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Lateral thrust of anterior cruciate ligament-insufficient knees and posterior cruciate ligament-insufficient knees

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Abstract Leaving anterior cruciate ligament (ACL) insufficiency and posterior cruciate ligament (PCL) insufficiency untreated frequently leads to osteoarthritis (OA). The purpose of this study was to evaluate dynamically the lateral thrust of ACL-insufficient knees and PCL-insufficient knees, and from the findings investigate the relationship between cruciate ligament insufficiency and OA occurrence. An acceleration sensor was attached to the affected and control anterior tibial tubercles, acting in medial-lateral and perpendicular directions. The lateral thrust immediately after heel strike was measured continuously by a telemeter under stabilised walking conditions. When compared to the contralateral healthy knee, the peak value of lateral acceleration immediately after heel strike was significantly larger in the ACL-insufficient knee; and lateral thrust was increased, but not significantly, in the PCL-insufficient knee. Given that lateral thrust of the knee during walking increases due to ACL or PCL injury, it may be a principal contributor to OA progression.

Résumé Les lésions non traitées du ligament croisé antérieur (LCA) et du ligament croisé postérieur (LCP) mènent fréquemment à l'arthrose. Le but de cette étude était d'évaluer les latérales des genoux LCA-insuffisants et des genoux LCP-insuffisants dynamiquement, et de chercher les relations entre l'insuffisance des croisés et la survenue de l'arthrose. Un capteur d'accélération a été fixée à la tubérosité tibiale antérieure du côté affecté et du côté témoin mesurant dans le sens médial-latéral et dans les directions perpendiculaires. La poussée latérale qui suit l'appui talonnier a été mesuré par un télémètre

dans des conditions de marche stabilisée. La comparaison au genou sain controlatéral montrait que le pic d'accélération latérale après l'appui talonnier était nettement plus important en cas d'insuffisance du ligament croisé antérieur et un peu plus important seulement en cas d'insuffisance du croisé postérieur. L'augmentation de la poussée latérale du genou à cause de l'insuffisance des ligaments croisés pendant la marche serait le facteur principal de l'évolution arthrosique.

Introduction

Lateral thrust of the knee associated with a shift of the load when walking is observed mainly in cases of gonarthrosis. Relative to the normal knee, thrust in gonarthrosis is significantly increased but can be successfully reduced or eradicated by treatment [11, 12]. Although this disease may be induced by various factors, the involvement of cruciate ligament-insufficient knee is widely acknowledged. Anterior cruciate ligament (ACL) insufficiency and posterior cruciate ligament (PCL) insufficiency frequently cause meniscal injury, which can progress to osteoarthritis (OA) with lateral thrust [2, 3, 5, 8, 13]. However, very few studies have dynamically evaluated whether any relationship exists between the onset of OA and lateral thrust of the knee during walking in patients with ACL or PCL insufficiency [6, 7, 10, 13, 14, 15]. To this end, we conducted such an evaluation during walking under routine daily life conditions and report the findings here.

Materials and methods

Normal knees

Sixty participants (32 men and 28 women) with a mean age of 27.2 (range: 25–34) years with normal healthy knees and hip joints were recruited to serve as controls. Participants were confirmed to have no abnormality of leg alignment when standing (genu varum or genu valgum).

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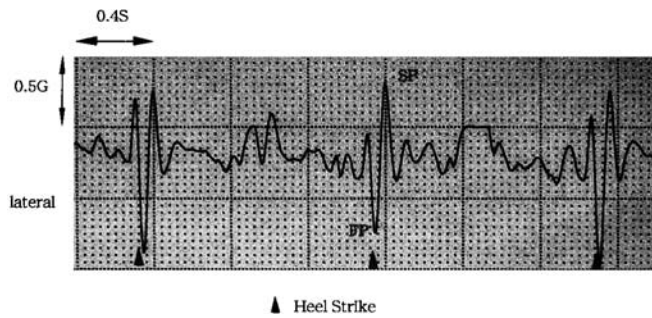


Fig. 1 Accelerographs of a normal knee showing the lateral thrust pattern in which the first acceleration peak (*FP*) appearing in the lateral direction after the heel strike is followed by the second peak (*SP*) in the medial direction

Anterior cruciate ligament-insufficient knees

We investigated 35 knees of 35 patients (21 men and 14 women) with a mean age of 24.5 (range: 16–45) years scheduled to undergo ACL reconstruction. The period from ACL injury ranged from 2 to 36 (mean 7.7) months. No patient evidenced arthropathy on X-rays. Patients that showed obvious abnormality of leg alignment upon standing were excluded, as were those who had concomitant ligament injury. Of the 35 knees with ACL insufficiency, medial meniscus injury was identified in ten knees, lateral meniscus injury in nine and a complicating cartilage injury in nine.

Posterior cruciate ligament-insufficient knees

Twenty knees of 20 patients (17 men and 3 women) with a mean age of 28.2 (range: 23–48) years were investigated. The period from PCL injury ranged from 3 to 36 (mean 15.4) months. Patients with obvious abnormality of leg alignment upon standing, with concomitant ligament injury or with arthropathy on X-rays were excluded. Of the 15 knees with PCL insufficiency, we found four had medial and two lateral meniscal injuries.

The lateral and medial thrust of the knee was evaluated according to the method of Wosk et al. [14]. We have demonstrated previously the repeatability and accuracy of this method [13, 14]. Unidirectional accelerometers (1823, NEC San-ei, Tokyo, Japan) were used to register the medial-lateral and perpendicular components of acceleration while walking. The devices were attached with adhesive tape to the skin overlying the subjects' tibial tubercles. In an attempt to minimise skin motion artefacts commonly produced when accelerometers are attached to the skin, we preloaded the accelerometers against the skin as described elsewhere [6, 11].

To assess the time of heel strike, a strain gauge of horizontal direction was attached to the skin overlying the tibial tubercle. Signals were recorded on a computer via a telemeter.

After ambulatory exercise was performed for each knee three times, data was collected while each subject walked for about ten gait cycles on a flat, level walkway at their normal speed. Care was taken that subjects maintained an even gait. Patients were monitored three times after sufficient practice. The middle three gait cycles, reflected by a stable waveform, were used for data analysis.

We categorised thrust patterns as lateral, medial and unclassifiable. A lateral thrust pattern (LTP) was defined as the first acceleration peak (*FP*) after the heel strike arising in a lateral direction followed by a second peak (*SP*) in a medial direction (Fig. 1). Conversely, a medial thrust pattern (MTP) was defined as the *FP* arising in a medial direction followed by a lateral direction *SP* (Fig. 2). An unclassifiable pattern (UP) was characterised by multiple peaks in mixed medial and lateral directions (Fig. 3).

The peak value of lateral thrust was compared between normal and ACL-insufficient knees, and normal and PCL-insufficient knees. Statistical significance was determined using Student's *t*-test ($P < 0.05$).

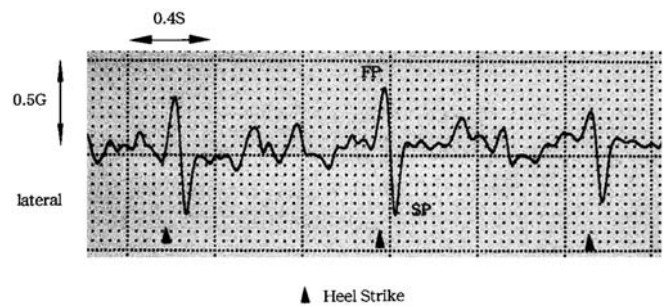


Fig. 2 Accelerographs of a normal knee showing a medial thrust pattern in which the first acceleration peak (*FP*) appearing in the medial direction after the heel strike is followed by a second peak (*SP*) in the lateral direction

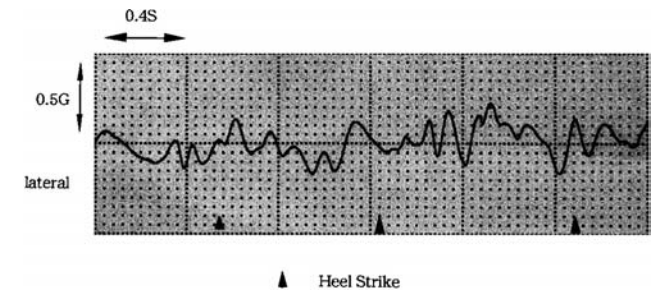


Fig. 3 Accelerographs of a normal knee showing an unclassifiable pattern

Results

Normal knees

LTP was identified as the first peak occurring immediately after heel strike in 40 of the 60 knees, and four knees were found to have UP. In the remaining 16 knees, the *FP* had an MTP.

Anterior cruciate ligament-insufficient knees

LTP was identified in 31 of the 35 knees with ACL insufficiency. In the remaining four knees, the *FP* had an MTP.

The peak value of the lateral acceleration immediately after heel strike was significantly larger in the ACL-insufficient knees when compared to healthy knees ($P < 0.0001$) (Table 1).

Posterior cruciate ligament-insufficient knees

Sixteen of the 20 knees with PCL insufficiency had LTP, and four knees were found to have UP. One knee was found to have MTP. Lateral thrust was increased in the PCL-insufficient knees compared to the unaffected normal knees, but the difference was not significant ($P = 0.19$) (Table 1). MTP was not detected in the PCL-insufficient knees or in the healthy knees.

Table 1 Thrust patterns and peak values of acceleration. Mean±SD

| Thrust pattern | Normal knees (number of knees) | ACL-insufficient knees (number of knees) | PCL-insufficient knees (number of knees) |
|----------------|--------------------------------------|---|---|
| Lateral thrust | 2.05±0.73 (m/s ²) (n=40) | 3.23±0.86* (n=31) | 2.23±0.78 (n=16) |
| Medial thrust | 1.96±1.42 (n=16) | 1.99±1.53 (n=4) | 2.41 (n=1) |
| Unclassifiable | (n=4) | (n=0) | (n=3) |

* Significant difference between ACL-insufficient knees and normal knees $P<0.0001$

Discussion

Rupture of the ACL has been called “The beginning of end for the knee” [8], as it causes OA of the knee. The expected course of untreated ACL rupture is one of progressive deterioration of knee function with meniscal tear, and degeneration of articular cartilage. ACL reconstruction is, therefore, necessary to prevent the occurrence of OA.

As yet, there is no consensus as to whether PCL insufficiency of the knee inevitably leads to arthritis, as it does with ACL. Comparable radiographic evidence found by Clancy et al. [1] and Cross et al. [2] demonstrated that when arthritis did occur it was in the medial compartment. However, Profile and Bergfeld [13] found that there was no relationship between length of follow-up and severity of arthritic change, and that 5–10 mm posterior instability will not progress inevitably to medial arthritis.

To date, dynamic evaluations of the instability of ACL- and PCL-insufficient knees during walking rarely appear in the literature. It is possible, to a certain extent, to visually confirm a distinctive lateral thrust in an OA knee during walking, but it is not easy to make a quantitative evaluation. For that reason, at our hospital we routinely use an accelerometer to measure lateral thrust in the knee during walking, and have previously reported its application to the treatment of OA of the knee [11, 12]. As it is not necessary to establish standard points for the accelerometer, the device is thought to be valuable in capturing even slight lateral thrust in knees that have not developed OA.

In the present study, we identified that lateral thrust in the normal knees was observed mainly when the mechanical axis was not centred for the knee joint and was, instead, somewhat to the inside of the knee. When we measured the lateral thrust of ACL- and PCL- insufficient knees using the accelerometer, we found that the lateral acceleration peak value immediately after heel contact was significantly larger in ACL-insufficient knees than in normal knees. From these findings, we can surmise that, in ACL-insufficient knees, the adduction momentum during walking increases as the shearing compression applied to the medial compartment increases, thereby accelerating the development of OA.

In the PCL-insufficient knees, there was an increase in the lateral thrust, but the difference was not significant. In addition, peak values of medial thrust did not change remarkably in ACL-insufficient or PCL-insufficient knees. These results are in agreement with those reported by Miyasaka et al. [9], who found that both cruciate ligaments work as secondary restrains on the varus-

valgus torque to MCL or LCL, with the ACL contributing more at extension and the PCL more at flexion. In particular, both cruciate ligaments play a large part in the function of varus restraint. An increase in varus instability was also identified to be small at extension, increasing gradually with increasing knee flexion [4]. In daily living activities, while there are a few activities requiring flexion of the knee, there are numerous activities that require extension of the knee. Therefore, there is a greater tendency for ACL insufficiency to cause OA of the knee.

Lateral thrust of the knee during walking increases in the presence of ACL or PCL injury, suggesting that this factor may also be a principal contributor to OA progression.

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