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Short communication

Hamstring muscle forces prior to and immediately following an acute sprinting-related muscle strain injury

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ABSTRACT

A thorough understanding of the biomechanics of the hamstrings during sprinting is required to optimise injury rehabilitation and prevention strategies. The main aims of this study were to compare hamstrings load across different modes of locomotion as well as before and after an acute sprinting-related muscle strain injury. Bilateral kinematic and ground reaction force data were captured from a single subject whilst walking, jogging and sprinting prior to and immediately following a significant injury involving the right semitendinosis and biceps femoris long head muscles. Experimental data were input into a three-dimensional musculoskeletal model of the body and used, together with optimisation theory, to determine lower-limb muscle forces for each locomotor task. Hamstrings load was found to be greatest during terminal swing for sprinting. The hamstrings contributed the majority of the terminal swing hip extension and knee flexion torques, whilst gluteus maximus contributed most of the stance phase hip extension torque. Gastrocnemius contributed little to the terminal swing knee flexion torque. Peak hamstrings force was also substantially greater during terminal swing compared to stance for sprinting, but not for walking and jogging. Immediately following the muscle strain injury, the hamstrings demonstrated an intolerance to perform an eccentric-type contraction. Whilst peak hamstrings force during terminal swing did not decrease post-injury, both peak hamstrings length and negative work during terminal swing were considerably reduced. These results lend support to the paradigm that the hamstrings are most susceptible to muscle strain injury during the terminal swing phase of sprinting when they are contracting eccentrically.

1. Introduction

Hamstring strains commonly occur whilst sprinting [1,2]. In order to optimise injury rehabilitation and prevention strategies, a thorough understanding of hamstrings function during sprinting is required. Computer-based musculoskeletal models have recently been utilised for this purpose, however, existing data are limited to treadmill sprinting and to the swing phase portion of the sprinting cycle [3,4]. In the current study, lower-limb muscle forces were determined using a unique dataset captured from a single subject whilst walking, jogging and sprinting prior to and immediately following a hamstring strain. Preliminary analyses of this dataset involving joint kinematics and inverse dynamics only have already been published [5]. In this study, new analyses were performed that aimed to: (a) evaluate the relative contributions of the primary hip extensor and knee flexor muscles to the net sagittal-plane hip and knee joint torques measured for sprinting; (b) compare hamstrings load across the different modes of locomotion; (c) determine if asymmetries in the biomechanics of the hamstrings were evident for sprinting; and (d) compare hamstrings load pre- and post-injury.

2. Materials and methods

Data were acquired from a male Australian Rules football player (height = 186.0 cm; body mass = 91.5 kg; age = 20.3 years). The study was approved by the institutional Human Research Ethics Committee and written informed consent was obtained. Kinematic data were recorded using a 3D motion analysis system with eight cameras sampling at 120 Hz. Three force-plates centred within a calibrated measurement volume of 4 m in length recorded all ground reaction force data. Thirty-six reflective markers were mounted on the subject at specific locations on the trunk, pelvis and both lower limbs. An initial standing calibration trial was performed to establish joint centres and anatomical coordinate systems.

After sufficient warm up, the subject performed a single trial of walking and jogging followed by ten sprinting trials, all at self-selected speeds. Nine sprinting trials were collected in an unimpeded and symptom-free manner. Five trials

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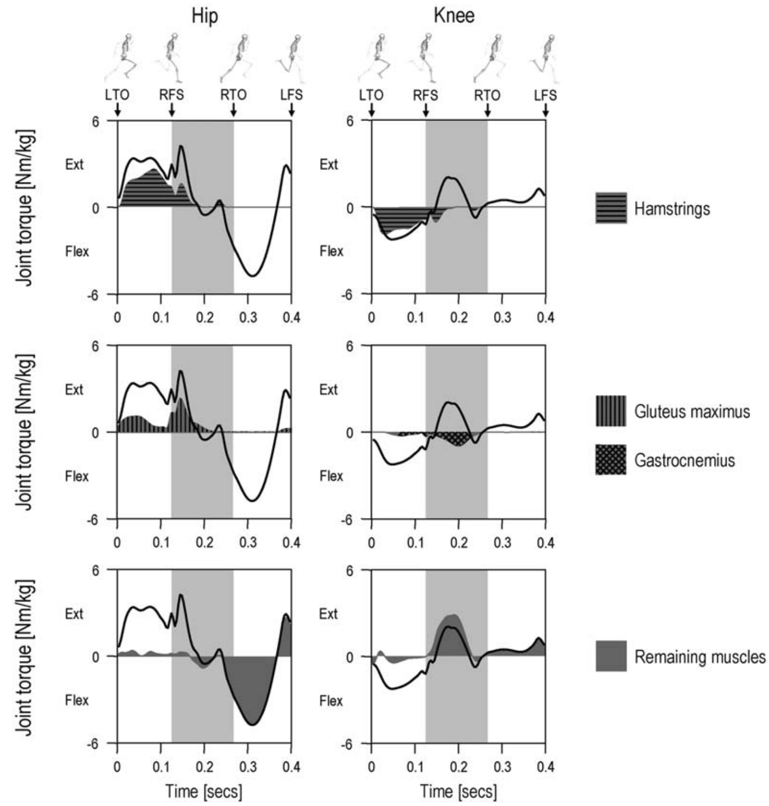

Fig. 1. Primary hip extensor (left panels) and knee flexor (right panels) muscle contributions to the net sagittal-plane joint torques (solid line) exerted about the hip and knee during the terminal swing, stance and initial swing phases of the sprinting cycle. The relative contribution of the hamstrings is indicated in the top panels (dark grey + horizontal lines). The relative contribution of the primary synergists to the hamstrings is indicated in the middle panels (gluteus maximus: dark grey + vertical lines; gastrocnemius: dark grey + crossed lines). The relative contribution from the remaining muscles is indicated in the bottom panels (dark grey). Note that the semimembranosus, semitendinosus and biceps femoris long head muscles were lumped together in the model to represent the hamstrings. The light grey shaded region shown in each figure represents the stance phase. Data are for the right leg for a single representative pre-injury trial from contra-lateral (left) toe-off to contra-lateral (left) foot-strike. LTO, left toe-off; RFS, right foot-strike; RTO, right toe-off; LFS, left foot-strike.

Table 1
Biomechanical parameters for the hamstrings during walking, jogging and sprinting.

Hamstrings muscle-tendon unit parameter	Walking (pre-injury trial)	Jogging (pre-injury trial)	Sprinting (pre-injury trials)		Sprinting (injury trial)
	Right	Right	Right	Left	Right
Length					
Peak length relative to rest length of muscle-tendon unit (%)	−3.17	−5.83	0.15 (0.48)	−0.47 (0.48)	−6.83
Force					
Peak force during terminal swing (F/kg)	9.60	15.16	46.54 (4.28)	43.81 (13.58)	49.56
Time peak force during terminal swing pre-foot-strike (ms)	66.67	58.33	55.00 (20.92)	33.33 (29.66)	16.67
Peak force at foot-strike (N/kg)	9.55	5.28	18.93 (9.33)	31.30 (10.61)	27.32
Peak force during stance (N/kg)	20.17	21.23	31.89 (11.37)	30.96 (6.13)	–
Time peak force during stance post-foot-strike (ms)	16.67	25.00	25.00 (5.89)	25.00 (0)	–
Velocity					
Peak negative velocity during terminal swing (m/s)	−0.25	−0.30	−0.52 (0.08)[a]	−0.48[b]	−0.30
Time peak negative velocity during terminal swing (ms)	200.00	175.00	106.25 (4.17)[a]	100.00[b]	125.00
Peak positive velocity during stance (m/s)	0.12	0.18	0.42 (0.02)	0.42 (0.02)	–
Time peak positive velocity during stance (ms)	741.67	41.67	38.33 (21.73)	50.00 (34.02)	–
Power					
Peak negative power during terminal swing (W/kg)	−0.88	−1.89	−21.05 (5.55)[a]	−24.86[b]	−4.35
Peak positive power during terminal swing (W/kg)	0.11	1.21	14.80 (0.91)	15.01 (1.58)	0
Peak positive power during stance (W/kg)	1.07	3.63	12.21 (5.15)	9.31 (1.81)	–
Work					
Negative work performed during terminal swing (J/kg)	−0.12	−0.16	−0.69 (0.07)[c]	−0.73[b]	−0.20

Negative velocity represents lengthening; positive velocity represents shortening; negative power represents absorption; positive power represents generation. For the walking and jogging trials, data were obtained from a single trial only. For the sprinting pre-injury trials, data represent the average (±1 S.D.) of five and four trials for the right and left legs, respectively, except: [a]data available for four trials only; [b]data available for one trial only; and [c]data available for two trials only. For the sprinting injury trial, the dashed line (–) indicates data are not available, as ground reaction force for the right leg was not recorded in this trial.