USE OF AN INDUSTRIAL ROBOT TO RECORD HUMAN KNEE KINEMATICS IN VITRO - EVALUATION OF THE TEST METHOD

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Introduction

In vitro experiments using 6-axis industrial robots are a common method for studying human knee kinematics, recording passive path (PP) during flexion, and measuring knee laxity at various angles. There is only limited research on the reliability of this test setup even if it has been used countless times for in vitro experiments [1-3]. To ensure reliability, the robot should have an automated determination of the force- and torque-free point at 0° flexion, high reproducibility, and sensitivity.

Method

Test specimens: An anonymized fresh-frozen human cadaveric right knee specimen with medial and lateral unicondylar knee prothesis was tested.

Robot set up: All tests were carried out with a 6-*df* robotic system (KUKA KR 150; KUKA Robotics) equipped with a 6-component force-torque sensor (Omega 160 IP60; ATI Industrial Automation, tolerances: force 2.5N, moment: 0.5Nm).

Finding the force and moment free state at 0° flexion: The goal was to develop a Matlab routine that automatically calculates the starting position, where no forces or torques are acting on the knee except for its own weight. The script determines the load on the robot arm and calculates the position where the knee is in a force-free and torque-free state, which will be used as the starting point of PP and the forces and moments will be set to zero. To test the accuracy of the tare program (TP), the tare point was determined 20 times. After each attempt, a manipulation was performed (e.g., internal rotation), and it was checked if the target values for forces and moments were within the measurement tolerances of the robot sensor.

Reproducibility of the passive path (PP): The PP from 0° to 60° was repeated 21 times using the same starting point. The leg was unclamped and clamped again after each trial. Mean and standard deviation were determined for anterior-posterior displacement, internal and external rotation as well as varus and valgus moments

Results

Validation of tare program: The TP works well and has a hit rate of 90% across all force and moment directions. The most inaccurate is the regulation of the varus and valgus moments where five measurements were outside the tolerance (see Table 1).

Tolerance	F_x	F_y	F_z	M_x	M_y	M_z
in	19	19	20	18	15	20
out	1	1	0	2	5	0

Table 1: Count of trials within/outside tolerance range of sensor.

Reproducibility of passive path: As Figure 1 shows, even with the same starting point 21 repetitions of PP cannot hit the same path twice. The largest range of correct solutions is observed for internal and external rotation.

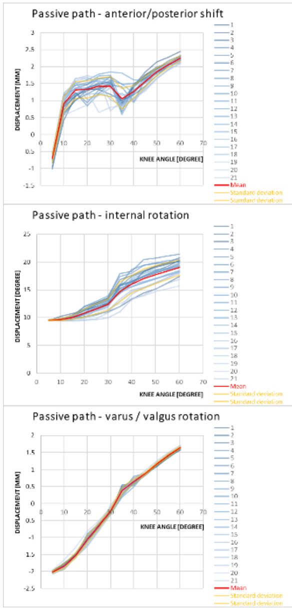

Figure 1: PP-21 repetitions

Discussion

TP can determine knee force- and moment-free state at desired knee angle reliably and is more accurate than a manual search.

The reproducibility study of PP showed that many solutions exist for finding force and moment-free state for a knee flexion. This finding is particularly important for studies comparing cadaver knee prosthesis kinematics to the native state. Therefore, analyse absolute, not relative values when measuring laxity. Further, ligament tension and thus the knee stiffness decreases with each pass of passive pathway due to both increased ligament stretching and temperature changes in the specimen and room. Conditioning of the leg according to the same protocol before the test is therefore recommended.

References

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