

Changes in the Mechanical Characteristics of the Plantar Flexor Muscles in Individuals with Diabetes Mellitus

Smita Rao¹, Charles Saltzman², H. John Yack¹

¹ Graduate Program in Physical Therapy and Rehabilitation Sciences

² Department of Orthopedic Surgery and Rehabilitation
 The University of Iowa, Iowa City, IA 52242

INTRODUCTION:

- Incidence and prevalence of Diabetes Mellitus (DM) is on the rise¹
- Foot ulcers are a common complication with grave consequences² and have been hypothesized to result from repetitive mechanical stress.
- Ankle ROM and stiffness³ have been identified as factors contributing to increased plantar stress, however evidence in support of this relationship is limited.

PURPOSE:

To examine the association between ankle ROM and stiffness, measured clinically and during gait, and plantar loading in individuals with and without DM.

1. Is peak passive dorsiflexion associated with peak dorsiflexion seen during gait?
2. Is passive ankle stiffness associated with ankle stiffness during gait?
3. Are ankle ROM and stiffness related to plantar loading?
4. Are these relationships different in subjects with and without diabetic neuropathy?

It is hoped that identifying associations will enhance our understanding of how ankle ROM and stiffness may influence plantar loading.

METHODS:

Passive testing: 25 subjects (15 females) with DM (mean age: 54±11 years, mean height: 1.71±0.09 m, mean weight: 96.4±26.0 kg) and 64 non-diabetic control subjects (26 females, mean age: 53±9 years, mean height: 1.71±0.11 m, mean weight: 86.6±15.2 kg). In subjects with DM, presence of neuropathy was documented using Semmes Weinstein monofilaments. Mean duration of DM (13±11 years), glycemic control (HbA1C : 8.2±1.8 %) and type of



Figure 1: Custom device used to measure ankle dorsiflexion while applying torques of 15.27, 20.37 and 25.46 Nm.

Gait testing: 10 subjects from both groups also participated in gait testing. Plantar pressures were recorded using in-shoe insoles (Novel Inc, St. Paul, MN), kinematic and kinetic data were collected using an active marker system and a force-plate embedded in the walkway (Kistler Inc.) as subjects walked at 0.89 m/s. Ankle stiffness was calculated during second rocker using the method described by Davis and Deluca⁴.



Figure 2: Markers placed on foot and leg

Statistical analysis: Linear associations were assessed using Pearson's product moment correlation. Differences between groups were examined using two sample t-test ($\alpha=0.05$)

RESULTS:

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Peak dorsiflexion in gait (degrees)	9.8 ± 1.9	11.7 ± 2.7
Peak passive dorsiflexion (degrees)*	10.7 ± 6.9	23.6 ± 3.9
Passive ankle stiffness (Nm/degree)*	1.49 ± 0.52	1.02 ± 0.17
Ankle stiffness during second rocker (Nm/degree)	6.52 ± 1.31	6.16 ± 1.75
Peak pressure (N/cm ²)	26.8 ± 6.2	24.5 ± 1.5
Stride length (m) *	1.06 ± 0.09	1.21 ± 0.07

Table 1: Summary of clinical and gait measures. * represents statistical significance.

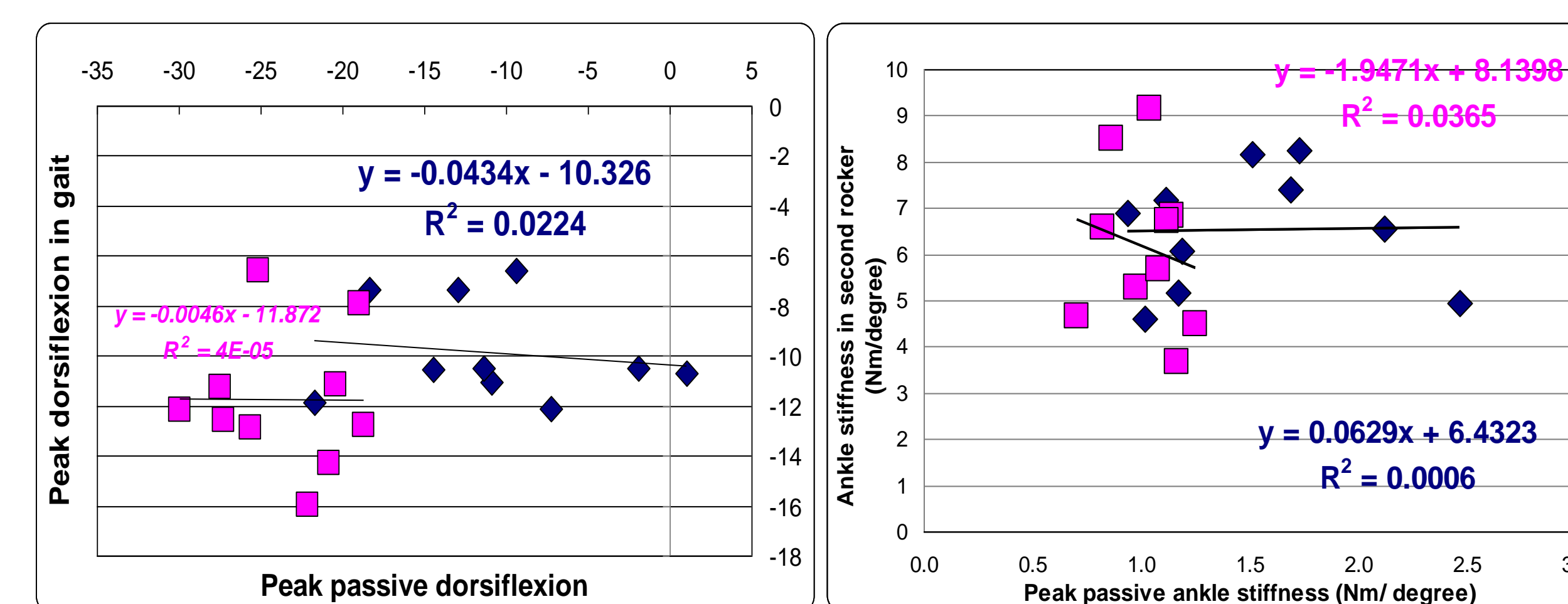


Figure 3: Correlation analyses did not reveal significant relationship between passive ankle ROM and ankle ROM in gait or between passive ankle stiffness and ankle stiffness during gait in either subject group: subjects with and without DM and neuropathy.

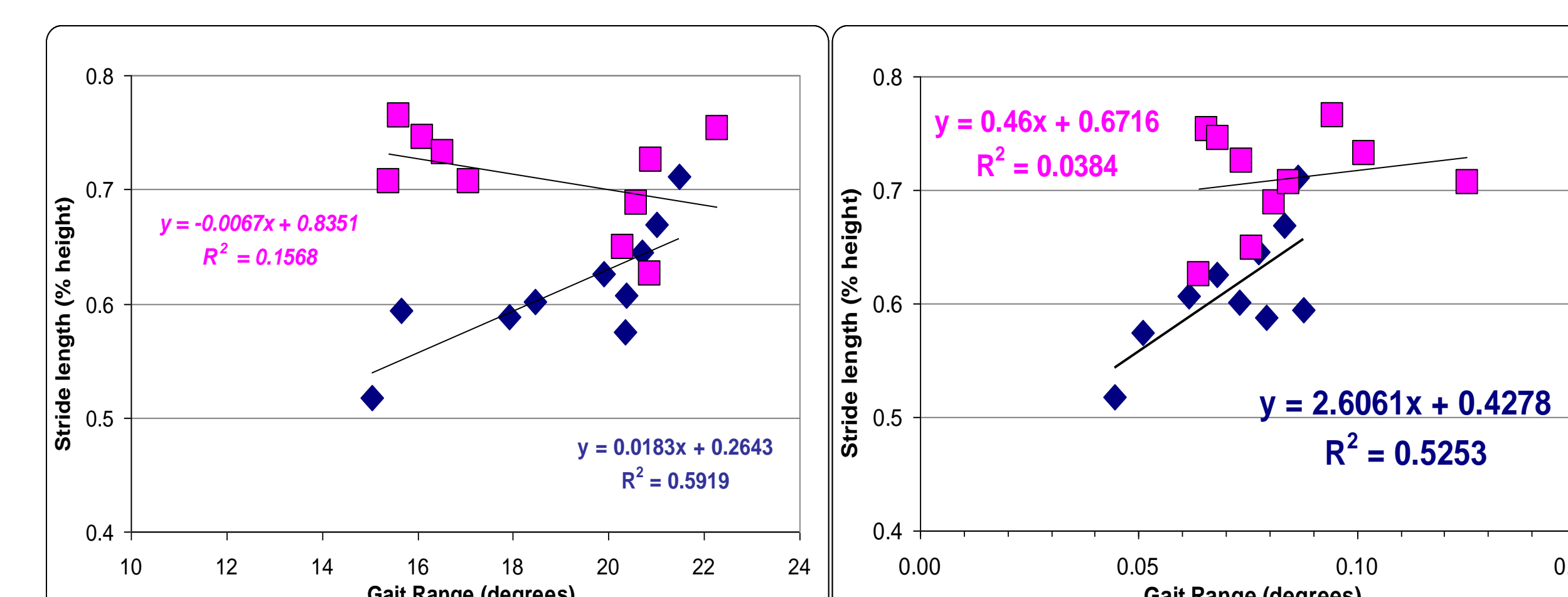


Figure 4: Unlike control subjects, in subjects with DM, stride length, was positively associated with ankle ROM utilized in gait ($r^2=0.59$, $p=0.01$) and also with dynamic gait stiffness ($r^2=0.53$, $p=0.03$).

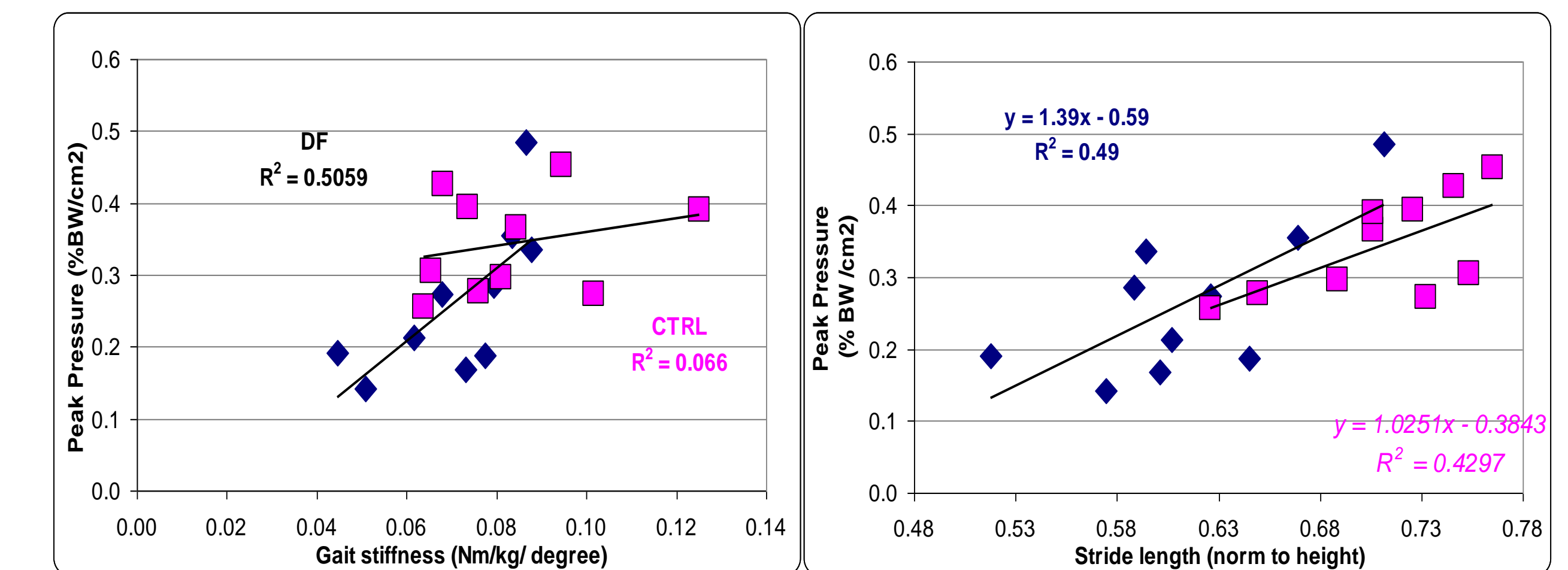


Figure 5: In subjects with DM: Peak plantar pressure showed a positive association with ankle stiffness during gait ($r^2=0.51$, $p=0.02$) and stride length ($r^2=0.49$, $p=0.03$). In control subjects: peak pressure was positively associated with stride length ($r^2=0.42$, $p=0.02$) but not with ankle stiffness during gait ($r^2=0.06$, $p=0.68$).

SUMMARY AND CONCLUSIONS:

These findings in patients with DM and neuropathy suggest:

1. **Subjects with DM have restricted passive ankle ROM and increased stiffness compared to control subjects.**

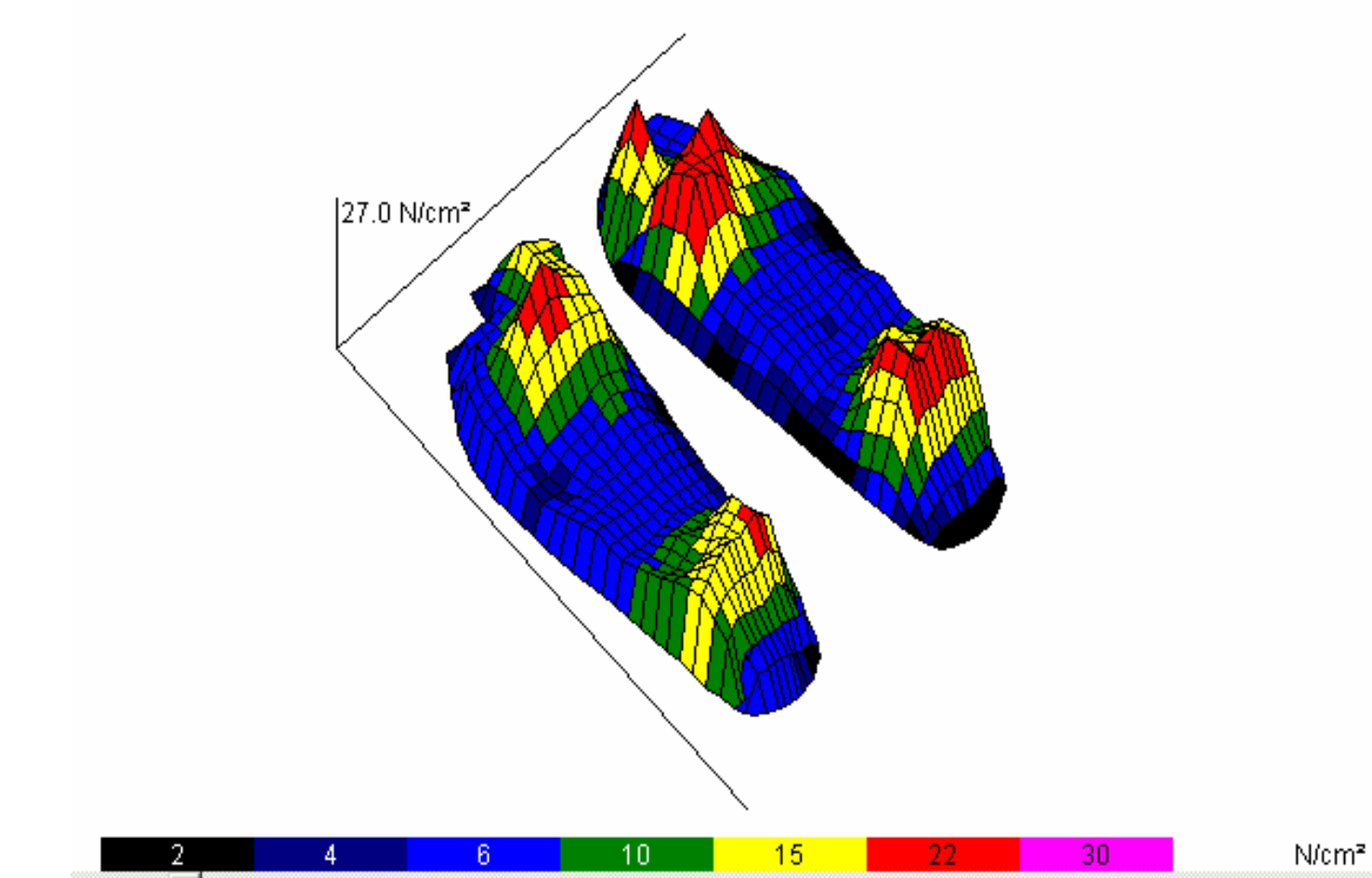
- However clinical measures of passive heel cord tightness did not represent ankle motion or stiffness utilized during gait.
- Peak passive stiffness was about 18 and 23% of ankle stiffness during gait, in control and DM groups respectively.

2. **Plantar loading may be modulated by kinematic patterns adopted during gait.**

- The interdependence of utilized ankle ROM, dynamic stiffness and stride length provides some insight into how peak pressures may be modulated in subjects with DM.

3. **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 the identical speed, 0.89 m/s (2 mph).**

- This may represent an effective strategy adopted by subjects with DM, who have not had problems with ulcers. Future studies are indicated to assess these associations in patients in whom ulcer formation is problematic.



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