EVALUATION OF TRAINING METHODS BY MEANS OF KINEMATIC MEASUREMENTS

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INTRODUCTION

The Proprioceptive Neuromuscular Facilitation (PNF) technique, developed by Kabat and Knott in 1951, uses the Inverse Myotatic Reflex (Autogenic Inhibition) of the Golgi tendon organ (G.t.o.) which is located in the muscle tendon and monitors its strain. The impulse of the G.t.o. is powerful enough to override the excitatory impulse from the muscle spindles. In fact, if the intensity of the contraction or stretch on the tendon exceeds a critical value, an immediate reflex inhibits the motor neurons that innervate the muscle. Consequently, because of this protective mechanism the muscle immediately relaxes, the excessive tension is removed and the joint range of motion can be amplified . This method, was developed and mainly used for therapeutic or rehabilitative purposes, but after '80 it was experimentally applied to sport training.

Moore and Hutton in 1980 obtained good results, with a training program based on PNF method for increasing the hip range of motion (r.o.m.). Later, many other researchers (Cornelius et al.1980 , Sady et al 1982; Prentice 1983; Hardy, 1985; Wallin et al. 1985; Etnyre et al. 1986; Condon et al. 1987; Guissard et al. 1988, and finally Cornelius et al. 1992) confirmed with experimental results the PNF method effectiveness.

A typical problem of PNF training procedures is the time required: many athletes, for instance, do not introduce this method in their standard training plan only because it is time consuming.

Therefore aim of this work is to verify if also a very simplified and very short PNF training procedure, - which is well accepted by the athletes - can be effective on joint active and passive range of motion.

Moreover, the experimental tests for checking the results must be executed on the field thus they also must be simple, clear and fast. For the field tests only simple and light biplanar electro-goniometers have been adopted, while for the laboratory ones an opto-electronic system has been also used.

MATERIALS AND METHODS

The tested group consists of 52 volunteer male subjects, aging between 19 and 23, performing several sports (athletics, karate, soccer, basket, volley, etc.) and attending ISEF sport school.

In the pre-training test the active and passive r.o.m. of the hip joint has been evaluated by means of a leg movement in the sagittal plane . Then the subjects began the specific PNF training program, which lasts 3 weeks and include a total number of only 10 sessions. At the end of program the r.o.m. test was repeated.

All the training sessions require a couple of subjects which, after an adequate warm-up alternate in the following exercise: a) one subject, supine, flexes actively the coxo-femoral joint with the knee fully extended while the second subject keep the other leg of the first in extended posture (hip and knee flexion = 0°)

b) subject one tries to extend the leg against the opposition of subject two which also helps him to keep the knee extended, this action last ten seconds (activation of Golgi reflex in the ischio-crural muscle-tendon system in isometric contraction); c) the same hip joint is again actively flexed by the first subject but now also the second subject contributes to the flexion: in this phase the range of flexion is increased. Both subjects repeat the exercise 5 times for each limb, with 2 minutes break between the flexion of the same limb.

During the training period, the subjects maintained all their physical activities except for the specific exercises involving hip muscle stretching because they may affect the result of the test.

In order to test the efficacy of the described training method, the following simple testing procedure has been adopted. The subject, supine with the trunk constrained to a special table warms up by means of three passive hip flexions made with the help of an assistant, and performs a set of three active maximal flexions of a leg at a time. The knee joint of the moving leg is constrained in extended position by means of a plastic holder and the ankle is blocked at 90 degree flexion by means of a special shoe. For sake of repeatability, the subject is asked to hit with the foot a flexible target placed over the table.

Hip flexion is measured and recorded by means of a flexible electro-goniometer whose ends are placed on the haunch and on the leg, along the line connecting the trochanter and the lateral femoral epicondile, at the same distance from trochanter.

The electro-goniometer used consists of two bases connected by cylindrical a measuring cable. Four special strain gauges are bounded to the external surface of the measuring cable along four generating lines of the cylinder. Each couple of opposite gauges constitutes two contiguous branches of a Wheatstone's bridge. Two connecting cables (4 wires each) link the first base to a data logger in order to power the two "Whetstone's bridges" of the gauges and to collect the data.

The standard gauge has two only two channels, thus it is not sufficient in general , if alone, to define the relative orientation of the two bases in the 3D space. Another similar electro-goniometer which measures only the cable torsion can be added.

The biplanar goniometer has two different electric circuits which read the projection of the angular displacements on two orthogonal planes x z and y z . However, the simultaneous motion of the measuring cable in two different planes make the relationship between the measured angles and the goniometer output more complex.

To simplify the discussion, let us suppose that the cable lies in a plane η defined by the axes Z1 and Z2 (**Fig.1**). The reference frames (1) and (2) are located at the ends of the chain and move consistently with them; an auxiliary frame **a** is positioned at the interface between the cable and the hinge and moves according to the first. As shown in Fig.1 α is the angle between Z_1 and Z_2 (or the coincident Z_a), φ is the angle between Y_1 and the plane η (and also between Y_a and η) and θ is the one between X_a and X_2 (or Y_a and Y_2).

The relative angular position between frames 1 and 2 can be represented by the following three coordinates:

α_x: x-flexion, α_y: y-flexion, θ: twist

where $\alpha_x = \alpha \cos(\phi)$ and $\alpha_y = \alpha \sin(\phi)$

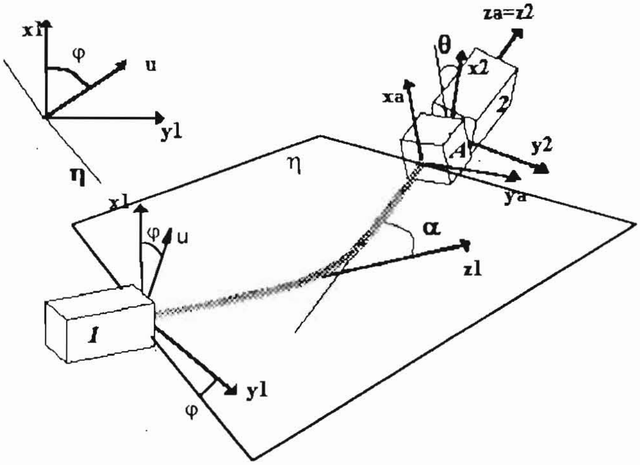

Fig.1

The standard biplanar electrogoniometer only supplies the value of α_x and α_y. The value of α and ϕ can be easily obtained from the goniometers outputs RCHA and RCHB as:

$$\alpha = \sqrt{RCHA^2 + RCHB^2} \quad (1) \quad \text{and} \quad \phi = atan2\left(-RCHB/_{RCHA}\right) \quad (2)$$

If the cable is rotated (twist angle $\theta \neq 0$) equation (1) gives an approximated value (α^*) of the flexion angle α

$$\alpha^* = \sqrt{RCHA^2 + RCHB^2} = \alpha \frac{\sin\left(\theta/2\right)}{\theta/2}$$

However, if θ (twist angle) is small $\frac{\sin\left(\theta/2\right)}{\theta/2} \cong 1$ we can assume: $\alpha^* = \alpha$

Laboratory tests by means of an opto-electronic system demonstrated that this condition is true for the exercise and the set up used for our field test.

On the contrary, an incorrect calibration procedure is a major source of errors. In fact, in the evaluation of the athlete movement, the gauges have been zeroed at the initial movement position and not with the basis perfectly aligned. This error can be easily corrected if the relative position of the bases is known by using the

$$\alpha^* = \sqrt{(RCHA + k_A)^2 + (RCHB + k_B)^2}$$

where k_A and k_B are the output of the electrogoniometer previously correctly calibrated and then placed on the subjects.

RESULTS

movement	*pre-training*	*post-training*	*increase*
Pas.flex.right limb	57°	65°	8°
Pass.flex.left limb	71°	82°	11°
Act.flex.right limb	56°	58°	2°
Act.flex.right limb	67°	74°	7°

The table shows the average values of hip joint excursion before and after 10 short sessions of PNF training on 52 athletes.

CONCLUDING REMARKS

Only 10 sessions of specific work seem to be effective on joint mobility.

The program requires a short work time - about 7'30" per athlete - therefore it can fit well the training rhythms of many specialties and can be applied to individual and collective sports.

The difference of the results obtained in the two sides, in favor of the left limb (non-dominant limb for most of tested people) can be related to an easier strengthening of their flexors (iliac-psoas), connected to a better neuromuscular synergy with the extensors (ischio-crurals): it likely means a more effective infra and intermuscular coordination.

Muscle fatiguing or soreness of the ischio-crurals observed in some subjects may be related to overload during isometric contraction and to training sessions too close. Thus it may be profitable to combine stretching exercises with the PNF techniques.

In general three measures are required in order to obtain a correct evaluation of each component of the joint rotation by means of the "flexible cable electro-goniometer" because they are coupled. However for certain setup and movement - like the one here adopted for testing hip range of motion- the gauge twist can be neglected. On the contrary, if the torsion is relevant (and is measured) the results of the gauge can be corrected by a simple algorithm if the cable maintain a curvature rather constant. Analogously the incorrect zeroing of the gauge during test can be corrected by means of a simple algorithm and few extra measures.

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