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Index:

"ISOKINETIC EQUIPMENT"

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GENERAL PRINCIPLES

Isokinetic devices are instruments that allow muscle exercises to be performed at a constant speed along the full range of motion.
After a phase of acceleration, once a given angular speed is reached, the isokinetic apparatus makes it impossible to exceed such speed since the muscle force which would allow an increase in speed of the lever is assorbed by the machine and returned as resistance. Therefore, since the maximum force varies according to the angle of the articulation, also the mechanic resistance met by the muscle will vary with the varying of the angle of the articulation, so that at the top of the range of motion it is low and increases in proportion to the increase in the mechanical advantage of the lever. So doing, the muscle meets a resistance which, expressed in a percentage of the maximum, remains constant along the full range of motion, which is the opposite of what happens in ordinary dynamic exercises where the tension varies with the varying of the lever. This means that the resistance that the patient meets constantly adapts itself in proportion to the force exercised by the patient him/herself. These features make the isokinetic equipment a very versatile instrument for use in rehabilitation and in functional assessments.
In rehabilitation, as is widely documented, it can be used for all kinds of re-educative treatments where return to normal muscle functions is required. Isokinetic exercise is in fact easy to modify according to the level of exercise required and so can be used either for extremely weak patients, as for example described by Merlini and colleagues, on a group of subjects suffering from spinal amiotrofia (2) and by Ciarimboli and colleagues on geriatric patients (3), or for very strong patients, as described in dozens of scientific studies on sports injury re-education.

Looking more closely at the contents of the 105 studies on orthopaedic rehabilitation, 25 treat the subject in general while the remaining studies treat specific articulations.
The knee is that most studied with 44 specific studies, followed by the ankle with 14 and the shoulder with 12 studies. Few studies however have been done on the remaining anatomical areas and in particular on muscular trauma which is the object of 4 studies, on the trunk (3), on the hip (2) and on the elbow (1). Besides the statistical analysis above, it is evident that in Italy it is already possible to define such methodology as a state of art and whoever wants to improve their knowledge in specific areas on the use of isokinetic equipment, can choose from a wide spectrum of experience documented by other colleagues.

"KNEE ISOKINETIC REEDUCATION PROTOCOL"

PARAMETERS TO BE EVALUATED FOR DEFINING A KNEE REHABILITATION WORKING PROTOCOL:

1) Type of load	horizontal - open chain exercises vertical - closed chain exercises
2) Type of exercise	concentric eccentric

3) Range of motion applied

4) Maximal or submaximal effort

5) Angular speed of the exercise for agonistic and antagonistic muscles

6) Number of repetitions and sets

7) Duration of pauses

8) Number of sessions per week

9) Duration of the treatment

TYPE OF LOAD

As already explained in an original study by Engle in 1983, the isokinetic methodology can be used either for exercises in a closed or an open chain.
In our experience, using devices for exercising in a closed chain (GENU 3, Easytech, Italy) allows a more suitable approach in certain rehabilitative situations as in the early phases of the re-education after the reconstruction of the ACL where the agonistic and antagonistic co contraction in closed chain exercise reduces to a minimum the forces of stress on the new ligament.
In the same way the closed chain isokinetic workout is more indicated for the re-education of the patello-femoral chondromalaciae because it reduces the patellofemoral compression forces (S Della Villa and Colleagues, 1991).
Open chain isokinetic exercise allows an analytic workout and therefore more intense work on the single muscle groups and permits a more rapid recovery of muscle force. It is therefore preferable in the later phases of re-education when there is less risk of complications.

TYPE OF EXERCISE: CONCENTRIC - ECCENTRIC

Some isokinetic dynamometers allow both eccentric and concentric isokinetic exercise.

Under eccentric conditions the muscle produces higher maximal forces in comparison to other types of exercise.
The real advantages of isokinetic rehabilitation in eccentric conditions are constantly under discussion still today. Whoever are in favour states the advantages given by being able to produce greater stress than that in "normal" isometric or concentric exercises. In reality the fact that greater

stress is produced does not necessarily mean a greater increase in strength through training. The greater force produced in eccentric conditions depends on the intrinsic properties of the muscle and therefore does not necessarily mean a greater nervous activation. Various authors have in fact demonstrated less electromiographic activity during eccentric exercise compared to concentric exercise.(Asmussen 1953; Basmajian 1967; Seliger and others, 1980). Whoever is not in favour calls upon the potential damage given by the high stresses produced. The close relationship between eccentric exercise, pain and muscle damage has often been demonstrated (Stauber 1989. Newham 1988; Sargeant and Dolan 1987).

From what is written above it can be concluded that the eccentric training would have more disadvantages than advantages. However we do not think that training with exercises that use eccentric muscle contractions are to be refused a priori. Almost all the muscles contract both concentrically and eccentrically during normal daily activities and during sports activities. Eccentric contractions are also present for example in pliometric exercises or during the warm-up and, more generally, every time that the muscle is subjected to a braking action (Cavagna 1989).

In our opinion eccentric isokinetic exercise is an interesting argument for further development by who is involved in research, while it is to be avoided or used with great care by who is involved in clinical activities in which eccentric rehabilitative activity could be performed alternating with numerous exercises in a natural weight-bearing, which are safer and more functional for the patient.

RANGE OF MOTION

The selection of the range of motion on which to base the isokinetic exercise must be chosen in consideration of three possible factors:
1. To protect anatomical structures involved in a particular range of motion. For example to avoid the last 30° of extension in the early phases of the re-education after reconstruction of the ACL avoiding high stresses on the new ligament (Della Villa and Coll. 1991).

2. To select a range of motion in which the patient can train without pain, as in the case of patellar chondromalaciae where only a modest part of the articulation can be trained (Della Villa and Coll., 1992).

3. To strengthen targeted muscular groups such as the vastus medialis where there is patellar instability, so that it is involved to a greater extent in the contraction of the quadriceps in the last 30° of extension (Davies 1985).

MAXIMAL AND SUBMAXIMAL EXERTION

Isokinetic exercise, because of its special characteristics, was conceived to be used under maximal effort but in clinical practice the rehabilitator can also use it in sub maximal form to:
a) allow the patient to get to know the exercises;

b) reduce stress on cartilage and on the patellofemoral joint;

c) increase joint lubrication;

d) give gradual light stress on a new ligament after reconstructive surgery;

e) prevent and overcome inhibitory reflexes that follow trauma injury and surgical operations.

ANGULAR SPEED

The angular speeds of isokinetic exercise can be classified as follows:
- slow speeds (0-100°/s)
- medium speeds (100-250°/s)
- fast speeds (250-400°/s).

When choosing the speeds the fact that the amount of force produced by the muscle fibre is in inverse proportion to the speed of contraction must be taken into account.
For this reason if you want to produce high stresses and do a strengthening training, the slow speeds must be used.
Parallelly, other criteria regarding choice of speed must be taken into consideration;
- slow speeds place greater stress on the joint;
- fast speeds reduce stress on the joint and are more true to those in normal use. You must consider that the angular speed of the knee when walking is around 240°/s, when running it is about 1100°/s and when playing football it can be as much as 2800°/s (Davies, 1985). Being able to adjust separately the speed of the agonistic and antagonistic muscles also allows a further adjustment of the exercise with regard to the specific requirements of the rehabilitator.

Schematically the following conclusions can be made:

- Exercise at fast speeds means acting above all on the neuromotorius coordination. Thanks to the contractions of the agonistic and antagonistic muscles following immediately one after the other the recovery of recruitment activity is helped:

- Exercise “at intermediate speeds at sub maximal exertion with brief pauses and long sets” means acting above all on the resistance to prolonged effort and helping to produce an increase in the haematic perfusion locally and in aerobic activity:

- Exercise “at low speeds at maximal exertion” permits a more rapid recovery of strength and muscle force.

The choice of angular speed is still one of the most debated aspects of isokinetic exercise. It can be added that while many authors used to advocate a specified type of training at a given speed (that is training at 150°/s meant an increase of force of only 150°/s) today various studies advocate an increase in force even at speeds lower than those of the training.
In practice, the advice given to solve this problem, is to include more than one speed range (slow, medium, fast) in each work protocol.

SETS, REPETITIONS AND PAUSES

2-3 sets of 10 contractions are often routinely employed for each angular speed required. The sets can also be made up of 5 contractions for the slow speeds or of 20 contractions for the other speeds.

You can also work by choosing intervals of 10”, 20” or 30” instead of a certain number of contractions, or even an open number of contractions to be continued until the torque values diminish by 50% compared to the initial values.

It is advisable however to annotate the work programme decided upon and any successive changes onto a treatment record card for each patient, on which the values achieved by the patient are to be written down on a daily basis to push him/her to constantly improve (Merlini and Coll., 1988).
The single strengthening work-out session can be carried out all in one go, or divided into two separate parts by an active resting period of 20-30' (stationary bicycling, stretching).
The total workload must be increased gradually, session-by-session, with the precaution of beginning with a modest load in the first 2 or 3 sessions (testing phase) during which the reactions of the patient are kept under control. If no problems, pain or swelling arise and the patient tolerates the workload with confidence, you can then pass on to heavier loads.
Moreover it is advisable initially to monitor the cardiovascular conditions of the subject checking the pulse rate and the blood pressure levels.

The total workload depends above all on the angular speeds used and the total number of contractions.
Using spectra of various angular speeds the average number of total contractions per session is 100-150 which can however be increased up to 300-400 for athletes in the later stages of rehabilitation.
In any case the isokinetic workout must be preceded by an adequate warm-up and training of the muscle and followed by a cooling-down stage and preventative cryotherapy. For those who have a heavy work load overall, a relaxing massage is advisable once the session is over.

NUMBER OF SESSIONS PER WEEK

How frequent the sessions are depends on the physical potential of the patient being rehabilitated. On average three sessions a week are advisable but in top level athletes, used to training, as much as ten sessions a week are possible, paying careful attention as to how the total work load is distributed that the patient is to undergo.

DURATION OF TREATMENT

The overall duration of the treatment obviously depends on the type of pathology to be treated.

Each cycle of treatment must be preceded by a bilateral test to establish the exact deficit of the injured leg compared to the non-injured leg. A control test is then repeated every 10-12 sessions to check, in comparison to the initial test, what results have been obtained.
Purely on an indicative basis, and underlining the fact that each response to treatment is individual, experience has shown that on average there is a 15-20% recovery of the force deficit every 10-12 sessions.

The recovery is even more rapid in cases where the functional deficit is due to a deficiency of the neuromotorius coordination rather than a simple hypotrophy of the muscle.

CONTRAINDICATIONS AND COMPLICATIONS

Apart from general contraindications suggested by common sense, given the large cardio respiratory exertion required by isokinetic exercise, the latter should not be proposed in the acute phases of knee trauma where the main features of the clinical picture are pain and inflammation, unconsolidated fractures and in the early phases of ligament reconstruction.

Moreover it should only be used when it does not provoke pain during the execution of the exercises. The experience of the rehabilitator is shown in his knowing how to adjust the parameters previously analysed so that the patient can train without suffering pain.

The most serious and frequent form of complication is that of tendonitis. To prevent tendonitis, warm-ups and stretching are performed before the session with cryotherapy on the joint at the end of the session, but above all by making gradual progress in order to avoid an excessive strain on the articulations in the first few sessions. Moreover a suitable amount of massage to relieve muscle tension is advisable when particularly heavy workloads are employed.

In conclusion, isokinetic exercise can be an excellent tool in the therapeutic arsenal of those involved in rehabilitation, but in virtue of its great potential it must be used with full knowledge of the facts and full understanding of its characteristics and its limits.

"THE FUNCTIONAL RE-EDUCATION OF THE KNEE: A PERSONAL EXPERIENCE"

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In view of the experience acquired in recent years by the Isokinetic centre of rehabilitation for sport in Bologna, patients suffering from traumatic pathologies of the knee have been rehabilitated following the same treatment programme divided into five phases. Using this programme a personalised protocol is determined for each single patient with regard to the specific pathology diagnosed . The objectives of the five phases are respectively:

Phase 1: - psychological assistance for the patient
- control of the inflammatory reaction

Phase 2: - recovery of joint movement
- return to correct ambulation

Phase 3: - recovery of muscle force and strength
- recovery of running ability

Phase 4: - recovery of coordination of complex gestures

Phase 5: - return to pre-injury sport-specific ability levels

A detailed account now follows of the phase with regard to the recovery of muscle strength through techniques of electro stimulation, isometric, isotonic, isokinetic exercises and closed chain exercising.

The programme during the third phase must be followed in progressive steps, taking the precaution to employ only modest work loads in the first few sessions in order to check the response of the patient and to avoid any overloading which could then cause joint effusion and pain. Moreover each session must be preceded by an adequate warm-up, include stretching exercises and finish with a massage of the muscles and cryotherapy.
The strengthening of the muscles can begin at a very early stage using **electro stimulation**, which can be used either only on the quadriceps or at the same time on both quadriceps and flexors in order to allow a co contraction of the two muscle groups. The use of electro stimulation will gradually be abandoned as the number of active strengthening exercises, which the patient is increasingly capable of performing, increases.
The **isometric exercises**, during which no joint movement takes place, are extremely effective for the return of muscle force. The contraction during isometric exercise must be kept for 8-10" and followed by a pause equal to three times the length of the contraction.
The **isotonic exercises** on equipment such as "leg extension", are dynamic exercises performed with a fixed resistance and at variable speeds. The exercises for the recovery of muscle force should be performed with short sets and maximal loads, and the exercises for the recovery of muscle strength with long sets and light loads. This principle is valid also for **isokinetic exercises** that are also dynamic and are performed using dynamometer software which allows the patient to do the exercises at a constant speed and to meet a resistance that adapts itself in proportion to the force exercised by the patient. They have the advantage of being able to submit the muscle to be rehabilitated to a maximal load along the full range of motion chosen and the performance can be

constantly monitored through the feedback system provided by the computer. To use this methodology better, wide spectra of angular speeds should be used, from 60° to 400°/second, employing medium-fast speeds (180°-240°/sec) in the first 3-4 sessions because they avoid overloading the articulation, medium slow speeds (180°-60°/sec) in the central part of the treatment because they are more effective for the recovery of the muscle force and fast speeds (300°-400°/sec) in the last few sessions because they are functional and more similar to that of normal daily activity.

The isokinetic workout must be preceded and ended with complete bilateral assessment tests. It is advisable to do the first maximal test after at least two isokinetic sessions to avoid problems caused by an overloading of the joint and in order to be sure that the patient has understood exactly the type of effort required. The final test must have as its objective a total recovery of the parameters of the injured extremity compared to the opposite extremity.

Several authors retain with regard to this point, that high values of the peak of torque of the quadriceps, eventually even higher than those relative to the healthy extremity, are a favourable factor of prognosis for the return to normal use.

Closed chain exercises are exercises, which are performed with the sole of the foot firmly placed on a supporting surface. In comparison to the exercises previously described, which can be defined as analytical because they involve only one single muscle group, closed chain exercises make the muscles of the hip, knee and ankle work together at the same time. Such exercises have the advantage of producing a simultaneous contraction of the extensor and flexor muscles of the knee thus resulting in a dynamic stabilization of the joint. For this reason they must be emphasized in the programmes for treating instability where the objective is to raise the amount of work done by the dynamic stabilizing systems and so compensate for the action of the static stabilizers, represented by the capsulo-ligamentous restraints.
Closed chain exercises can be performed in natural weight bearing, with mini-squats and wall sliding and exercising on isotonic machines such as a leg press. For those who have isokinetic equipment available, closed chain exercises can be performed changing the position of the patient and the position of the footrest compared to the more conventional position. Moreover they can be performed on machines with elastic strength springs which allow as well as closed chain exercises, a pliometric work-out meaning that the patient can lift his\her foot of the platform, throw him\herself forward and return to his\her original position and throw him\herself forward again. The latter exercises can be carried out with the foot rotated towards the inside or the outside, according to whether the activity is to be concentrated on the internal or external rotary muscle of the knee.
Closed chain exercises can be performed alternating concentric and eccentric phases following physiologically correct movements represented by the triple flexion and triple extension of the hip, knee and ankle. Therefore they are to be preferred to analytical eccentric exercises performed on isokinetic equipment that are limited to the flexion-extension of the knee in a sitting position.
Isometric, isotonic, isokinetic and closed chain exercises should all be included in a rehabilitation programme, based on the principle of specificity of training in that the more "training" stimulus the muscle receives the more complete the return to normal function will be.
Moreover it should not be forgotten that the muscles are only the final effectors in a long line of dynamic processes, which use information also collected by the proprioceptors in the articulations. To achieve the maximum recruitment of these stabilizing processes, proprioceptive gymnastics must be included at increasing levels of difficulty using moving tables, mini-trampolines and external stimuli to create a destabilizing effect.

Once the patient has recovered muscle strength and proprioceptive control, functional exercises are inserted in the programme, which reproduce the gesture of normal daily living, using a moving belt and electronic staircase.
The programme concludes with starting to run again in a straight line and with side wards movements, and progressing to changes of direction and jumps. During the treatment sessions the conditions of the knee joint and the structures near the muscle-tendon junction must be kept under constant control because a really effective rehabilitation programme always runs the risk of complications arising due to overloading of the joint.
The total duration of the programme is variable and depends on the results of the isokinetic testing and the stress level tests on the sports field. On average the treatment sessions take place three times a week for periods of about 4-8 weeks.
Once the rehabilitation is finished it is very important to work out a maintenance programme with the patient whom he/she can realistically put into practice and to agree on periodic clinical follow-ups conclusive in defining the effectiveness of the programme and to pick up any potential occurrence of damage to the osteoarticular structures.

"ISOKINETIC TESTING FOR REHABILITATION"

One of the most important features of isokinetic exercise is that of being able to perform muscular contractions at a constant angular speed along the full range of motion; the resistance produced by the dynamometer is proportional to the force exercised by the muscle and this means that a maximal load can be placed on any point of the range of motion. This load is recorded by the isokinetic equipment and displayed either in graphic form or by a series of numerical parameters for a clinical evaluation.
In this way the isokinetic dynamometer provides the doctor with a wide range of information on the dynamic muscular contraction, which would otherwise be difficult to obtain (Osternig, 1986).

The tests carried out using the isokinetic devices which have been described above in detail, help provide the answer to two fundamental questions that arise when we want to bring a subject who has suffered an injury back to pre-injury ability levels for normal daily activities and for sport.

What were the conditions of the patient at the beginning of the treatment?
How is he at the end of the rehabilitative cycle of treatment?

These are the two questions that the rehabilitator asks himself but the patient, too, naturally wants to return as soon as possible to his normal social and sports activities certain of being cured.
Between the two tests that are performed at the beginning and at the end of the cycle of rehabilitation treatment, control tests are also performed so as to have a constant clear picture of the evolution of the physical and pathological conditions of the patient. This means that the protocol can be continuously adapted to the physical and pathological conditions of the patient in order to obtain the best results session by session. The test results should always be interpreted by the doctor and included in the general clinical records of the tested subject. The quantitative data obtained, plus the doctor's ability, make for a better understanding of the functioning of the subject's muscles and joints.

To carry out an isokinetic test the type of articulation and movement must first be chosen , then the angular speed to be under examination is decided and the number of contractions that the subject must perform.
On the choice of numerical parameters there is no one opinion: for the doctor who intends to use the isokinetic methodology for evaluation means, we advise him to establish his own protocol of test procedures and to follow it regularly in order to compile his own personal databank thus acquiring a hands-on experience which will enable him to interpret the data with increasingly more precision and reliability.
Our experience recommends carrying out the tests for rehabilitation of the flexor-extensor muscles of the knee, with only two angular speeds: 90°/sec. and 180°/sec., for 4 contractions and for 20 contractions respectively. There are other general factors to be taken into consideration when setting up tests:

a) the lower the angular speed, the higher the stress on the joint: it is therefore not advisable to perform tests at speeds lower than 90-100°/sec. on subjects with joint pathologies;
b) the speeds between 200 and 300°/sec. are those nearer to functional movement and represent a more realistic indication of the subject's ability;
c) for the faster angular speeds (300-400°/sec.) the phase that can really be considered isokinetic is minimal because of the acceleration and the deceleration that occur during the exercise. The data obtained may not be reliable.

d) Data obtained for the force parameters vary according to whether the isokinetic device has a sliding lever or a fixed arm.

Test Procedures

During the evaluation test it is important that all the conditions pertaining to the procedure are kept constant so that the data obtained is reliable and can be confronted with other data obtained in subsequent tests.
Before carrying out the test the speed and the way in which the patient will perform the movement needs to be decided: both factors vary depending on the articulation to be tested, on the aim of the evaluation and on the type of patient.
Two different speeds are sufficient for the majority of patients with knee pathologies for evaluation purposes.
The number of repetitions also depends on the type of muscle contraction probed. For a test at 90°/sec. 4-6 repetitions are enough to obtain the best possible performance of force from the patient; a higher number would not provide useful information and would overtire the patient. For a test at 180°/sec. in which strength and ability is to be evaluated, the patient is asked to perform 20 consecutive contractions for a period of about 30 seconds in order that a reduction of the contractile ability of the muscle becomes evident. While carrying out the tests, rest periods are needed between tests at different speeds, long enough to allow the muscle to recover. It is therefore advisable to perform the endurance test last of all.
The correct positioning of the patient on the isokinetic apparatus is of primary importance for the reliability of the results: the axis of rotation of the dynamometer must be aligned with that of the articulation. The correct position must be maintained throughout the whole test with the patient well anchored to the seat so as to isolate as much as possible the muscle action that is to be evaluated.
Given that the carrying out of an isokinetic test demands an intense muscular effort, an adequate warm-up must always be done on a Cyclette and stretching exercises to prevent any possible muscle damage.
Once the test is completed movements to relax the muscles are recommended and ice needs to be applied on the injured knee to prevent any painful reaction.
The test should not be carried out in the presence of tissues not fully healed, serious joint effusion, pulled or contracted muscles, pain and extremely reduced joint-movement.

Suggested protocol to carry out isokinetic testing of the knee

-selection of speed and type of exercise
-warm-up: 5 min. on Cyclette
-stretching exercises
-positioning of the patient on the GENU 3
-instructions for the patient
-warm-up: 10 sub maximal contractions
-rest: 10 seconds
-test at 90°/sec. 4-6 maximal contractions
-rest: 2 minutes
-warm-up: 10 sub maximal contractions at 180°/sec.
-test at 180°/sec. From 18 to 22 consecutive contractions
-rest: 3 minutes
-repetition of procedure for opposite limb
-cool-down: 5 minutes on Cyclette (gently)

-cryotherapy for the injured knee

Obtainable data with the isokinetic test

To acquire the data the isokinetic device GENU 3 uses the SW programme.
The base quantity recorded is the **torque** that is the force multiplied by the distance from the axis of rotation to the point of application of the force itself. The measurement is expressed in N/m (Newton/metres). The programme provides other important data.
The **maximum peak of the torque,** which signals the highest value obtained during the test of the torque. It can be considered as the maximum force that a muscle group is capable of producing at the specific angular speed being investigated. The joint angle is also indicated at which such a value has been obtained.
The **total work** obtained, which expresses the product of the torque multiplied by the angular distance. The amount of work performed provides information on the ability of the muscle to produce force along the full range of motion. On the trace the work corresponds to the area subtended by the torque curve. The programme also signals the **work per single repetition**.
The **power** expresses the work in a unit of time measured in watts and the **exertion index** represents a measure of the effort made during the muscular exercise and expresses the decrement of the work performed by the muscle during a series of maximal contractions in a fixed period of time or for a fixed number of repetitions.
The programme adds some numerical data to the read-outs of the above information. To sum up, the following are displayed:

- the number of repetitions
- the angular speed established
- the **maximum of the torque**
- the **maximum work for each repetition**
- the **average of maximum values of the torque**
- the **average work for each repetition**
- the **maximum instant power**
- the **total work**
- the **exertion index**
- the angle in which is obtained the maximum torque
- the ratio between the flexor and extensor muscles

Interpretation of the obtained data

With the GENU3 programme it is possible to create a subjective record for each patient. It is extremely useful for the storing and changing of the data obtained during the tests and makes it easier to compare subsequent evaluations.

P*eak torque*. The absolute value obtained can be evaluated on the basis of personal experience or by comparing standard data provided that it relates to the same isokinetic machine. We advise the eventual creation of a database in order to acquire reliable comparative tables in which there are no variables, which inevitably occur when changing isokinetic system or even the work environment. Obviously, the more details that remain unchanged, the greater will be the reliability of the test.

Peak torque with bilateral comparison. This is the easiest and most immediate comparison. It is used above all in the evaluation of unilateral muscular hypotrophy and as a rehabilitation goal. It is one of the most interesting data available but should not however be considered only on its own. For

it to be considered of significance, the difference between the two limbs must be more than 10-15%; lesser differences are to be considered as a physiological variability. It is equally necessary to bear in mind which limb is the dominant one and whether the opposite limb is or is not in normal conditions of muscle force.

Work per repetition: absolute and comparative values.
A deficit of this value in comparison with the opposite limb without a proportional deficit of the peak of torque, points to a deficiency of muscle activity in a particular sector of the range of motion. Once this sector is pinpointed, the re-education of the muscle should be aimed at recovering strength where the deficit was shown to be.

Flexor/extensor ratio. The flexor/extensor ratio is a very important exponent for the correct evaluation of the test results and the doctor should never omit its observation. In our experience, in tests performed at 90°/sec., the flexor/extensor ratio should be, depending on the sex and activity levels of the patient, around the following values:
-sedentary male: 55-60%
-sportsman: 60-70%
-sedentary female: 45-50%
-sportswoman: 50-60%

These figures however are purely indicative and will clearly differ markedly according to the type of sport pursued and the position played on field.

Peak torque/body weight ratio. This ratio allows the normalization of the values of peak of torque in relation to the body weight of the subject. Parker and Coll. (1983) in a study on 84 players of American football aged between 15 and 18 showed that the torque values of the lower extremity can be calculated based on the body weight. The body weight can be used to determine an acceptable range of torque values inside which subjects can be considered qualified to participate in sports activities, also from the point of view of injury prevention.

Total work and exertion index. These parameters are of fundamental importance in evaluating the strength and tiring of the subject under examination. In our test protocol they are analysed in detail, with the test at 180°/sec.
In order to evaluate the strength and to be certain of the complete return to normal activities at the end of the rehabilitation programme, the parameter to be taken into consideration is that of the value of total work compared to that of the opposite healthy extremity taken as a point of reference.
The exertion index is instead an extremely interesting datum in the evaluation of athletes in endurance sports such as marathon runners and cyclists.

Morphology of the curve: The fundamental aspects to be observed in the single curve are (fig.1):
1. *Peak of torque*: it must be checked that the peak in the various contractions recorded always reaches similar values and occurs at the same angle of articular movement.
2. *Gradient of the first part of the curve*: shows the speed with which the muscle is capable of reaching the maximum torque value, if this gradient is modest it means that the subject has difficulty in generating enough force at the beginning of the muscle contraction.
3. *Gradient of the final part of the curve*: for the quadriceps it should be convex, if it is concave it means that the subject has difficulty in producing force in the final phases of the extension.
4. *Subtended surface area of the curve*: this area corresponds to the work performed by the muscle and should be considered as an index of the ability of the subject to produce high torque values along the whole range of motion. In certain conditions it may not be proportional to the peak of the

torque. The curves A and B in fact although they show the same peak of torque, subtend different surface areas. At other times a deficit in the subtended surface area of the curve corresponds to a deficit at the peak of the torque (fig.2).

5. *Morphology of the curve*: in order for an alteration in the morphology of the curve to be considered of importance, it must appear regularly in the various recorded contractions. The evaluation of the morphology of the curve and the interpretation of any irregularities depend on the experience of the doctor more than in any other aspect of the test.

In our opinion the isokinetic test provides information which is above all quantitative and alterations in the regularity of the trace cannot be considered indicative of specific pathologies: we believe that it is more realistic to consider any changes of the curve as a momentary force deficit almost always due to the onset of pain. This deficit can be studied in greater depth in relation to the angle in which it appears and it can be stimulating to try and correlate the force deficit at that given angle with the articular or muscular components that are involved.

6. *Passage between two reciprocal contractions*: the contraction of the flexors should begin immediately after the end of the contraction of the quadriceps. A delay at this level, if not voluntary, is not physiological.

REHABILITATION TESTS

ARTICULATION

knee

MOVEMENT

flexion-extension

PREPARATION OF THE PATIENT

+ warm-up for 10'-15' with stationary bicycling and stretching exercises for quadriceps, flexors and triceps surae muscle
+ careful stabilizing of the patient
+ precise alignment of the lever - patient's limb: the fulcrum of the lever must correspond to the medial femoral condile
+ suitable period of time for the patient to familiarize himself with the isokinetic apparatus

TEST PROCEDURE

+ the isokinetic test must be performed bilaterally every 12 rehabilitation sessions
+ first test the healthy limb and then the injured limb
+ perform the test at two angular speeds:
- 90°/sec for 4 movements
- 180°/sec for 20 movements

INTERPRETATION OF THE TEST

+ morphologic analysis of the trace at 90°/sec (please note that there are no path gnomonic traces, all alterations that are regularly repeated in the 4 repetitions must be integrated with the other clinical data obtained)
+ analysis of bilateral comparison of the different parameters under examination, in the following order of importance:
- peak of torque
- average peak of torque
- work per repetition
- analysis of flexion/extension ratio
- analysis of muscle strength examining only the total work parameter of the test at 180°/sec (without looking at the exertion index which has little relevance for a pathological subject)

WRITING UP OF TEST REPORT

+ it must be concise
+ it must contain only four quantitive pieces of information, two for the extensors and two for the flexors:

Extensors

- bilateral comparative deficit, of force
- bilateral comparative deficit, of strength

Flexors

- bilateral comparative deficit, of force
- bilateral comparative deficit, of strength

In the writing up of the report it is customary to express the force deficit as the deficit of the values of peak of torque at 90°/sec and the strength deficit as the deficit of total work at 180°/sec
+ add some brief information on the morphology of the curve and the flexor/extensor ratio

Quantifying of the muscle deficit

+ because of a need for clearer explanations, above all in the legal medicine field, the following classification of the deficit has been adopted:

- a less than 10% deficit: minimum
- a 10 - 25% deficit: light
- a 26 - 50% deficit: medium
- a 51 -75% deficit: serious
- a higher than 75% deficit: very serious