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HIGH PLANTAR-FLEXOR PASSIVE STIFFNESS INCREASES ACHILLES TENDON LOADING DURING LANDINGS

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INTRODUCTION

Up to 50% of all sporting injuries are classified as overuse injuries with Achilles and patellar tendinopathies being among the most common, particularly in sports involving repetitive landing [1,2]. During landings, external forces must be absorbed rapidly and eccentrically, which places high loads on extensor mechanisms such as the plantar-flexors and quadriceps. Furthermore, the passive tissues of any musculotendinous complex contribute substantially to the overall forces borne by the entire muscle-tendon unit while actively contracting [3]. As such, it is postulated that limited flexibility through high plantar-flexor passive stiffness or, alternatively, limited dorsiflexion range of motion, may be associated with excessive soft tissue loading and hence, overuse injuries [1]. However, no research has systematically investigated the effects of passive plantar-flexor stiffness on lower limb mechanics during the performance of a dynamic landing task. Therefore, the purpose of this study was to determine how plantar-flexor passive stiffness affected loading at the Achilles and patellar tendons during landings.

METHODS

Passive dorsiflexion range of motion (PROM) and plantar-flexor passive stiffness (PPS; KinCom dynamometer) were quantified for 42 physically active males. The PPS values were obtained by measuring the slope of the torque-angle curve between 15° and 20°, generated while passively stretching the plantar-flexors at 5°.s⁻¹ [4]. All 42 participants were then ranked from the lowest to highest stiffness (Nm.°⁻¹), with the middle 10 PPS values being removed from any further analysis to ensure distinct participant groups; low (LPS) or high (HPS) PPS (see Table 2).

Three-dimensional ankle and knee joint kinematics were then quantified using an OptoTrak 3020 motion analysis system while the participants performed 5 single limb drop landings onto a Kistler force platform at a vertical descent velocity of 3.21 ± 0.17 m.s⁻¹. Achilles tendon forces during each landing were calculated by dividing the internal plantar-flexor moment by the Achilles tendon moment arm [5]. Similarly, the patellar tendon forces were calculated by dividing the internal quadriceps extensor moment by the patellar tendon moment arm using the equation developed by Herzog and Read [6]. Outcome variables characterizing ankle and knee kinematics and forces generated during landing were then compared between the LPS and HPS groups using a series of independent *t*-tests (*p* < 0.05).

RESULTS AND DISCUSSION

During the single limb drop landings, the LPS group encountered a significantly greater peak vertical ground reaction force, although the peak Achilles and patellar tendon forces were not significantly different between the participant groups (see Table 2). However, the HPS group absorbed their peak Achilles tendon force at a significantly greater percentage of their PROM and displayed significantly more dorsiflexion at the time of their peak eversion angle (see Table 2). Experiencing a peak Achilles tendon strain at approximately half of their PROM (see Table 2), while eccentrically contracting their plantar-flexors during an abrupt landing, would certainly place some of the soft tissues of the HPS group under stress at a substantially more lengthened range than their LPS counterparts. Furthermore, as the functional action of the plantar-flexors is to plantar-flex and invert the foot, excessive dorsiflexion, coupled with a substantially everted foot, would produce even greater tensile loading of the Achilles

tendon and other soft tissues. Therefore, it is reasonable to speculate that the HPS group, already with an inherently high PPS (see Table 2), may have experienced strain of their passive tissues at a more compromised physiological range than their LPS counterparts.

It is also likely that the greater knee flexion angle displayed by the HPS group when landing (see Table 2) contributed to a reduction in the peak vertical ground reaction forces they experienced relative to the LPS group. However, this meant that the HPS group flexed their knees by an excessive 77.5° (see Table 2). Although we found no significant difference for peak knee flexion between the groups, the HPS group flexed their knees by approximately 8° more than the LPS group. From a clinical perspective, the soft tissues of the quadriceps complex, including the patellar tendon, must have been more lengthened in the HPS group. It is reasonable, therefore, to postulate that this additional knee flexion may place the soft tissues of the knee extensor mechanism, under a more compromising physiological load more regularly in the HPS group.

CONCLUSIONS

These results indicate that, when performing single limb drop landings, participants with high passive plantar-flexor stiffness, absorbed external loads

through the plantar-flexor and quadriceps complexes at potentially compromising and injurious physiological ranges. The implications of this finding for repetitive sports movements are that high plantar-flexor passive stiffness may cause repetitive overloading of passive structures such as the Achilles and patellar tendons, thereby exposing these athletes to more risk of incurring overuse injuries such as tendinopathies.

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Table 2: Ankle flexibility and landing variables for the low (LPS) & high passive tension (HPS) groups.

VARIABLE	LPS		HPS		p
	N	Mean (SD)	N	Mean (SD)	
Passive plantar-flexor stiffness (PPS; Nm.° ⁻¹)	16	1.0 (0.2)	16	2.2 (0.4)	0.000
Passive dorsiflexion ROM (PROM; °)	16	28.1 (16.6)	16	27.1 (5.5)	0.823
Peak vertical ground reaction force (N)	16	5272 (1186)	16	4420 (1119)	0.045
Peak vertical ground reaction force (N.kg ⁻¹)	16	7.1 (1.3)	16	6.2 (1.4)	0.058
Peak dorsiflexion angle (°) *	15	25.9 (4.3)	16	26.7 (4.9)	0.651
Peak ankle eversion angle (°)	16	13.5 (8.8)	16	16.6 (7.0)	0.287
Dorsiflexion % at peak ankle eversion angle #	16	68.5 (18.9)	16	93.2 (24.8)	0.003
Peak Achilles tendon force (N.kg-1)	16	5.5 (0.9)	16	5.7 (0.6)	0.337
Dorsiflexion % at peak Achilles tendon force #	16	29.5 (13.4)	16	49.3 (26.3)	0.012
Peak knee flexion angle (°) *	9	69.5 (10.4)	14	77.5 (12.8)	0.128
Peak patellar tendon force (N.kg-1)	16	6.1 (1.0)	16	6.0 (0.8)	0.389

* Indicates a reduced sample size due to missing data points; # Dorsiflexion % = dorsiflexion angle at event/ PROM