# KNEE STABILITY: MECHANICAL CONTRIBUTIONS OF INDIVIDUAL MUSCLES

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## INTRODUCTION

The knee joint is an inherently complex structure that relies less on the shape of its articulating surfaces for stability than any other joint in the lower extremity [1]. The anatomical structure of the knee, and its location between the body's two longest weight-bearing bones, make it particularly susceptible to injury and subsequent instability. Non-operative treatment options, such as functional training and functional knee brace use, have qualitatively been shown to restore knee joint stability by improving muscular recruitment of key stabilizers. However, little is known about the potential contributions of individual muscles to the rotational stability of the knee. Mechanical stability is defined as the "the ability of a loaded structure to maintain static equilibrium even at small fluctuations around the equilibrium position" [2]. Recently, a new approach to calculate stability about any joint has been proposed by Potvin & Brown [3]. The objective of this paper is to use this method to determine the individual contributions, of the 13 knee muscles, to rotational stability about the valgus-varus and the flexion-extension axes of the knee.

## METHODS

A seven segment biomechanical model of the lower extremity was developed based on the work of Delp *et al* [4] and was used to describe the relative joint rotational and translational characteristics of each segment. The inputs to the stability model were: 1) muscle force (assumed to be 100% of maximum), 2) three-dimensional muscle length, 3) functional moment arm and 4) local muscular coordinates with respect to the knee joint, defining either the origin and insertion or, when applicable, nodes on either side of the joint. These data were determined for rotations about the knee's flexion-extension (z) and the valgus-varus (x) axes for two different functional positions (a neutral and a squat position with the hip and knee both flexed to 90°). Fifth order polynomial equations were fit to Nisell's data [5] to determine the exact x and y translations of the femoral-tibial joint and the patella that occur simultaneously with knee flexion-extension. Additionally, seventh and third order polynomial equations were used to predict the active and passive muscle force length effects, respectively, for both postures.

## RESULTS AND DISCUSSION

Overall, the average summed stability in the squat position was approximately 1.3 times higher than in the neutral posture for both the flexion-extension and the varus-valgus axes. Table 1 provides a brief summary of the dominant muscles that provide the greatest stabilizing potential when activated to 100%. Muscles with greater cross-sectional areas and high geometric stability (related to having large functional moment arms and short fibre lengths) proved to be the greatest contributors to knee stability. The semimembranosus (SM), for example, has a physiological cross-sectional area that is an average of 3 times greater than that of semitendinosus (ST), biceps femoris long head (BFL) and short head (BFS) [6]. Interestingly, the stability provided by the BFS ranked third as a flexing stabilizer in the squat position. Its geometric stability in this posture is slightly greater than that of SM and is 2.75 times greater than the ST. The maximum force potential of the BFS is about 1.2 times higher than the ST, while its stabilizing potential is about double. The BFS, it seems, almost qualifies as the ideal stabilizer, as it has a relatively short length and a long flexor moment arm [3].

Identification of the key knee stabilizers may prove to be useful during rehabilitation following ligamentous injury, and in setting surgical decision-making criteria. For example, the SM has great potential to stabilize the ACL deficient knee about the flexion-extension axis, particularly beyond 20° of knee flexion. Unfortunately, injury to medial or lateral structures leaves the knee rather vulnerable to valgus or varus instability. In the squat posture, the tensor fascia latae offers the second greatest stability potential. Results of a dissection study revealed that the tensor fasciae latae (TFL) has a greater role in stabilizing the knee than the fibular collateral ligament, as the knee is less resistant to varus angulation when the TFL is sectioned [1]. However, its potential to stabilize the knee is only 20% of that from SM. Rationale for surgery or functional knee bracing would seem to be indicated in severe LCL injuries, as the lateral knee stabilizers offer less support in either posture compared to muscles acting in the flexion-extension axis.

## CONCLUSIONS

The stability model used in this study offers great insight into the stabilizing potential of the individual knee muscles. In a future project, this methodology will be used to determine the potential stabilizing benefits that functional knee braces may provide to ACL deficient patients.

## REFERENCES

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**Table 1. Top two ranked individual muscle contributors to knee joint stability. Overall rank given in brackets.**

| Z-axis (Flexion-Extension) | | | | X-axis (Valgus-Varus) | | | |
|---|---|---|---|---|---|---|---|
| Neutral | | Squat | | Neutral | | Squat | |
| Extensors | Flexors | Extensors | Flexors | Lateral | Medial | Lateral | Medial |
| Rect fem. (1) | Med Gas (5) | Vas Lat (3) | SM (1) | Lat Gas (2) | Med Gas (1) | Lat Gas (2) | Med Gas (1) |
| Vas Lat. (2) | SM (6) | Vas Med/Int (4) | BFL (2) | Vas Lat (3) | SM (9) | TFL (3) | none |