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## Appendix

# **Extended Description of the Biomechanical Testing and Loading Protocol**

## Preparation of the Quadriceps Tendon

The quadriceps tendons of the specimens were divided in 3 parts. Each part was inserted into Chinese finger traps and was connected to them by means of suturing. A cord was passed through the loop of each finger trap in a 3-point load-distributing anchor fashion and through a hook, with the latter connected to the testing machine actuator with a steel cable (Fig. E-1).

## Specimen Mounting on the Machine

Figure E-2 shows the interconnection between the quadriceps tendon and the steel cable of a specimen mounted for mechanical testing in detail. The 3-point load-distributing anchor allowed equal pulling forces on each part of the quadriceps tendon.

# Loading Protocol

Each specimen underwent cyclic loading at a one-sixth Hz test frequency in load control simulating a sitting patient performing knee extension-flexion movements against gravity between 90° of flexion and full knee extension. Load control was preferred over displacement and/or stroke control as both of the alternatives could result in specimens not reaching full knee extension and/or 90° of flexion during cyclic loading, on the basis of the unpredictable creeping behavior of the ligaments. Starting at a preload of 20 N with the knee flexed at 90°, pulling of the quadriceps tendon until 300 N (full knee extension) was performed. The preload was used to control the movement in the changing phase between knee flexion and extension, and to prevent over-swinging of the knee. The peak load required to fully extend the knee was determined in a pilot test specimen with the same weight attached to it as was used in all specimens. In this pilot specimen, the load was stepwise increased in manual control until full knee extension was confirmed by means of visual judgment. An amount of 300 N was found sufficient, which is slightly above the theoretical values reported by Hungerford and Barry<sup>32</sup> and by Kaufer<sup>33</sup>.

A modified bell-shaped loading profile between 20 N and 300 N was applied at one-sixth Hz to realize a more homogeneous angular speed and is shown for 1 loading cycle in Figure E-3. The curve features a steep load increase at the beginning and the end of the extension and flexion phases, whereas this load increase flattens in the middle of each phase. The steep part at the beginning of knee extension compensates for the elastic behavior of the tendons and allows immediate initiation of knee movement. In the mid-loading phase, the moment arm in the joint is the greatest, requiring a flattened load increase to maintain angular velocity. The final steep part is used because the moment arm in the knee joint becomes small again at the end of the cycle. As a result, the bell-shaped profile is advantageous over a pure sine or ramped curve because it provides more constant knee movement.

The same weight was attached to all specimens, mimicking a moment arm around the knee joint equivalent to that of an average person weighing 70 kg<sup>7</sup>. Furthermore, the same loading protocol and machine proportional-integral-derivative controller values were applied to all specimens. Therefore, the tests can be considered as reproducible.

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Fig. E-1 Example of a specimen with a prepared 3-part quadriceps tendon connected to Chinese finger traps.





Mounted specimen with the quadriceps tendon connected to the steel cable of the testing machine prior to biomechanical testing.

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Bell-shaped loading profile between 20 and 300 N, applied at one-sixth Hz frequency, shown for 1 loading cycle.