volume velocity of the blood flow, and hence the efficiency of the venous pump, was four times less than that of the imitation of walking and 2.7 times more than lying down. In the sitting position on the table, the feet not touching the floor, the volumetric flow velocity decreases somewhat due to the action of gravity on the body and the tibia in the longitudinal direction (Fig. 3).

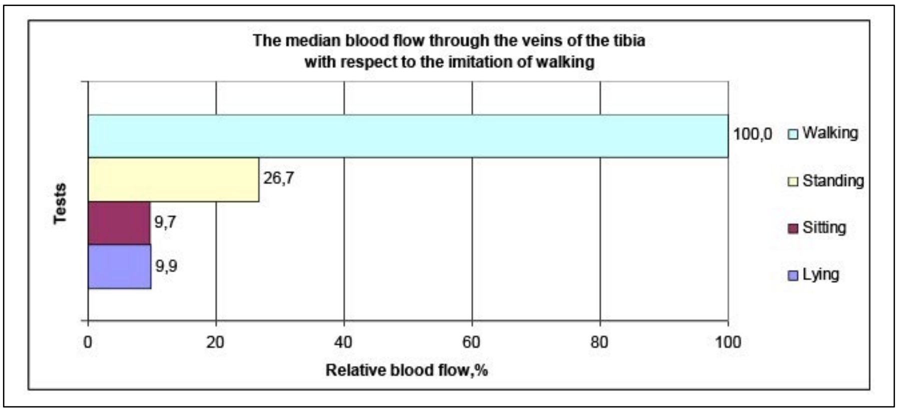

Fig. 3. Average values of volumetric blood flow in vena poplitea and soleal sinuses in the tests standing, sitting and lying in relation to the imitation of walking.

It can be assumed that, with natural walking, the difference with other samples would be even greater, but in this case, it is practically impossible to register the blood flow by the apparatus for technical reasons.

Hence, the venous pump in the standing position is functioning, but much worse than when walking. Its activation is probably associated with a constant switch of muscles to ensure dynamic stabilization of the body.

The pronounced activation of the venous pump occurs with a rapid contraction of muscles, which follows from tests No. 3,4,6,7. The graph of bulk blood flow in all samples relative to the sample with imitation of walking confirms this (Fig. 4).

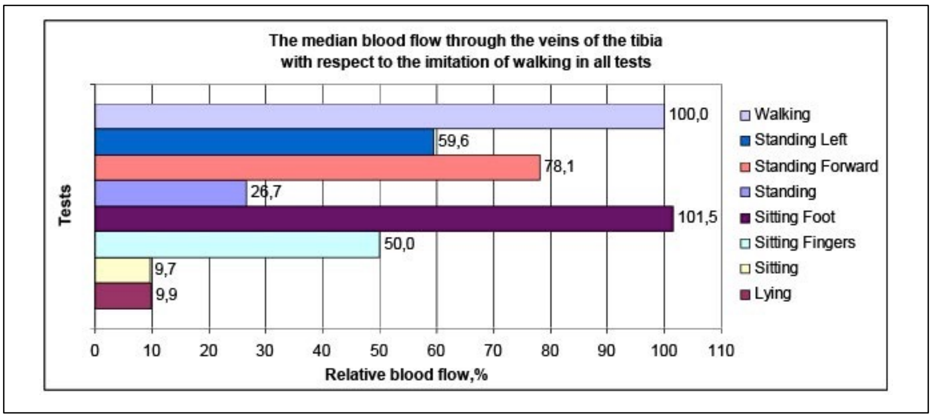

Fig. 4. Average values of volumetric blood flow in vena poplitea and Soleal sinuses in all tests for the test with imitation walking.

A plantar flexion of the toes brings about 50% of the activity of the venous pump in relation to walking Plantar flexion of the entire foot gives the same result as walking. A quick tilt of the body forward brings about 78% of the activity of the venous pump in relation to walking, and the inclination to the left: 60%.

After such a result, a natural question arose: what will be observed with a very slow deviation of the body forward ?

I conducted such an auto-experiment. I very slowly (within 20 seconds) leaned forward to the limit of stability, trying to do it evenly. The figure 5 shows the record of blood flow in V. poplitea.

Despite trying a smooth body inclination, the movement was still uneven. The graph of the linear velocity of blood flow determines several peaks at the beginning and a gentle hump at the end of the record, due to an increase in the rate of deflection of the body.

The linear velocity of blood flow in this case approximately corresponded to Standing steady with closed eyes (Fig. 6).

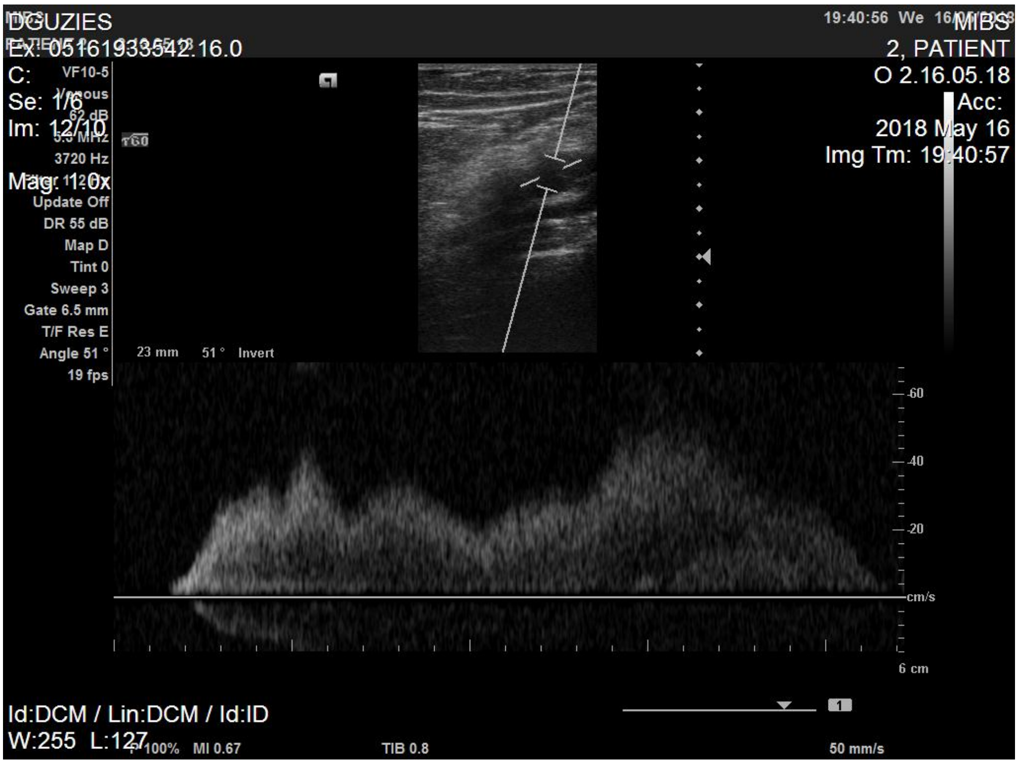

Fig. 5. Blood flow in V. poplitea with a slow deviation of the body forward by 150 mm in 20 seconds (approximately half a period of slow postural sway)

Above the popliteal vein. Below is a graph of the linear velocity of blood flow. To the right of the graph is a scale of linear blood flow velocity in cm/s, at the bottom of the graph the time scale in seconds.

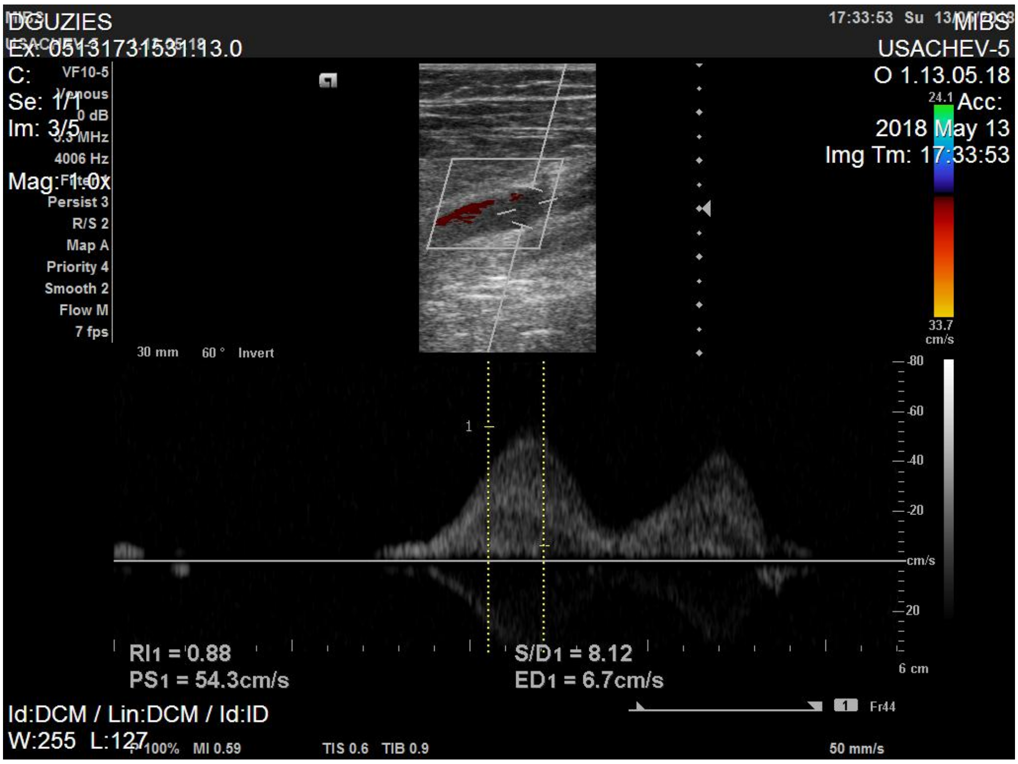

Fig. 6. Blood flow in V. poplitea in the vertical position of the body with closed eyes. Above the popliteal vein. Below is a graph of the linear velocity of blood flow. To the right of the graph is a scale of linear blood flow velocity in cm / s, at the bottom of the graph the time scale in seconds.

This graph also has two humps, which indicates the unevenness of the deviations of the body with a calm standing.

We also found out at which foot movement a greater venous return occurs, with a dorsal and a plantar flexion of the foot (Fig. 7).

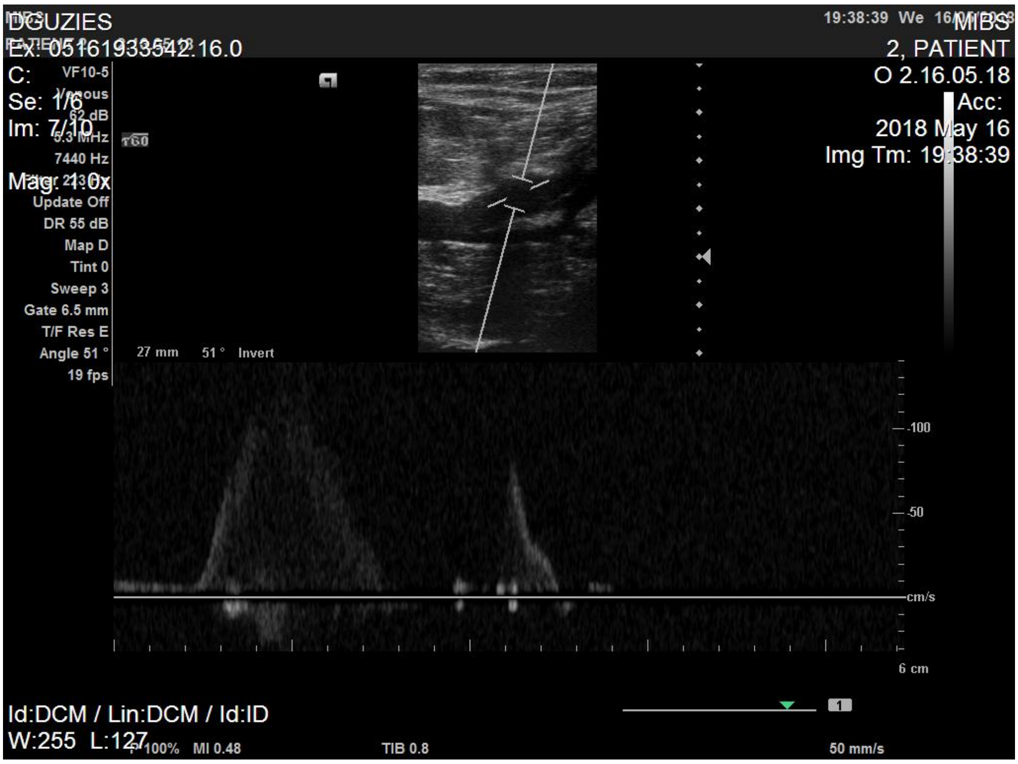

Fig. 7. Dynamics of the linear velocity of blood flow in the popliteal vein during a dorsal then a plantar flexion of the foot Above the popliteal vein. Below is a graph of the linear velocity of blood flow. To the right of the graph is a scale of linear blood flow velocity in cm/s, at the bottom of the graph the time scale in seconds.

With the dorsal folding of the foot, the linear velocity of the blood flow was 120 cm/s, and with the plantar flexion 80 cm/s.

And finally, we found out that when the body moves back and forth rapidly the velocity in the popliteal vein, when it moves backward, is half of that when it moves forward (Fig. 8).

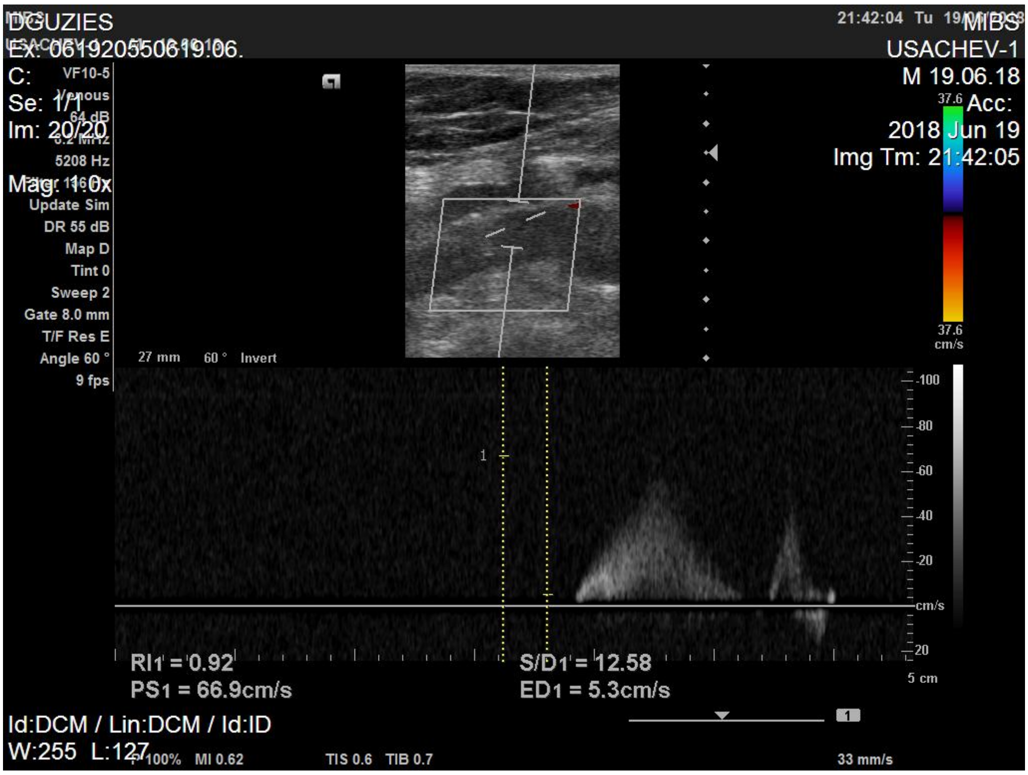

Fig. 8. Dynamics of the linear velocity of blood flow in the popliteal vein during rapid movement of the body back and forth. Above the popliteal vein. Below is a graph of the linear velocity of blood flow. To the right of the graph is a scale of linear blood flow velocity in cm/s, at the bottom of the graph the time scale in seconds.

With a slow movement of the body back and forth, the linear velocity of blood flow in the popliteal vein with the backward movement was only 10 cm / s, while at the forward motion it was 50 cm/s (Fig. 9).

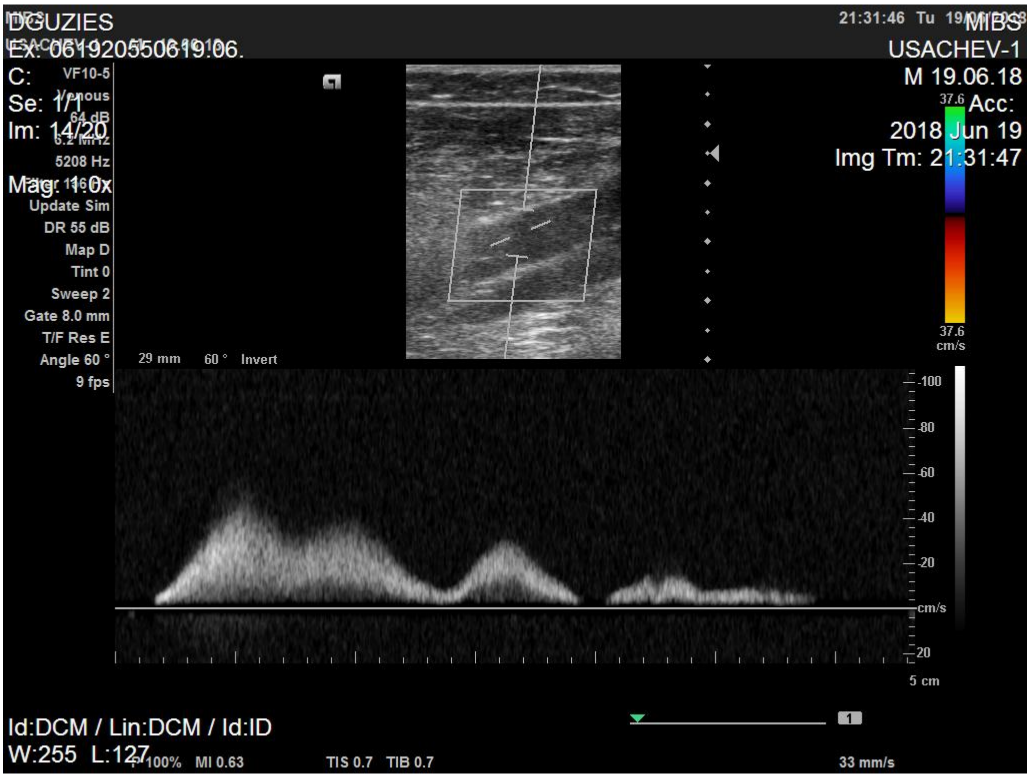

Fig. 9. Dynamics of the linear velocity of blood flow in the popliteal vein with slow movement of the body back and forth. Above the popliteal vein. Below is a graph of the linear velocity of blood flow. To the right of the graph is a scale of linear blood flow velocity in cm/s, at the bottom of the graph the time scale in seconds.

We did not manage to obtain a graph of the linear velocity along Soleal sinuses.

Conclusions.

1. The intensity of the venous pump is mainly determined by the rate of muscle contraction.

2. The venous pump is more effective during the imitation of walking, the dorsal folding of the foot and the movement of the body forward. With plantar flexion of the foot and movement of the body back, probably, the blood supply to the calf muscles occurs, which agrees with the data of Inamura K., Mano T., Iwaze S. (1990), obtained by means of impedance measurement.

3. With a quiet standing, the efficiency of the venous pump is 4 times worse than when imitating walking on the spot, but still 2,5 times better than lying and sitting.

4. It can be concluded that the postural system facilitates the return of venous blood to the heart, but the main function of the venous pump is with active foot, walking and running movements.

References

1.- Inamura K., Mano T., Iwaze S. (1990) One-minute wave of body sway related to muscle pumping during static standing in human. In Brandt T., Paulus W., Bles W. (Eds) Disorders of posture and gait 1990. Georg Thieme (Stuttgart), 53-57.

2.- Inamura K., Mano T., Iwaze S. (1999) Role of Postural Sway as a compensatory Mechanism for Gravitational Stress on the Cardiovascular system. Gait and Posture, 9, suppl.1, S5.