EXTENSOR KNEE MOMENT ARMS

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INTRODUCTION

Musculo-tendinous units control joint motion by exerting moments about them. The quadriceps is the main muscle acting across the knee, and numerous models of the extensor apparatus have been suggested to understand movement co-ordination in healthy individuals (Brand,1985. Fick,1877. Singh,1993). These models are also used to formulate rehabilitation programs for Sportsmen following knee extensor injuries and in the management of extensor paresis. Moments exerted by a muscle about a joint are dependent on both moment arms and muscle forces. The moment arm of a musculo-tendinous unit is the perpendicular distance from its line of action to the center of joint rotation. This estimation becomes imprecise when the axis of rotation of the joint cannot be located with accuracy. In the past, this center of rotation for the human knee has been variously understood to be the cruciate crossing points, the instant centers or evolute centroids and helical axes (Blankevoort,1988).

Brand (Brand,1985) noted that the moment arm of a musculo-tendinous unit can be found if it crosses a joint nearly perpendicular to the axis of rotation. He calculated the moment arm of the musculo-tendinous unit being studied from the derivative of relative excursion of that unit with respect to joint angulation. This method has been used by other researchers. Since recent work has shown that the knee has a fixed flexion-extension (FE) axis (Hollister,1993 Singh,1993) and the quadriceps and patella track perpendicular to this axis, I used Brand's method to measure the mechanical advantage of the quadriceps tendon.

MATERIALS AND METHODS

Fourteen fresh frozen cadaver knees were prepared, the soft tissues being preserved. The knees were mounted with their extensor surface down, over the base platform, using femoral fixator pins thus enabling the shank to be flexed through 110°. A Steinmann pin was inserted along the longitudinal axis (LR) in the tibia (Hollister,1993 & Singh,1993) and an extremely accurate inclinometer / goniometer was clamped to it.

A thick, mono-filament nylon suture was placed in the quadriceps tendon and passed proximal in the line of the femur over a precisely machined pulley. A second goniometer linked to the pulley. This suture was tensioned with a 9.8 N force. This was repeated for the patellar ligament. Hence, both the Patellar ligament (or patellar minus) moment arm and the Quadriceps moment arm (or patellar plus) could be recorded sequentially. The motive force necessary for joint flexion was provided manually. The excursion of both tendons was recorded by noting the number of degrees of angular displacement (ω) at the second goniometer for each 15° of femoral flexion recorded at the first goniometer.

Calculation of Moment arm:

Excursion (**e**) at the knee = Excursion at the pulley

Excursion at the pulley per degree = $\mathbf{2\pi d/360 = e}$

and $\mathbf{e \times \omega \times 3.82}$ = excursion per rad. (each motion step is 15 degrees)

(where ω is the angular displacement at the pulley for every 15 degrees of flexion at the knee goniometer and d is the radius of the pulley). Quadriceps moment arms were recorded in all fourteen knees.

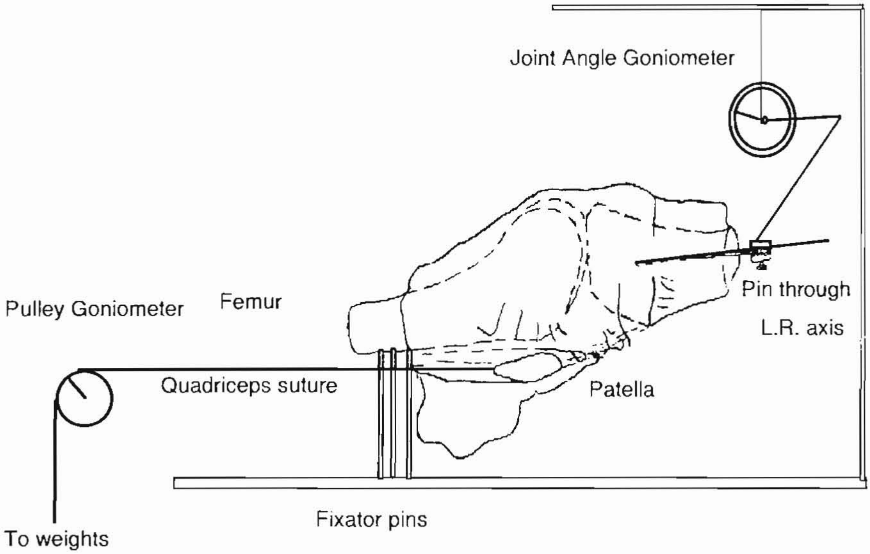


Fig 1: Experimental set-up: a diagrammatic representation.

RESULTS

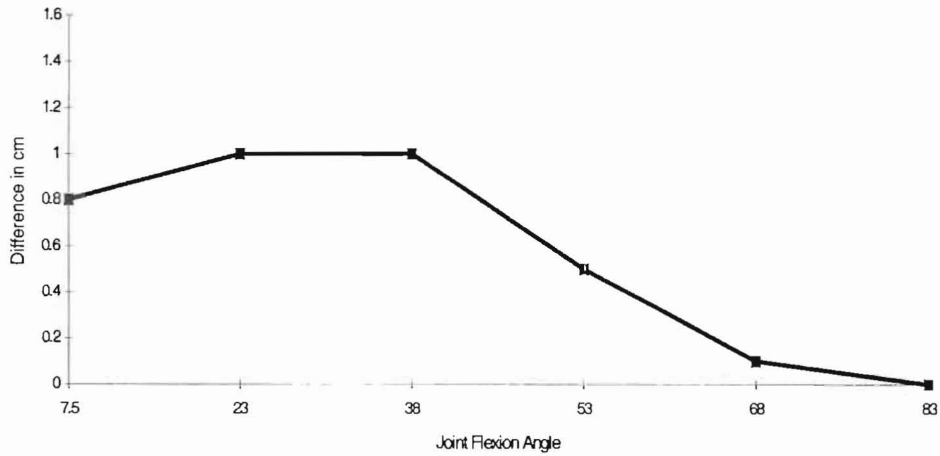
The moment arm for the patellar tendon was longest (3.44 cm s.d.$\pm$ 0.36) at 30° of flexion, decreasing to a minimum (2.57 cm s.d.$\pm$ 0.34) at 90° of flexion (fig 3). Quadriceps muscle moment arms were maximum (4.22 cm s.d. $\pm$ 0.52) at 23° of flexion and least (2.65 cm s.d. $\pm$0.18) at 83° of flexion (fig 3). All the knees exhibited similar curves for both the patellar and quadriceps tendons. The difference between the two curves of each knee is the mechanical advantage of the patella (fig 2).

DISCUSSION AND CONCLUSION

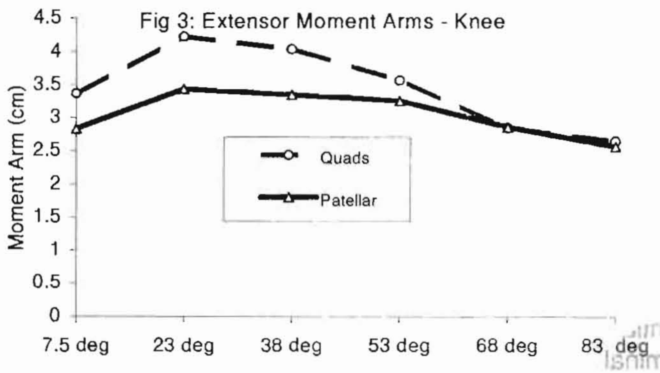
The quads has a substantial moment for knee flexion-extension. The maximum moment arm is in the terminal 30° of extension. However, extensor moments and moment arms calculated referring to instant center rotation (ICRs) or cruciate crossing point location follow a set trend. The moment arms are smaller in the first 30° of flexion due to the close proximity of the ICRs to the extensor apparatus;

they then increase for the 45-60° range as the ICRs migrate posteriorly, and the extensor apparatus enters the inter-condylar groove (fig 2).

Fig 2: Difference in Patellar tendon and Quadriceps Moment Arms

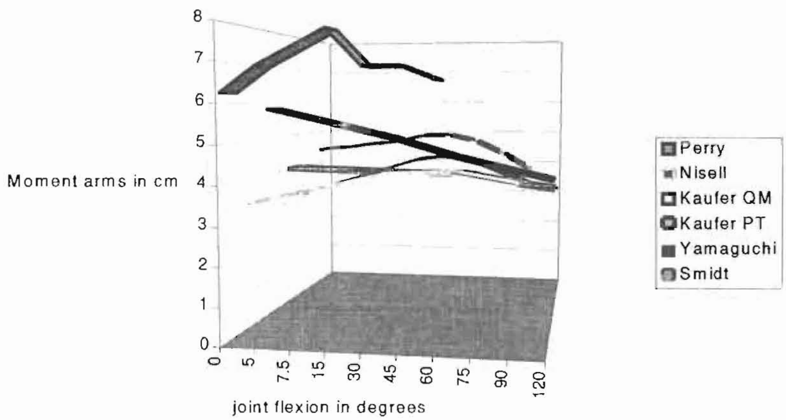


Further joint flexion approximates the quads tendon in the inter-condylar groove and the ICRs, whose posterior migration has slowed. A fundamental knowledge and accurate modeling of the kinematics of gait and running is indispensable for evaluating and improving athletic performance. These implications are profound for force and moment calculations about the knee. The design of protective braces etc., will also be profoundly affected.



The change in the magnitude of the moment arm for the patellar tendon and the quadriceps muscle with total knee replacement is significant It is known from studies of total knee arthroplasties (Singh, 1996) that patients following total knee surgery walk with a stiff-knee gait and heel strike with the knee in extension simulating patients with weak quadriceps. This is consistent with a major decrease in the quadriceps tendon moment arm produced by the total knee arthroplasty. The amount of tension in the quadriceps tendon that is required to produce the same torque is increased by at least one-third. This would result in an increase in the patello-femoral joint reaction force and may account for some of the difficulties following total knee arthroplasty. The changes in quadriceps moment arms after the insertion of a prosthesis designed on the variable ICR theory of kinematics, suggests strongly that normal knee kinematics cannot be based on a similar philosophy. In fact, the presence of a fixed flexion - extension axis would be in line with the increased extensor moment arm noted in the first 23° of joint extension.

Fig 4: Knee Extensor Moment Arms - others



The accurate location of a joint's axis is an essential perquisite for torque and joint force analysis. These require precise moment arm measurement - a procedure easily performed once the axes of a joint are known . A precise three dimensional analysis of musculo-tendinous moments about a joint is essential prior to embarking on reconstructive surgery following sports injuries.

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