PATELLOFEMORAL JOINT FORCE DURING KNEE EXTENSION IN OPEN KINETIC CHAIN EXERCISE

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INTRODUCTION

The compressive force generated by quadriceps activation results in patellofemoral joint cartilage overload, which is reported by patients as "anterior knee pain" [1]. On strength training and rehabilitation of knee injuries, open kinetic chain exercises (OKC) has been widely spread [2]. Unfortunately, Johnson et al. [3], and Pizzimenti [4] have reported that strength training machines have been developed to impose a variable resistance which not always follows muscle force-length relationship [5].

Since, we have evidences that strength training machines should impose different resistance depending on their mechanical design [5,6], the aim of the present study was to simulate knee joint loads in an OKC knee extension exercise performed in a strength training machine by computational simulation.

METHODS

A 2-D theoretical mechanical model was developed through a simulation of the right leg of one subject of 1.7 meters of height and 70 kg of weight performing knee extension in OKC on strength training machines, as previously conducted [6]. A model of a strength training machine (*Atrex machine* – Righetto, Brazil) was evaluated by mechanical simulation, as previously described by Bini et al. [6].

The mechanical simulation model was based on Newton's mechanics, considering constant angular velocity. The muscle resultant force perpendicular to the tibiofemoral joint was included into the model as the force generated by the quadriceps muscle group, and it was computed by the ratio of muscle resultant moment and the moment arm of quadriceps muscle group [7]. For the calculation of patellar tendon force, the force generated by quadriceps muscle group was adjusted by factors reported by Sharma et al. [8] for each of the five knee angles analyzed (0.98 for full knee extension, 0.59 for 30 deg., 0.56 for 45 deg., 0.55 for 60 deg., and 0.49 for 90 deg.).

Mechanical model for the calculation of patellofemoral compressive force was based on Bressel [7], with effective moment arm length for quadriceps muscle based on data from Kellis & Baltzopoulos [9]. All analysis have been conducted for five knee extension angles (full knee extension, 30 deg., 45 deg., 60 deg., and for 90 deg.) into Excel 2003 (*Microsoft Corporation*) and MATLAB®.

RESULTS AND DISCUSSION

The ratio between the force required to overcome the resistive force (human force - HF) and the resistive force of the machine (RF) is reported in table 1.

Table 1. Ratio between human force (HF) and resistive force of the machine (RF). Courtesy of Bini et al. [6].

Knee Joint Angle (deg.)	Full extension	30	45	60	90
HF·RF⁻¹ ratio (%)	86	81	74	66	43

There was an increase on HF/RF ratio with the reduction of knee joint angle. It is also observed for patellofemoral compressive force, which is depicted in figure 1.
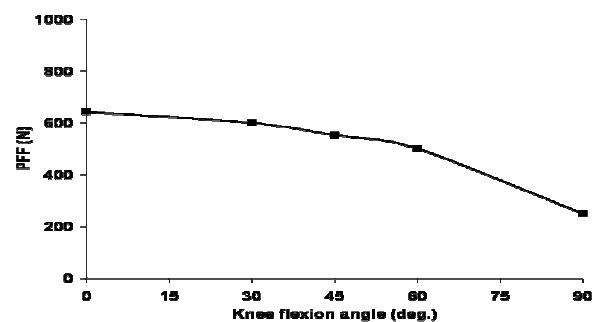
Figure 1. Patellofemoral compressive force on five knee extension angles.

The evaluated strength training machine reduced. patellofemoral compressive force at higher knee flexion angles but does not minimize it between full extension and 60 deg. It has been reported that when knee flexion angle is higher than 60 deg., almost 100% of quadriceps force is transmitted to patellofemoral joint [10].

CONCLUSIONS

The variable resistance of the evaluated strength training machine was able to reduce patellofemoral compressive force when knee flexion angle is higher than 60 deg.

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