DYNAMIC ASSESSMENT OF ANTERIOR CRUCIATE LIGAMENT USING AN ELECTRONIC FORCE PLATE

by T. K. BAGGA FRCS, R. VAISHYA MS and D. C. JAFFRAY FRCS

The active force exerted by the movement of arms and trunk with the knee in extension was measured in 25 patients with anterior cruciate ligament deficient knee. The electronic force sensitive foot plate was used to measure the force.

Two sets of measurements were carried out. The antero-posterior stress test for measurement of Fy and the rotational stress test for measurement of Mz. Peak values obtained in anterior cruciate deficient knee were compared with the normal knee on the other side.

The measurement of the difference in Fy was found to be a reliable indicator of instability of the knee, but no significant difference was found in the peak torque values (Mz) between the two knees. This study suggests that this test may be useful in the objective measurement of knee instability. Details of the method used and its possible indications are discussed.

Keywords : force plate ; anterior cruciate ; ligament.
Mots-clés : plate-forme de force ; ligament croisé antérieur ; évaluation dynamique.

RÉSUMÉ

T. K. BAGGA, R. VAISHYA et D. C. JAFFRAY. Évaluation dynamique du ligament croisé antérieur à l'aide d'une plate-forme de force électronique.

La sollicitation dynamique exercée par le mouvement des bras et du tronc avec le genou en extension fut mesurée chez 25 patients dont le genou présentait un ligament croisé antérieur déficient. Une plate-forme de force fut utilisée ; il s'agissait d'une plate-forme électronique sensible.

Deux ensembles de mesures furent réalisés, correspondant au test de sollicitation antéro-postérieure pour la mesure de la composante de force Fy et au test de sollicitation en rotation pour la mesure du moment Mz. Les pics de valeurs enregistrés avec le genou au ligament croisé antérieur déficient furent comparés avec les résultats obtenus pour l'autre genou qui était normal.

La mesure de la différence des valeurs obtenues pour Fy s'est avérée constituer un indicateur fiable de l'instabilité du genou ; par contre, aucune différence significative n'est apparue dans les valeurs des pics du couple Mz.

Cette étude suggère que ce test peut être utile pour la mesure objective de l'instabilité du genou. Les détails de la méthode utilisée et ses indicateurs possibles font l'objet d'une discussion.

SAMENVATTING

T. K. BAGGA, R. BAISHYA en D. C. JAFFRAY. Dynamische beoordeling van de voorste kruisband door gebruik van een elektronische krachtplaat.

De aktieve kracht, uitgeoefend door de armen en romp, bij gestrekte knie werd gemeten bij 25 pa-

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tiënten met een voorste kruisband, waarvan de werking tekort schiet.
Er werd gebruik gemaakt van een elektronische kracht-gevoelige voetplaat.
Twee paar metingen werden uitgevoerd. De voor-achterwaartse stress-test voor het meten van Fy en de draaïings stress-test voor het meten van Mz.
Piek-waarden, verkregen in knieën met voorste kruisbanden waarvan de werking tekort schiet, werden vergeleken met de normale knie aan de andere kant.
De meting van het verschil in Fy bleek een betrouwbare aanwijzing te zijn voor instabiliteit van de knie, maar er werd geen significant verschil gevonden in de piek-torsiewaarden Mz tussen beide knieën.
Dit onderzoek suggereert dat deze test bruikbaar kan zijn in het objektief meten van knie-instabiliteit.
Bijzonderheden van de gebruikte methoden en de mogelijke indikaties worden besproken.

INTRODUCTION

The anterior cruciate ligament (ACL) plays an important role in maintaining the stability of the knee, but the degree of symptoms of instability following anterior cruciate ligament varies (1). The commonly used clinical tests such as anterior drawer and Lachman and pivot shift are helpful in making the diagnosis but the grading of these tests is entirely subjective and it does always correlate with the degree of symptoms of instability.
Cruciometers have been used recently to measure the displacement of the tibia on the femur during stress testing but these devices are reliable only when the patient is anesthetised or completely relaxed (2). The measurement of displacement of the tibia on the femur does not always correlate with the degree of instability.
In this study an attempt has been made to measure the force that a patient can tolerate while stressing his knee actively, thus simulating the mechanism that produces the patient's symptoms (2).

MATERIAL AND METHODS

The principal component of the equipment was a force plate measuring 600 mm × 400 mm. This plate has force transducers that can measure force in three different planes as well as the moment of rotation in the horizontal plane. These transducers were connected through a signal processor to an oscilloscope. The signals were recorded on the oscilloscope and transferred to hard copy by a graph plotter (fig. 1).

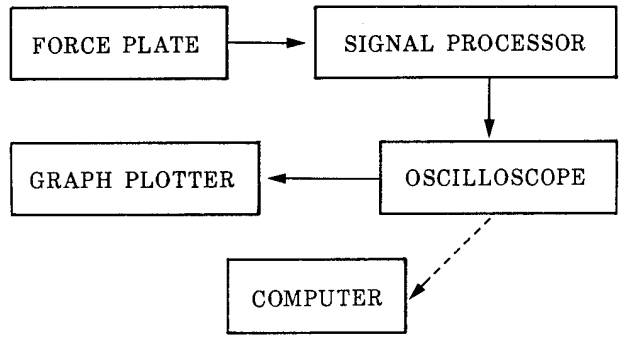

Fig. 1. — Schematic diagram of the apparatus used.

Twenty-five patients with isolated A.C.L. injury to the knee with sinificant symptoms suggestive of knee instability were included in this study (Group A). Most of these patients had confirmation of the diagnosis by the arthroscopic examination before the tests were performed. The same tests were performed on 15 volunteers with both knees normal (Group B). Both groups had comparable age and sex distributions.
All the patients were asked to stand on the platform keeping one leg off the ground. They were asked to keep their foot stationary and knee fully extended while doing these exercises. They were asked to carry 10 lbs weight in each hand and swing their arms and trunk in the antero/posterior direction to obtain the recording of Fy. The Fy was defined as the maximum amplitude or the peak force tolerated by the patient in each cycle while performing the antero/posterior stress test.
The second part of the test was carried out in a similar manner, but the patients were to keep their arms abducted at about 90° and swing their arms and torso in a rotary manner to record the moment of rotation (Mz). The Mz was defined as the maximum amplitude or the peak loading force tolerated by the patient during each cycle

of exercise while performing the rotary stress test. Both tests were performed for 30 seconds after the patients had a few minutes to practice the exercises. All the patients were asked to do exercises at the place they found comfortable without losing their balance. The recordings were traced from the oscilloscope to plain paper by a graph plotter.

The patients were asked to do the same exercises standing on the other leg. If the patient lost his balance while carrying out the test, the whole procedure was repeated.

The peak values obtained in one knee during each cycle of exercises (fig. 2) were measured and compared to the other side. These figures were analyzed statistically by 't' tests.

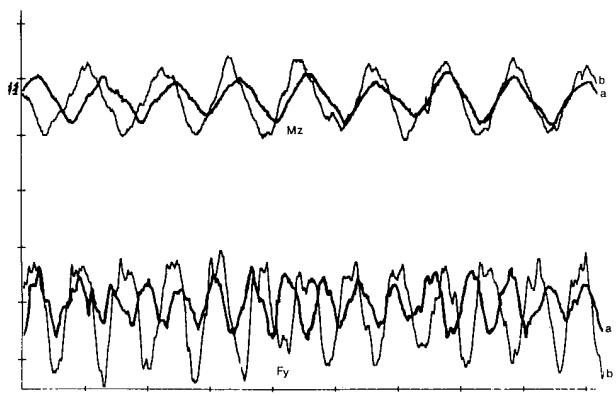

Fig. 2. — Graph of data from the patient with symptoms of severe instability, on measurement of Fy. Thick set line : A.C.L. deficient knee. Thin set line : normal knee.

RESULTS

The peak loading values were lower in the injured or non dominant leg. The average difference in the values of Fy and Mz between the affected and the normal knee is shown in table I.

The peak loading values obtained for each leg were measured in newtons. These values varied depending on the force applied by the motion of arms and torso. The unit of measurement of Mz was the newton-meter.

In Group A all the patients except one showed statistically significant differences in the peak loading values between the injured and the uninjured knee on the measurement of Fy (antero-posterior stress test) with the 't' value 2.896. The symptoms tended to correlate well with the degree of the patient's symptoms on the Lysholm scale (3). No significant difference was obtained in Fy between the two knees in Group B although the peak loading values were slightly lower in the nondominant knee. No significant difference was found on measurement of the peak loading force on performing the rotational stress test (Mz) between the two knees in either Group A or Group B (table I).

Table I. — Results of measurement of Fy and Mz

Group	Forces	Average difference	Range
A	Fy	21.18%	8.1%-39.8%
	Mz	5.17%	1.62%-8.03%
B	Fy	4.4%	2.01%-6.12%
	Mz	4.17%	1.03%-6.2%

DISCUSSION

In this study an attempt has been made to determine whether the measurement of forces tolerated by the patient while loading the knee actively bear any correlation with the symptoms of instability. In general the difference in Fy (A-P stress test) between the two legs correlated well with the degree of the patients symptoms. The patient whose knee gave way occasionally while playing contact sports had the lowest difference in Fy. These values correlated well with the subjective symptoms of the patients measured on the scale prepared by Lysholm and Gillquist (3). In one patient the difference of average Fy between the injured and the uninjured side was only 8.1% but he injured his knee 18 years ago and he had managed to play soccer and squash without any significant disability. His primary complain was pain in the knee.

The force plate has been used commonly in the gait analysis and biomechanics and it has been found to be a reliable instrument for measuring the force (6). The measurement of difference in Fy or Mz was found to be entirely reliable although the loading values obtained with each cycle of exercise varies. This was confirmed by performing the test several times on the same patient and recording the peak loading values. The most reliable and reproducible indicator was found to be the difference in Fy or Mz between the two knees instead of the measurement of force in newtons in each knee.

It was rather surprising to find that there was no significant difference in the rotational stress test, since most patients with ACL deficient knee have a degree of instability on activity involving twisting motion. This can possibly be explained by the fact that all these tests were performed with the knee in full extension and in this position the knee has quite a high degree of tolerance to rotational stress. Markolf *et al.* (4, 5) in his experiments found that there was very little movement of the tibia on the femur during rotational stress when the knee was in extension. In its present form the test can be performed with the knee in flexion, but extra devices are needed to measure the center of the hip, knee and ankle joint to give the angle of knee flexion with the time scale so that vector analysis can be done.

The test does have some limitations. It is not likely to be useful in acute injuries or in the presence of marked wasting of muscles. It may be of limited use only when both knees are involved.

CONCLUSIONS

In this preliminary study, the antero-posterior stress test has been found to be reliable and reproducible and it involves active participation of the patient, thus giving an idea about the dynamic stability of the knee joint. It is also noninvasive.

We believe that this test could prove to be an excellent research tool for measurement of knee instability. This could also be useful to assess the benefit from the physiotherapy, bracing or surgery in ACL deficient knee.

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