

**PRELIMINARY STUDY ON THE VALIDITY OF AN INSTRUMENTAL METHOD OF  
EVALUATING PROPRIOCEPTION IN PATIENTS UNDERGOING TOTAL KNEE  
ARTHROPLASTY**

STUDIO PRELIMINARE SULLA VALUTAZIONE DELLA PROPRIOCEZIONE NEI  
PAZIENTI OPERATI DI PROTESI TOTALE DI GINOCCHIO.

G.Felicetti\*, G.Chiappano\*\*, A.Molino\*\*, E.Brignoli\*, R.Maestri\*\*\*, M.Maini\*

Fondazione Salvatore Maugeri, IRCCS

Istituto Scientifico di Montescano (PV)

\*Divisione di RRF I , \*\*\*Servizio di Bioingegneria

\*\*Scuola di Specialità in Medicina Fisica e Riabilitazione – Università degli Studi di Pavia.

Guido Felicetti

Giovanni Chiappano

Alberto Molino

Elvira Brignoli

Roberto Maestri

Maurizio Maini

Address of the author to whom all correspondence and proofs should be sent

Guido Felicetti

Istituto Scientifico Riabilitazione

27040 Montescano (PV)

tel +39 0385 247221

fax +39 0385 61386

e-mail [gfelicetti@fsm.it](mailto:gfelicetti@fsm.it)

## INTRODUCTION

Until a few years ago, proprioceptive rehabilitation was only added as the last stage of a retraining programme, with the drawback that it was often neglected, particularly by the patient, who was convinced of having completely recovered function of the damaged limb. This was probably the consequence of the lack of knowledge about the physiological mechanisms that regulate proprioception and perhaps also of the belief that proprioception would reappear spontaneously during classical rehabilitation sessions without any specific proprioceptive retraining being carried out (1).

After any trauma, and even more so after arthroplasty of the knee, rehabilitation must be aimed not only at restoring "mechanical" stability, in this case the responsibility of the orthopaedic surgeons, but also "functional" stability. This can be achieved through a correct use of muscle stabilisers capable of creating real, active virtual strapping of the joint (2). It has, however, also been demonstrated that the functional stability of the lower limb and its joints depends on the support base experience situations of low stability at high frequency. Thus, high frequency destabilisation of the support base, through proprioceptive exercises, makes the whole lower limb more stable, rendering it better prepared to respond adequately to abnormal stimuli in both static and dynamic situations.

Surgical introduction of a prosthetic joint, such as that of the knee, interferes with the correct transmission of proprioceptive afferent information, complicating functional recovery of the lower limb. Several studies show that, after total knee arthroplasty, articular movement perception (3), guaranteed by quick-perception receptors, is altered, while articular position perception, carried out by slow-adapting receptors, is not particularly compromised (4).

According to Grob (5), there is a low relation between evaluation tests performed on knee movement perception and tests performed on articular position.

These data suggest that dynamic tests are fit for an accurate evaluation of proprioceptive sensitivity after knee arthroplasty.

Static tests performed on single joint appear not to be reliable for the correct evaluation of complex multi-joint control and perception (6 , 7).

A reliable test on proprioceptive sensitivity should be able to study polydynamic function; at present this goal is far to be reached because of the low reproducibility of the test, due to different variables, such as pain.

Matre (8) in a study performed on tibiotarsal joint points out that a painful stimulus experimentally induced, can compromise joint movement perception, but it does not influence the correct perception of static joint position.

Despite these profound changes, the potential for arthroproprioceptive motor control remains surprisingly very high. It is extremely important to carry out exercises in instability management, not only in the preparatory pre-operative stage, but particularly in the subsequent stage of rehabilitation. Such exercises reactivate the mechanisms of postural control that are already severely compromised by the preceding chronic degenerative joint disease and that will be further modified during surgery and the post-operative period.

However, at this point it is worth specifying that when talking about restoring afferent proprioception, this refers not only to a quantitative increase, but also a qualitative improvement. In fact, during chronic pathological conditions of the musculoskeletal apparatus, such as those necessitating a prosthetic knee joint, besides the quantitative reduction in the afferent information, inevitably there are also qualitative changes leading to the transmission of proprioceptive information which is inappropriate to allow the CNS to carry out an effective control function. These alterations are found in the joint predominantly affected ( in our case, the knee), but also in adjacent areas which are functionally inter-related in the overall movements of the lower limb; this explains why it is also necessary to evaluate and treat the ankle joint. This evaluation and treatment must incorporate a visual demonstration of the afferent proprioception to avoid the risk of perpetuating the flow of qualitatively altered information and basing the process of functional recovery on this faulty information. Feed-back methods are particularly well suited to the improving the quality of the

afferent information and consequently the control of movements carried out by the knee and ankle.

Given this background, the aim of this study was to use a computerized proprioceptive footboard (Pro-Kin Tecnobody company - Italy) to verify:

- 1) whether patients who have undergone a total knee replacement, admitted to our Centre during the post-acute period to carry out post-operative rehabilitation, have a proprioceptive deficit;
- 2) the reliability of the above mentioned equipment in recording the proprioceptive deficits.

### *LITERATURE REVIEW*

A review of recently published international literature quickly reveals that the clinical findings and opinions on proprioception in subjects undergoing arthroplasty of the knee are very discordant.

The studies by *Simmons, Lephart and Rubash* (9,10) in 1996 showed that proprioception did not improve after successful knee arthroplasty, independently of whether only the posterior cruciate ligament (PCL) was preserved or both the anterior and the posterior cruciate ligaments were preserved. The authors also emphasized that preservation or removal of the PCL had no effect on proprioception. In patients with an initial modest arthritis, the post-operative score was almost identical to the pre-operative one. In the cases in which the pre-operative arthritis was severe, those in whom the PCL was replaced performed better than in those in whom the PCL was preserved.

In 1997 *Ishii and Terajima* (11) presented a study comparing angular sensitivity before and after a total knee arthroplasty (TKA). The results from the tests on 55 prosthetic knee joints confirmed that this sensitivity is not altered in the post-operative period.

Other studies comparing proprioceptive function in subjects who had or had not undergone TKA were carried out in 1999 by *Fuchs and Thorwesten*. (12). These authors found a variable degree of proprioceptive deficit in patients who had had a TKA, both in the limb

which had been operated on and in the contralateral one. This deficit of proprioceptive sensitivity was particularly marked at 60° of knee flexion.

In 2000, *Pap and Meyer* (3) presented a study analysing the causes of decreased proprioception in patients after knee replacement surgery. They hypothesised that the deficit could be correlated with the surgical removal of intra-articular receptors which are normally involved in proprioception.

In the same year, other authors, *Weiler H.T. e Awiszus* (13) reached the same conclusions as *Pap and Meyer*.

## MATERIALS AND METHODS

Two groups of subjects were considered in this study: the first group was formed of 34 patients who had undergone a TKA and the second comprised 20 healthy subjects used as controls.

The patients were aged between 60 and 70 years old and had a TKA in order to overcome disability consequent to degenerative disease, not alleviated by prior medical, physical or rehabilitative treatments. They were admitted to our Centre to undergoing a course of post-acute rehabilitation. At the time of evaluation they were able to remain upright and to walk a few steps with a grazing load on the operated limb and with the help of two Canadian crutches.

The control group comprised subjects of the same age as that of the patients but who did not have any motor or cognitive disability.

All the individuals underwent a careful evaluation of proprioception in the operated limb, or in the dominant limb in the case of controls, using a computerised, electronic, stabilimeter made of a mobile footboard with fluid oil dynamic piston rods (figure 1). The subject placed only the operated limb on the footboard, which was attached to a computer screen showing the route which the patients had to copy using a cursor controlled by the footboard itself. The load was limited to 20% of the body weight in both pathological and control subjects.

The system is equipped with a data acquisition board that electronically transduces the slightest angular movement made by the sophisticated mobile footboard. When the patient moves this footboard with his or her weightbearing limb, the data acquisition board converts every movement into electrical impulses, sending them directly to the computer. The electrical impulses processed by the system's software are displayed on the computer screen in the form of a trace which is strongly related to the movement of the mobile footboard.

The patients were asked to cover a sequence of three traces, two being linear routes (one vertical and one horizontal), and one being a circular route. These three traces are the only ones available in our computerised system. At the extremities of the two linear routes and along the whole circular route, there were objectives which had, compulsorily, to be trod on by the cursor commanded by the patient during the test; when this had been done, the test was considered to have been completed (figures 2 – 3).

The subjects had to carry out each test in the shortest possible time but also perform it to the best of their ability, that is by covering the predefined trace precisely as well as reaching the objectives placed along it.

Indeed, the parameters we considered in order to evaluate the performances of our subjects were, for each of the three traces, the *time* necessary to carry out the test and the *percentage of the route* covered. In accordance with the advice of the equipment device's manufacturer, 100% was considered optimal.

The patients underwent two evaluation sessions on different days; the first session was performed about 10 days post-operatively and the second two days after the first evaluation. This test-retest procedure was used in order to assess the reproducibility of the test.

The parameters (TIME and %ROUTE) for each test in the first evaluation session were compared with the corresponding values of the same subject in the session on the second day's test.

Subsequently, in order to verify the presence of any proprioceptive deficit in the group of patients, the mean of the data (TIME and %ROUTE) relating to each of the three tests

carried out by this group of subjects was compared with that of the corresponding values of the control group (see *statistical analysis*).

## STATISTICAL ANALYSIS

The statistical analysis was based on a model that assumed that the data obtained from each subject could be divided into two main components: a constant component, reflecting the real or predetermined value, which describes the patient's characteristics of interest, and a variable component which changes from measurement to measurement. This component represents the effect of various factors potentially responsible for the measurement variability, including any involuntary movements made by the subject during the execution of the test and level of concentration, through recording different sessions. The random component is considered to be normally distributed with zero mean and fixed variance.

The measurement variability was evaluated considering the standard deviation of the random component, normally referred to as standard error of measurement ( $SE_{meas}$ ).

The  $SE_{meas}$  can be used to calculate the confidence interval for the unknown real value of the subject. Thus, if  $x$  is the value of a parameter (%ROUTE or TIME) in a given subject, an approximate 95% confidence interval for the real value  $\pi$  in the subject will be:

$$x - 1.96 \cdot SE_{meas} \leq \pi \leq x + 1.96 \cdot SE_{meas} \quad (\text{table I})$$

between a parameter in a given subject in two different evaluations. That is, still considering a patient undergoing rehabilitation treatment, in order to be 95% sure that the change seen in a parameter between the start and the end of treatment is not merely due to casual variability, the change in  $\Delta x$  must be:

$$|\Delta x| > 1.96 \cdot \sqrt{2} \cdot SE_{meas} \approx 2.8 \cdot SE_{meas} \quad (\text{table II})$$

Paired t-test was used to compare the average value (on the 3 measurements) of %ROUTE and TIME between the first assessment and the second one on both patients and controls.

Unpaired t-test was used to compare the average value (on the 3 measurements and the 2 repetitions) of %ROUTE and TIME between the patients and controls.

Separate t-tests were done for each of the parameters in order to compare the results of the control group and those of the group of patients.

The data are presented as mean  $\pm$  SD. The level of statistical significance was set at 0.05.

The standard error of measurement ( $SE_{meas}$ ) between the results of the first and second sessions of tests was used as a measure of reproducibility.

## RESULTS

Tables 1a and 1b summarize the descriptive statistics of the variables considered (%ROUTE and TIME) in this study for both groups (patients and controls) and at both test times. The same tables also report the corresponding  $SE_{meas}$ .

We found a reduction in the TIME parameter between the first and the second day of measurement in both populations, but only in the control group it was statistically significant ( $p = 0.013$ ). Also the %ROUTE improved between the first and the second day, but the difference was very little and not statistically significant.

Comparing the two populations, both TIME and %ROUTE parameters were significantly better in controls than in patients ( $p < 0.001$  and  $p < 0.007$  respectively).

## CONCLUDING REMARKS

The statistical analysis highlights one important problem concerning the methodological validity of these assessments of proprioception, which should be taken into consideration when interpreting the data from the tests. This type of evaluation is too strongly influenced by the subject's general characteristics (age, mental lucidity, concentration, eyesight, speed of reflex reactions, overall motor performances, etc.) to provide a very reliable indicator of his or her proprioception. This is clear from analysing the variations in the parameters %ROUTE and TIME when a test is repeated twice. The obvious question is therefore: if only one measurement is considered, and this is subject to random variability, what is the patient's real value? Let us take the parameters of %ROUTE3 and TIME3 in the patients as practical examples. If the value for %ROUTE 3 is 130, the real value (with 95% confidence) lies within

the range from 109 to 151. In the same way, if the value of TIME 3 is 60, the real value (with 95% confidence) is in the range from 39 to 81.

Furthermore, in order to evaluate the efficacy of rehabilitation treatment, it is essential to be able to analyze *changes* in results. This raises the following question: how great must the difference be between baseline values and follow-up values in order to be sure that this difference is not merely the result of casual changes in both measurements? Going back to the previous examples, %ROUTE 3 must differ by more than 30 to have a 95% level of confidence that a real change has occurred. This is a very large value considering that 100 is the best performance possible. The same holds for TIME 3, where the change necessary for a change is 30 sec., about 50% of the value.

In order to overcome this problem and to improve the reproducibility and, in consequence, the validity of these measurements, repeated measurements in the same evaluation session are advisable. We suggest three repetitions of every test (a reasonable compromise between increased precision of measurements on the one hand, and containing the variability due to the patient and experimental costs on the other). This strategy reduces the variance of the measurement by 1/3, which has the effect of a  $1 / \sqrt{3}$  reduction in both the confidence interval for the fixed value (equation 1) and of the threshold for a significant change.

Despite the above mentioned statistical caveats, the data from this study were sufficiently valid and clear to be able to state with certainty that TKA has an effect on proprioception. This is demonstrated from both the greater time necessary for patients to complete the test, and the greater surface covered in order to trace the route.

In conclusion, on the basis of this information, we consider that proprioceptive training should be included in the already well established rehabilitation protocols used for functional recovery after knee prosthesis surgery. This proprioceptive training, intended as real "neuromotor reprogramming", should be aimed at stimulating the proprioceptors to increase their afferent input to the central nervous system, thus contributing to reactivating the stimulus-response

recognition circuits which were already compromised by the pathology and then by the surgery. This will improve functional stability and thus recovery of the limb itself.

In the light of the foregoing, this study will be continued by analysing the benefit deriving from proprioceptive rehabilitation in subjects undergoing TKA. The same equipment will be used and two groups of patients will be examined before surgery and at discharge from the rehabilitation hospital. One group will receive standard rehabilitation, the other group will receive the same protocol plus proprioceptive training.

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## SUMMARY

The aim of this study was to use a computerized proprioceptive footboard (Pro-Kin company) to verify:

- 1) whether patients who have undergone a total knee arthroplasty (TKA), admitted to our Centre during the post-acute period to carry out post-operative rehabilitation, have a proprioceptive deficit;
- 2) the reliability of the above mentioned equipment in recording the proprioceptive deficits.

**Materials and methods** Two groups of subjects were considered in this study: the first group was formed of 34 patients (Means age 60.5 Years) who had undergone a TKA and the second comprised 20 healthy subjects used as controls.

All the individuals underwent a careful evaluation of proprioception in the operated limb, or in the dominant limb in the case of controls, using a computerised, electronic, stabilimeter made of a mobile footboard with fluid oil dynamic piston rods. The system is equipped with a data acquisition board that electronically transduces the slightest angular movement made by the sophisticated mobile footboard.

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The subjects had to carry out each test in the shortest possible time but also perform it to the best of their ability, that is by covering the predefined trace precisely as well as reaching the objectives placed along it.

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Subsequently, in order to verify the presence of any proprioceptive deficit in the group of patients, the mean of the data (TIME and %ROUTE) relating to each of the three tests carried out by this group of subjects was compared with that of the corresponding values of the control group

**Results.** We found a reduction in the TIME parameter between the first and the second day of measurement in both populations, but only in the control group it was statistically significant ( $p = 0.013$ ). Also the %ROUTE improved between the first and the second day, but the difference was very little and not statistically significant.

Comparing the two populations, both TIME and %ROUTE parameters were significantly better in controls than in patients ( $p < 0.001$  and  $p < 0.007$  respectively).

**Concluding remarks.** This type of evaluation is too strongly influenced by the subject's general characteristics (age, mental lucidity, concentration, eyesight, speed of reflex reactions, overall motor performances, etc.) to provide a very reliable indicator of his or her proprioception

Despite the above mentioned statistical caveats, the data from this study were sufficiently valid and clear to be able to state with certainty that TKA has an effect on proprioception. This is demonstrated from both the greater time necessary for patients to complete the test, and the greater surface covered in order to trace the route.

**Key words:** proprioception, total knee arthroplasty, evaluation.

### **Figure 1**

Experimental setting for the evaluation of proprioception by means of a computerized system ( Pro-Kin 254 ).

The limb under evaluation is placed on a mobile footboard with fluid oil dynamic piston rods. The movements of the footboard are converted into electrical signals and acquired on a Personal Computer. A dedicated software processed these signals and displays the trace on the PC screen.

### **Figure 2**

Example of traces related to the execution of the proprioception test: linear route.

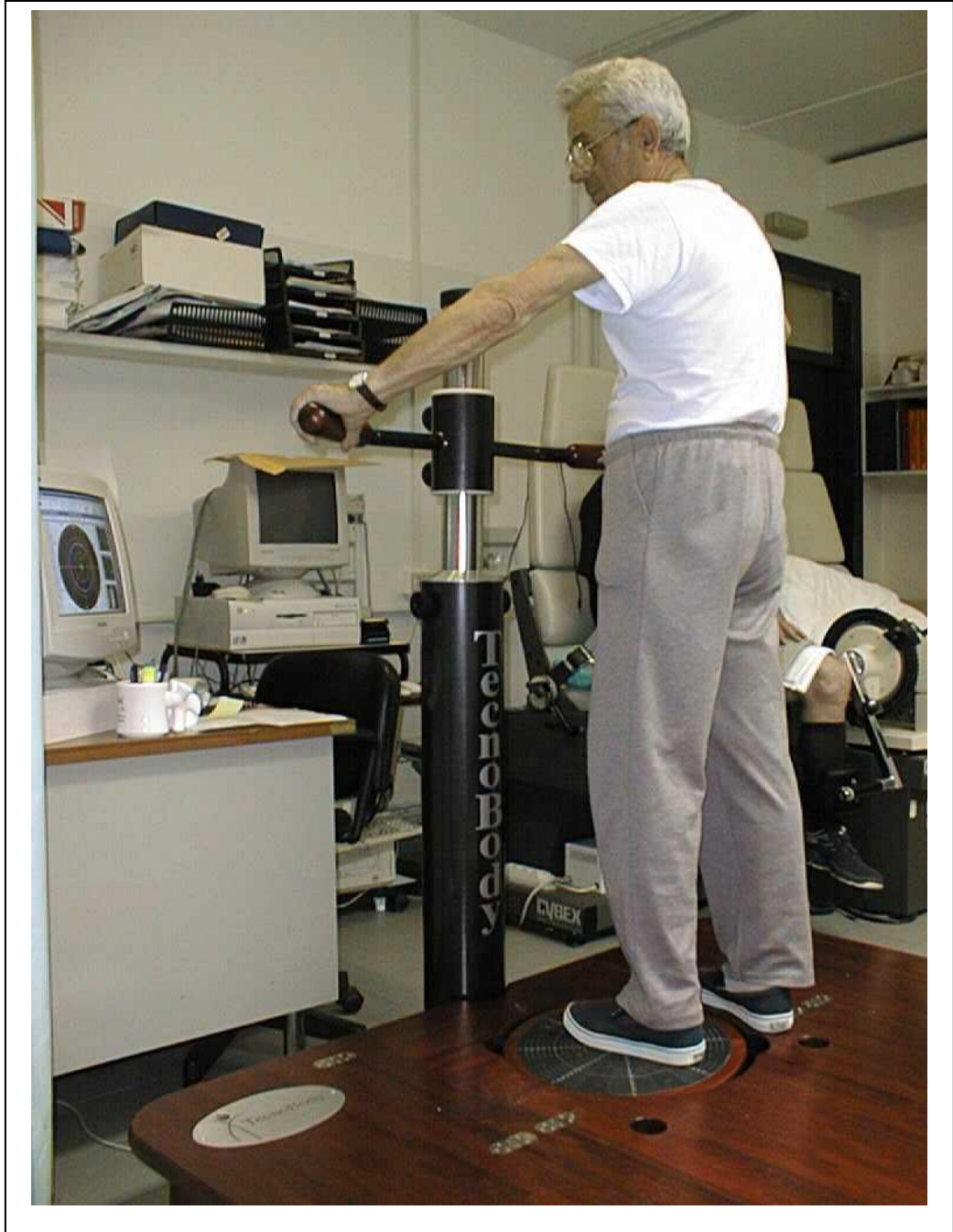
The initial and final points of the route to be covered, joined by a straight line, together with the path effectively traced by the patient are displayed.

### **Figure 3**

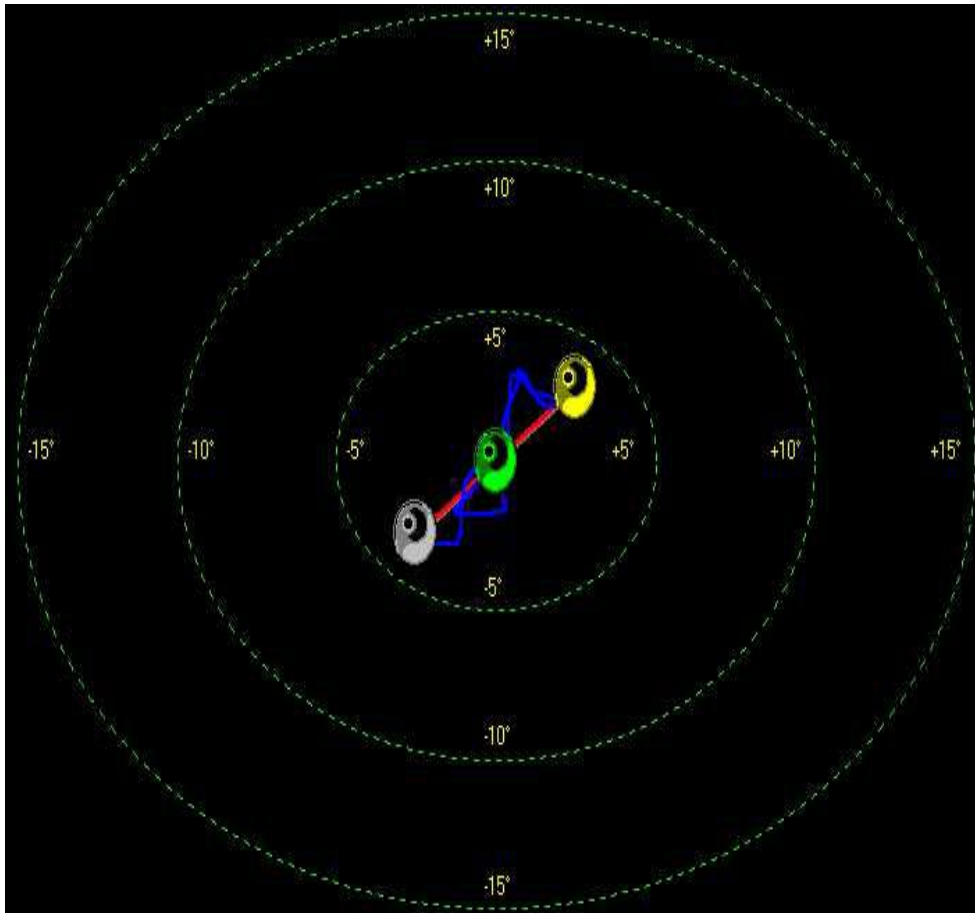
Example of traces related to the execution of the proprioception test: circular route.

The initial point and 8 intermediate points on the target circle joined by straight lines, together with the path effectively traced by the patient are displayed.

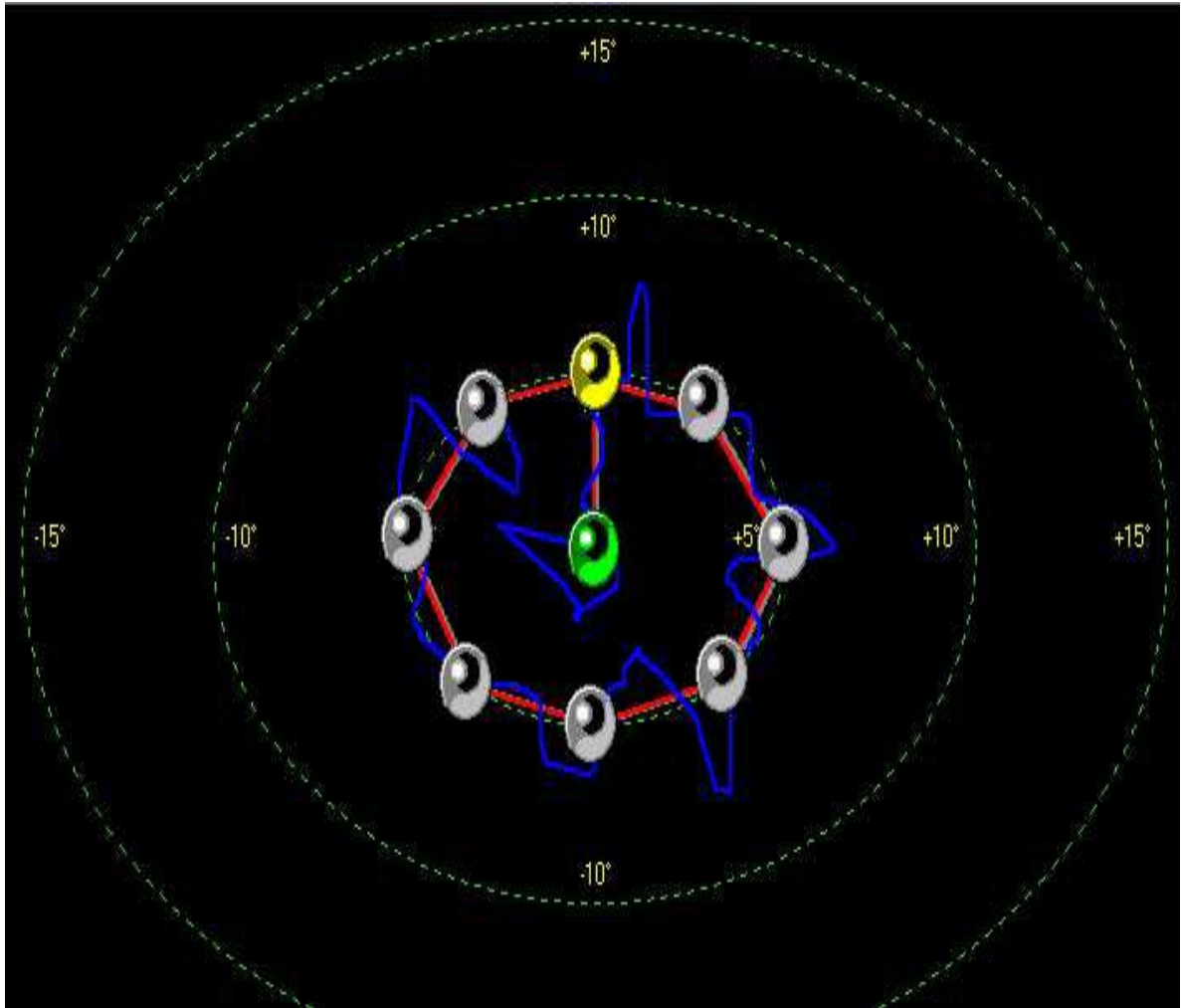
Patient Position ( Fig. 1 )



Tracing of Valuation n. 1 ( Fig. 2 )



Tracing of Valuation n .2 ( Fig. 3 )



**Table I - (patients):**

	First Measurement	Second Measurement	$SE_{meas}$
TIME 1 (sec.)	$22.6 \pm 11.2$	$19.7 \pm 10.7$	5.1
%ROUTE 1 (%)	$124.2 \pm 21.3$	$122.3 \pm 23.7$	17.5
TIME 2 (sec.)	$21.0 \pm 8.8$	$18.8 \pm 8.2$	6.4
%ROUTE 2 (%)	$134.2 \pm 26.0$	$130.7 \pm 23.6$	16.2
TIME 3 (sec.)	$50.7 \pm 19.8$	$48.7 \pm 19.3$	10.9
%ROUTE 3 (%)	$132.6 \pm 26.0$	$132.5 \pm 24.1$	10.6

**Table II (controls):**

	First Measurement	Second Measurement	$SE_{meas}$
TIME 1 (sec.)	$13.4 \pm 6.8$	$12.9 \pm 6.0$	3.0
%ROUTE 1 (%)	$119.4 \pm 19.0$	$113.9 \pm 13.4$	16.3
TIME 2 (sec.)	$13.4 \pm 5.1$	$11.1 \pm 4.5$	3.5
%ROUTE 2 (%)	$121.7 \pm 13.8$	$116.4 \pm 11.0$	9.2
TIME 3 (sec.)	$35.4 \pm 15.0$	$28.1 \pm 13.9$	9.9
%ROUTE 3 (%)	$119.8 \pm 25.8$	$110.6 \pm 11.0$	18.8