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WORKSHOPS OF THE SOO (2010, LA ROCHELLE). SYMPOSIUM: PAINFUL MEDIAL KNEE COMPARTMENT SYNDROME IN OVER-45-YEAR-OLDS

Painful medial knee compartment syndrome in over-45-year-olds. II—Technical note: Biomechanical considerations: Theoretic analysis of load distribution in the knee according to plane and to gait phase

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KEYWORDS
Varus deviation;
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Knee

Summary Varus deviation as defined by Thomine is the basis for understanding load distribution between the medial and lateral tibial plateau; it was originally defined in the frontal plane. Analysis in the sagittal and horizontal planes leads to a concept of *varizing area*. Varizing area sheds light on how, during gait, load predominates in the medial and postero-medial knee. It also accounts for the following two findings: (a) degenerative lesions are mainly medial, even when the mid-knee axis is normal; (b) degenerative lesions are mainly posterior.

Introduction

Load distribution between the medial and lateral compartments of the knee is generally considered in the frontal plane and in a posture of unipedal balance. The present

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Figure 1 Frontal plane. The difference between knee center and body-weight is Thomine's varus deviation.

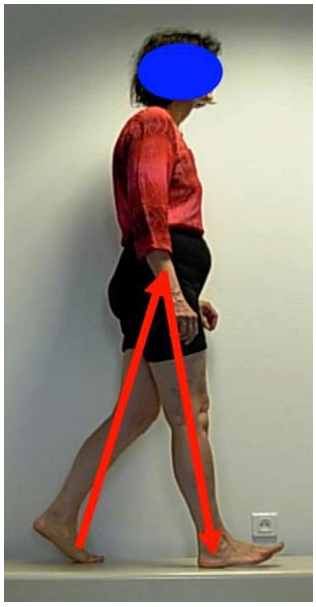

Figure 2 Sagittal plane. During gait, the knee is always at or forward of the gravitational line.

technical note presents a theoretic analysis of load distribution according to plane and gait phase. Standing and walking represent a succession of balance-states in uni- or bipedal weight-bearing. In bipedal weight-bearing, the gravitational line crosses the weight-bearing surface: i.e., lies between the two feet. Moving from bipedal to unipedal weight-bearing, the gravitational line shifts to the weight-bearing side and meets the new weight-bearing surface: i.e., the weight-bearing foot. Observation of unipedal weight-bearing (Fig. 1) shows that there is constantly a distance between the center of the knee and the gravitational line. This distance was referred to as the global varus deviation (GVD) or more simply ''varus deviation'' by Thomine et al. in 1979 [1]. They suggested conventionally identifying the center of gravity and the S2 vertebra, to trace the gravitational line as the line between S2 and the weight-bearing foot.

To determine a reference value, varus deviation was measured in a control group [2] ($n = 80$: 47 female, 33 male) free of lower-limb pathology. Tibial plateau half-width was chosen as unit of measurement, to enable comparison independently of the subject's size and weight. Mean varus deviation was 1.2, with 90% of values lying between 1 and 1.5 and none less than 0.7 (i.e., the gravitational line was systematically medial to the center of the medial condyle). Theoretically, if the gravitational line lies outside of the center of the medial condyle (varus deviation less than 0.66), unipedal stance is impaired by the degree of valgus deformity.

Analysis of movement in three planes

Frontal plane

The frontal plane is the one usually considered. In unipedal weight-bearing, the stress acting on a normal-axis knee is the body weight, which follows the gravitational line. The gravitational line joins the center of gravity (pelvic center) to the weight-bearing point on the ground (i.e., the foot); it passes neither through the femoral head nor through the center of the knee, but flush to the medial edge of the knee. A normal-axis knee is thus offset with respect to the gravitational line. In unipedal weight-bearing, the body-weight therefore exercises a force of compression between femur and tibia, amplified proportionally to the degree of varus deviation. It is then distributed between the medial and lateral tibial plateau. All in all (Fig. 1), in unipedal weight-bearing, the knee (whether with normal axis or in varus or slight valgus) is subjected to stress proportional to the varus deviation.

Sagittal plane

In upright posture, the gravitational line passes exactly through the knees. In walking, the knee is alternately forward and backward of the gravitational line. Stress, however, passes not through the gravitational line but through the line of force. For the forward limb (initiating the step), the line of force goes from the center of gravity (pelvic center) to the step contact with the ground (i.e., the heel), passing exactly through the knee. For the rear limb (completing the step), the line of force goes from the ground contact (i.e., forefoot) to the center of gravity, passing behind the knee, which at the end of the step is slightly flexed to initiate the thrust that will move the body forward. During gait, the knee is thus always at or forward, but never backward, of the line of force (Fig. 2), which is why loading predominates in the posterior knee.

Horizontal plane

What happens in the horizontal plane is somewhat a combination of what happens in the frontal and sagittal planes.

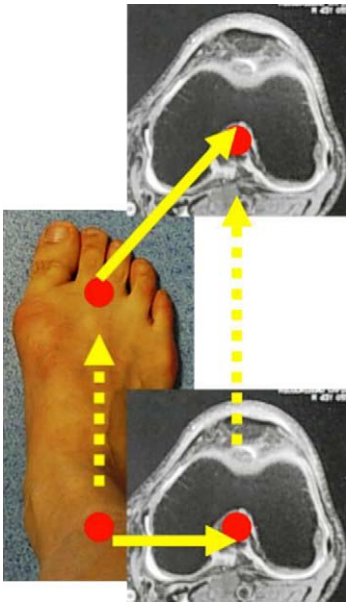

Figure 3 Horizontal plane. Horizontal representation of knee movement during gait. Loading predominates medially and posteromedially.

To see this, one should imagine a bird's-eye view of the respective positions of the line of force and the knee (Fig. 3). At the start of the step, the knee is in extension, and the line of force meets the ground at the heel, passing flush to the medial edge of the knee; the load is thus distributed throughout the knee. In the middle of the step, weight-bearing on the ground moves to the middle of the foot; the knee is slightly flexed and forward: the line of force thus remains immediately medial to the knee. At the end of the step, weight-bearing on the ground moves to the forefoot; the knee is well flexed and thus forward of the line of force; the varus deviation has thus become oblique, with the line of force running medially and posteriorly to the knee; during this phase, loading is predominantly posteromedial. Thus analysis in the horizontal plane shows that, during gait, there is not one but a multitude of varus deviations, and we can consider a ''varizing area'', which is the sum of all these varus deviations. This varizing area accounts for the fact that loading predominates medially and posteromedially, even in a normal-axis knee. If the knee is in varus (Fig. 4), varizing area is considerably increased. When the knee is in flexion (Fig. 5), there is likewise amplification, which explains why degenerative lesions tend to be posteromedial. When the knee is in severe valgus, the line of force lies outside of the medial condyle, and loading becomes lateral.

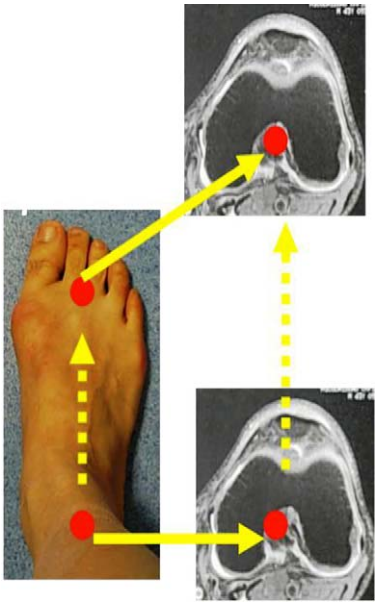

Figure 4 Horizontal plane. Horizontal representation of knee movement during gait. In genu varum, varizing area is increased.

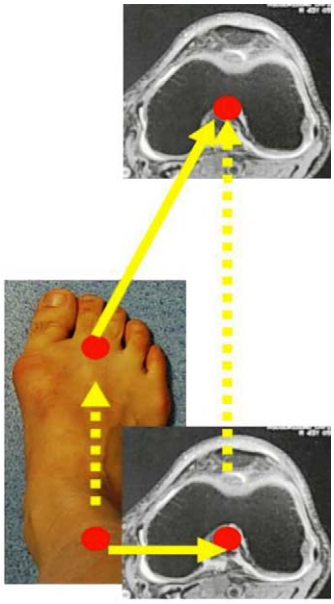

Figure 5 Horizontal plane. Horizontal representation of knee movement during gait. In flexed knee, varizing area is increased.

Conclusion

Varus deviation as defined by Thomine is the basis for understanding load distribution between the medial and lateral plateau; it was defined in the frontal plane, under unipedal weight-bearing. One can, however, also consider varus deviation in the horizontal plane and during gait: summing all of the resultant varus deviations defines a *varizing area*. In a normal-axis knee, the varizing area accounts for the fact that loading predominates medially and posteromedially, and for the following two findings:

- degenerative lesions are mainly medial, even when the mid-knee axis is normal;
- degenerative lesions are mainly posterior.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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