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Tendon and fascial structure contributions to knee muscle excursions and knee joint displacement

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ABSTRACT

Background: Semitendinosus and gracilis muscles whose tendons are used in surgical reconstruction of the anterior cruciate ligament maintain their contractile ability, and a limited decrease of hamstring muscles force is observed postoperatively despite important changes.

The goal was to quantify the influence of the myofascial structures on excursions and moment arms of knee muscles to attempt explaining the above-mentioned post-surgical observations.

Methods: Hamstring harvesting procedures were performed by a senior orthopaedic surgeon on seven lower limbs from fresh-frozen specimens.

Femoro-tibial kinematics and tendons excursion were simultaneously recorded at each steps of the surgery.

Findings: No significant difference was demonstrated for excursions and moment arms after tenotomies and gracilis tendon harvesting ($P \geq 0.05$).

The first significant semitendinosus excursion ($P < 1.17 \times 10^{-4}$) and moment arm ($P < 6.88 \times 10^{-5}$) decrease was observed after semitendinosus tendon harvesting (46% of the initial excursion).

Interpretation: Gracilis and semitendinosus myofascial pathway is crucial for force transmission towards the knee joint.

1. Introduction

Semitendinosus (ST) and gracilis (G) tendons are commonly used in surgical reconstruction of the anterior cruciate ligament using different types of grafts and harvesting techniques. Surprisingly, ST and G muscles maintain their contractile ability, and only a limited decrease in force of the hamstring muscles is observed postoperatively during active knee flexion and internal tibial rotation (Armour et al., 2004; Gomez et al., 1990; Lipscomb et al., 1982; Maeda et al., 1996; Nakamura et al., 2002; Ohkoshi et al., 1998; Yasuda et al., 1995; Zarins and Rowe, 1986).

A so-called myotendinous path is usually assumed to transmit force between the muscle fibres and the moving bony segment (Tidball, 1991; Trotter et al., 1985). The above-mentioned clinical observation contradicts the myotendinous force transmission theory, and questions the current notions regarding the role of tendons. Are tendons the only anatomical structures required for transmission of muscle force to bones? Are there other structures that could explain muscle force transmission without a proper tendon? Additionally, opposing results are found in the literature and hamstring weakness after harvesting is sometimes reported (Burks et al., 2005; Hioki et al., 2003).

The epimuscular myofascial pathway (including loose connective tissue and neurovascular tract) has been suggested as a potential force transmission course organized in parallel with the myotendinous pathway (Huijing, 2009). In 2010, Yucesoy et al. (Yucesoy et al., 2010) assumed, without quantification, that "*post-operatively unchanged peak knee flexion moment may be ascribable, at least in part, to epimuscular myofascial force transmission from G and ST muscles to the knee joint via neighboring hamstrings muscles*".

The ST and G are connected to the knee joint through various fascial structures displaying a complex anatomical architecture. Firstly, as superficial muscles, they attach to the deep fascia (DF) through loose connective tissue. Secondly, loose connective tissue connects the G to the semi-membranous and sartorius muscles (Fig. 1). Finally, the tendons have different fascial bands that insert into the deep fascia of the thigh and/or shank (Reina et al., 2012; Tuncay et al., 2007; Yasin et al., 2010).

Despite these descriptions, the myofascial pathway is not widely considered in the biomechanical and orthopaedic literature and, to our knowledge, has never been the topic of any extensive quantitative scientific study related to the human knee functional behaviour. It also raises new questions about what is the functional importance of myofascial force transmission compared to myotendinous force. Could

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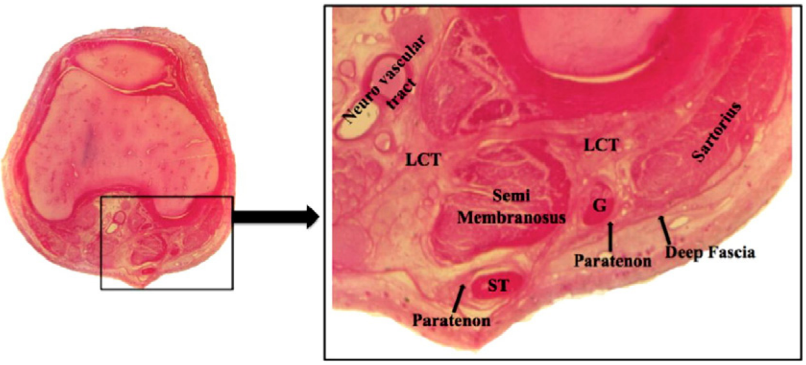

Fig. 1. Superior view of a transverse section of a left foetal knee (LABO collection). Different muscles and fascial structures may be observed: sartorius, gracilis (G), semi-tendinous (ST), and semi-membranous muscles are connected to the neurovascular tract and the deep fascia by loose connective tissue (LCT). Note the proper sheath (paratenon) around G and ST and the continuity between all fascial structures thanks to the LCT.

the mechanical role of the myofascial structures explain some of the surgical outcomes described in the literature? A supplementary question is therefore related to the quantity of resected myofascial tissue and the postoperative outcomes.

The goal of this study was to quantify the influence of the myofascial structures on some of the biomechanical properties (i.e., excursion, moment arms) of knee muscles. Extensive biomechanical measurements using state-of-the-art protocols were performed in-vitro before and after harvesting G and ST tendons. Results were compared to intact conditions.

2. Methods

Seven fresh-frozen lower-limbs (4 males and 3 females) were obtained from the University body donation programme (mean age = 70 years; standard deviation [SD] = 10 years). None of the specimens showed any macroscopic sign of knee joint or lower limb muscle disorders. Careful dissection was performed by a trained anatomist to recline the skin and subcutaneous fat tissue, taking care to keep the deep fascia untouched. The pelvis and femur were rigidly attached to the experimental jig (Fig. 2). In anatomic position using rigid pins running through the skeleton and jig components. The jig allowed normal knee flexion–extension displacements.

2.1. Muscle attachments

A nylon wire was sutured to different muscles (gracilis [G], semi-tendinosus [ST], semi-membranous, sartorius, and biceps femoris) at the proximal part of distal tendons. In order to respect the presence of fascial anatomical structures related to the muscles, each wire was carefully inserted below the deep fascia, allowing them to run along the physiological muscle pathway. Only a very small incision and minimal dissection of the deep fascia and loose connective tissue were required to attach the wires to the tendons, respecting fascial integrity. Each wire ran proximally through tunnels drilled into the bone at the level of the muscle origin to allow joint loading along approximate physiological muscle lines of action. Finally, the wires were attached to the mobile axis of five linear variable displacement transductors (LVDT, Solartron Metrology®, West Sussex, UK). Note that only the results of G and ST are presented in this study.

2.2. Tendon excursion and kinematics measurements

Linear variable displacement transducers (LVDTs) allowed us to measure excursion (An et al., 1983) of the distal tendons of the ST, G, semi-membranous, sartorius, and biceps femoris muscles during

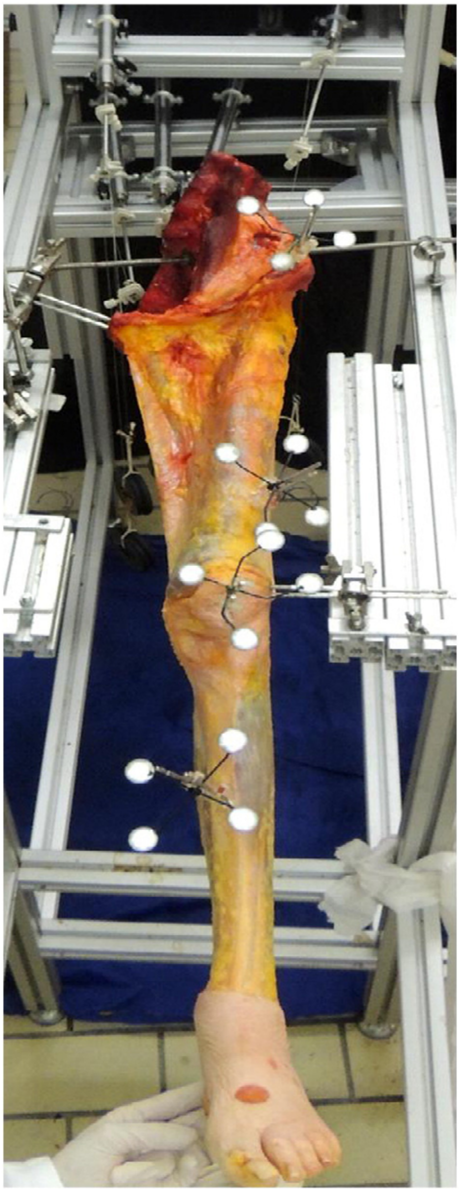

Fig. 2. Specimen attached to the experimental jig. Technical clusters (TCs) attached to the bones of interest and the five linear variable displacement transductors (LVDT) are visible.