CHANGES IN MECHANICAL CHARACTERESTICS OF THE PLANTARFLEXOR MUSCLES IN INDIVDUALS WITH DIABETES MELLITUS

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INTRODUCTION

Foot ulcers are estimated to develop in 15% of all individuals with DM[1] and have been linked to repetitive mechanical stress. Loss of ankle range of motion (ROM) and increased stiffness are two factors that have been implicated as potential contributors to plantar loading[2].

Attempts to document changes in passive ankle ROM and stiffness in individuals with DM have uncovered mixed results[3,4]. Differences in criteria for determining passive end ROM and for quantifying stiffness, as well as variations in the extent of pathology in subjects with DM, may account for ostensible differences in ankle ROM and stiffness. During gait: attempts to document plantar loading have not controlled for the confounding effect of walking velocity, which has been shown to influence plantar loading[5]. The biomechanical relationships between passive and dynamic gait measures of ankle ROM and stiffness, and plantar loading are not well understood. The **purpose** of our study was to examine the association between passive ankle ROM and stiffness measured at rest and during gait, in individuals with DM and neuropathy, and to use this information to help understand how ankle ROM and stiffness may influence plantar loading.

METHODS

Twenty-five subjects with DM, neuropathy and no ulcer and 80 age and gender matched non-diabetic controls participated in clinical ankle ROM and stiffness testing. Ten subjects from each group were tested during gait. In subjects with DM, type and duration of DM, most recent HbA1c levels and presence of neuropathy (using Semmes-Weinstein monofilaments) was documented.

Passive Testing: Passive ankle ROM was quantified as angular displacement between the tibial crest and the plantar aspect of the foot, measured with a custom built device, while applying torques of 15, 20 and 25 Nm. Passive ankle stiffness was calculated as the slope of the curves over 15-25 Nm intervals. **During gait:** Plantar pressures were recorded at 60 Hz using in-shoe insoles (Novel Inc, MN), ankle ROM was measured using kinematic data collected using infrared markers (Northern Digital Inc, Waterloo, Canada) placed on the foot, leg and thigh segments, kinetic data was collected using a force-plate embedded in the walkway (Kistler Inc., NY) as subjects walked at 0.89 m/s. Data was processed to yield sagittal plane ankle kinematics and kinetics and ankle stiffness was calculated during second rocker.

RESULTS AND DISCUSSION

Passive: Subjects with DM showed higher ankle stiffness (0.016 vs. 0.005 Nm/kg/º, $p<0.001$) and less peak dorsiflexion (13.5 vs. 21.5º, p<0.001) than age and gender matched control subjects during clinical testing. **Gait:** The groups did not show differences in stiffness (0.068 vs. 0.076 Nm/kg/º, $p=0.97$) or peak dorsiflexion (9.8 vs. 11.7º, $p= 0.93$) utilized during gait.

Passive: Ankle stiffness with the knee extended was significantly associated with ankle stiffness with the knee

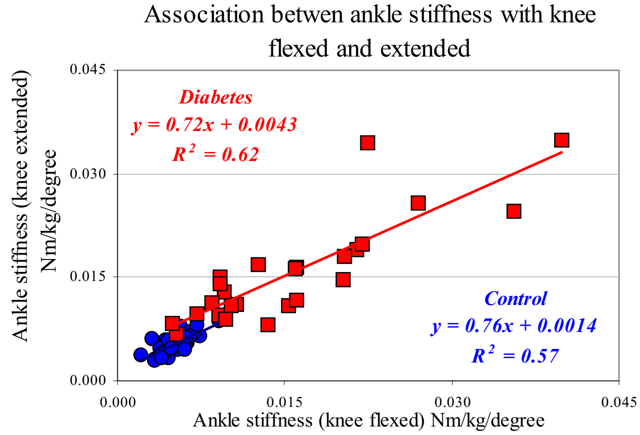

Figure 1: Graph depicting association between passive ankle stiffness with the knee flexed and extended in subjects with diabetes (red squares) and non-diabetic controls (blue circles)

flexed in subjects with DM, as well as in non-diabetic individuals (Figure 1). In subjects with DM, HbA1c levels and duration of DM showed fair association with ankle stiffness in the knee extended position (r^2 = 0.48 and 0.24 respectively, $p<0.01$). **Gait:** In subjects with DM: peak plantar pressure showed a positive association with ankle stiffness during gait ($r^2=0.51$, $p=0.02$) and stride length ($r^2=0.49$, $p=0.03$). In control subjects: peak pressure was positively associated with stride length ($r^2=0.42$, $p=0.02$) but not with ankle stiffness during gait ($r^2=0.06$, $p=0.68$).

CONCLUSIONS

The unique findings of our study revealed that while subjects with DM had restricted passive ankle ROM and increased stiffness compared to control subjects, these measures did not represent ankle motion or stiffness utilized during gait. Peak passive stiffness was about 18 and 23% of ankle stiffness during gait, in control and DM groups respectively, suggesting that individuals with DM may utilize higher contribution from passive stiffness to ankle stiffness during second rocker in gait.

In spite of differences in ankle ROM and passive stiffness, subjects with DM demonstrated ankle stiffness and plantar pressures, similar to control subjects, while walking at identical speed, 0.89 m/s. This may represent an effective strategy adopted by subjects with DM to modulate plantar loading using kinematic pattern.

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