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Analysis of the significance of the measurement of acceleration with respect to lateral laxity of the anterior cruciate ligament insufficient knee

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Abstract The purpose of this study was to assess dynamically the lateral thrust of anterior cruciate ligament (ACL) insufficient knees, and from the findings determine any relationship between ACL insufficiency and the later development of osteoarthritis (OA). We investigated 80 knees in 40 patients awaiting ACL reconstruction and 25 knees of 25 patients, which had undergone ACL reconstruction. An acceleration sensor was fixed to the anterior tibial tubercle and this 'acted' in two directions – medial lateral and perpendicular. The peak value of the lateral acceleration immediately after heel strike was significantly greater in the ACL insufficient knees when compared to their opposite normal knees. When the periods from injury were compared, the lateral thrust of the injured side after 3 years or more was significantly greater than in the first 3 years. There was no significant difference between the normal knees and the ACL reconstructed knees. The results indicated that the lateral acceleration peak value was significantly greater in the ACL insufficient knees than in their opposite normal knees.

Résumé A partir d'une évaluation dynamique de l'instabilité de genoux atteints d'insuffisance du ligament croisé antérieur (LCA), nous avons tenté de déterminer la relation entre l'apparition de l'arthrose du genou et l'insuffisance du LCA. Notre étude a porté sur 40 patients (80 genoux) devant subir une opération de reconstruction du LCA et 25 patients (25 genoux) après l'opération de reconstruction du LCA. Des détecteurs d'accélération ont été placé sur la tubérosité tibiale antérieure. Les pics d'accélération latérale suivant immédiatement le contact au sol du talon étaient significativement plus élevés chez les patients avec un genou atteint d'insuffisance du LCA que chez les patients normaux. Il est également apparu que les pics d'accélération latérale étaient significativement plus élevés dans les cas ou le délai après l'altération du LCA étaient de 3 ans ou plus que dans les cas ou cette période était inférieure à 3 ans. L'opération de reconstruction a permis une diminution significative des pics d'accélération au point que ceux-ci ne présentaient aucune différence significative avec ceux enregistrés avec les genoux normaux.

Introduction

It is widely accepted that anterior cruciate ligament (ACL) insufficiency accompanied by lateral thrust causes medial osteoarthritis (OA) [1–3, 5]. Lateral thrust is a sideways movement of the knee which occurs suddenly in the early stance phase of gait. However, there are very few reports of the dynamic assessment of this lateral thrust of the knee during walking [4, 6]. The purpose of our study was to evaluate dynamically the lateral thrust which occurs in ACL insufficient knees, and from the findings investigate any relationship between ACL insufficiency and the later occurrence of osteoarthritis (OA).

Materials and methods

We investigated 80 knees in 40 patients [mean age 24 (16–50) years] each of whom had one damaged knee and were awaiting ACL reconstruction (group 1), and 25 knees of patients whose ACL had already been reconstructed (group 2). The period from injury in group 1 ranged from 2 to 168 months (mean 27.4 months) and the lateral thrust of these 80 knees was measured before ACL rupture was confirmed by arthroscopy. Of the 40 knees with ACL insufficiency, we found 12 with a medial meniscus injury, 11 with a lateral meniscus injury and 14 with a complicating cartilage injury. The 25 knees in group 2 had already had their ACL reconstructed and the lateral thrust of these 25 knees was measured 6 months after surgery.

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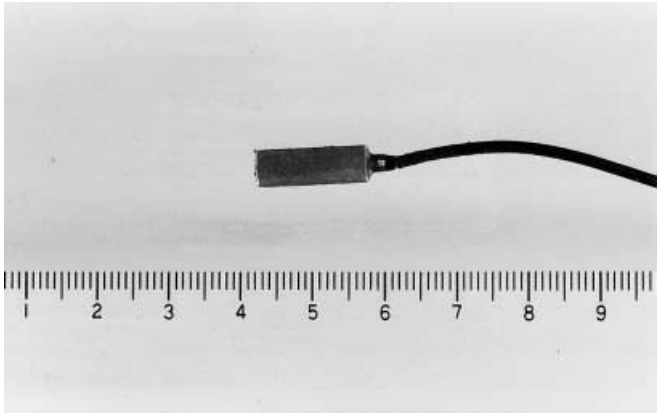

Fig. 1 The unidirectional accelerometer used in the study

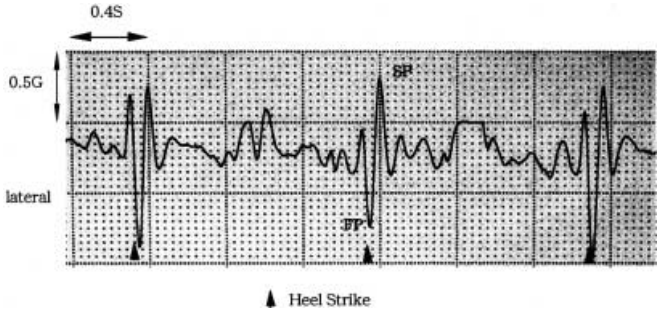

Fig. 2 Accelerographs of a normal knee showing the lateral thrust pattern in which the first acceleration peak (*FP*) appears in the lateral direction after the heel strike followed by the second peak (*SP*) in the medial direction

We used Wosk's technique [8] to assess the lateral and medial thrust of the knee, attaching (with adhesive tape) a unidirectional accelerometer (type 1823; NEC San-ei, Tokyo, Japan) to the skin over the tibial tubercle (Fig. 1). However, skin motion artefacts are common if the accelerometer attached to the skin is used to gather data and we attempted to reduce these errors to a minimum by preloading the accelerometer against the skin. This technique measured the horizontal medio-lateral component of acceleration during walking. In order to assess the time of heel strike, a strain gauge was attached to the skin on the sole of each heel of the subjects. Signals from these two devices were recorded on a computer via a telemeter. Data was collected while each subject walked at their normal speed for about ten gait cycles on a flat level walkway. Care was taken to ensure that subjects maintained an even gait and for data analysis only the middle three gait cycles were used.

Results

Normal knees

There were three 'patterns' observed in the accelerographs obtained from the 40 normal knees – lateral, medial and unclassifiable. A lateral thrust pattern was found in 30 knees with the first acceleration peak (FP) occurring after heel strike, followed by a second peak (SP) which arises in a medial direction (Fig. 2). Four knees

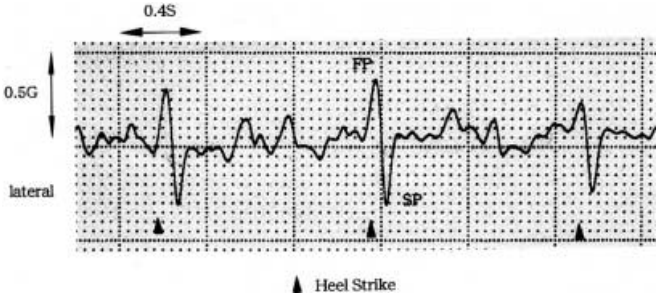

Fig. 3 Accelerographs of a normal knee showing the medial thrust pattern in which the first acceleration peak (*FP*) appears in the medial direction after the heel strike followed by the second peak (*SP*) in the lateral direction

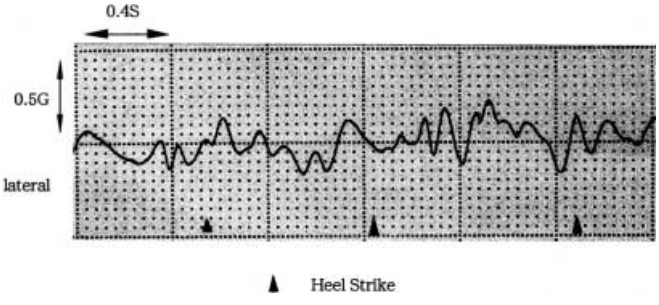

Fig. 4 Accelerographs of a normal knee showing the unclassifiable pattern

demonstrated a medial thrust pattern. The FP is in a medial direction and is followed by a lateral direction SP (Fig. 3). An unclassifiable pattern was found in six knees with multiple peaks in mixed medial and lateral directions (Fig. 4).

ACL insufficient knees

A lateral thrust pattern was found in 36 ACL insufficient knees. The amplitude of the FP was significantly increased when compared with the normal knees (Student's *t*-test: $P<0.0001$; Table 1). A medial thrust pattern was found in four knees. When the periods from injury were compared, the lateral thrust of the injured side after 3 years was significantly greater than before 3 years (Table 2).

ACL reconstructed knees

Of the 25 knees which had undergone ACL reconstruction, 14 showed a lateral thrust pattern, 6 showed a medial thrust pattern and 5 had an unclassifiable pattern. The peak value of lateral acceleration was significantly greater in the ACL insufficient knees when compared to the ACL reconstructed knees ($P<0.0001$). There was no significant difference between the normal knees and the ACL reconstructed knees.

Table 1 Thrust patterns and peak values of acceleration. Means ± SD are shown; number of knees are *in parentheses*

Thrust pattern	Normal knees (m/s^2)	ACL insufficient knees (m/s^2)	ACL reconstructed knees (m/s^2)
Lateral thrust	1.86±1.45 (*n*=30)	3.59±1.03 (*n*=36)*	2.17±1.1 (*n*=14)#
Medial thrust	1.96±1.53 (*n*=4)	1.99±1.53 (*n*=4)	1.88±1.59 (*n*=6)
Unclassifiable	– (*n*=6)	– (*n*=0)	– (*n*=5)

*Significant difference between ACL insufficient knees and normal knees, $P<0.0001$
#Significant difference between ACL reconstructed knees and normal knees, $P<0.0001$

Table 2 Peak values of lateral acceleration in the ACL-insufficient knees. Means ± SD are shown; number of knees are *in parentheses*

Thrust pattern	Over 3 years after injury (m/s^2)	Under 3 years after injury (m/s^2)	*P*-value
Lateral acceleration	4.28±1.19 (*n*=10)	2.41±0.25 (*n*=26)	<0.001

Discussion

A great deal of research has been reported concerning the secondary OA changes which occur in ACL insufficient knees [1–3, 5]. However, there are almost no reports of studies which have dynamically evaluated the instability of the ACL insufficient knee during walking. It is sometimes possible to confirm visually a distinctive lateral thrust in an OA knee during walking, but it is not easy to assess this quantitatively. For this reason we have been using an accelerometer to measure lateral thrust in the knee during walking and this may help to decide the best treatment for OA of the knee [6, 7]. As it is unnecessary to establish standard positioning of the accelerometer, these measurements are thought also to be of value in revealing even slight lateral thrusts in ACL insufficient knees which have not yet developed OA.

In this study we measured the lateral thrust of ACL insufficient knees using an accelerometer and found that the lateral acceleration peak value immediately after heel contact was significantly greater in ACL insufficient knees than in normal knees. From this we can surmise that in ACL insufficient knees the adduction momentum increases during walking, thus causing an increase in the shearing compression applied to the medial compartment, and this in turn accelerates the development of OA.

In addition, our results also indicate that the lateral thrust is significantly greater in knees 3 years or more after injury when compared with the findings in the first 3 years. This suggests that if an ACL insufficient knee is left untreated, tension from the repeated medial movement is applied to the lateral soft tissue structure which gradually becomes stretched and lax. As a result the lateral thrust of the knee during walking may increase and this may encourage the development of OA or accelerate this degeneration if there is also a damaged meniscus.

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