Impact of Achilles Tendon Lengthening on Functional Limitations and Perceived Disability in People With a Neuropathic Plantar Ulcer

MICHAEL J. MUELLER, PT, PHD, FAPTA[1]
DAVID R. SINACORE, PT, PHD[1]
MARY KENT HASTINGS, PT, DPT, ATC[1]
DONOVAN J. LOTT, MSPT, CSCS[2]
MICHAEL J STRUBE, PHD[3]
JEFFREY E. JOHNSON, MD[4]

OBJECTIVE — An Achilles tendon–lengthening (ATL) procedure is effective at reducing ulcer recurrence in patients with diabetes, peripheral neuropathy, and a plantar ulcer, but its effects on functional limitations and perceived disability are unknown. The purpose of this study is to report the effects of an ATL and total contact casting (TCC) on the functional limitations and perceived disability of patients with neuropathic plantar ulcers.

RESEARCH DESIGN AND METHODS — Twenty-eight subjects with a mean age of 55 ± 10 years and a BMI of 33 ± 6 kg/m^2 participated. All subjects had a history of diabetes, loss of protective sensation, limited ankle motion, and a recurrent forefoot ulcer. Subjects were randomized into two groups: an ATL group (n = 14), who received treatment of ATL, and TCC and a TCC group (n = 14), who received TCC only. Subjects completed a modified physical performance test (PPT) and the SF-36 Health Survey before treatment, after primary treatment and healing of the plantar forefoot ulcer, and 8 months after initial ulcer healing.

RESULTS — There were no significant changes in functional limitations as measured by the PPT between groups or over time. The physical summary score of the SF-36 decreased slightly from before treatment to 8 months after initial ulcer healing in the ATL group (35 ± 7 to 31 ± 6), whereas the TCC group score increased during this time (34 ± 8 to 39 ± 11; $P < 0.05$).

CONCLUSIONS — The ATL resulted in no measurable change in functional limitations, but patients receiving an ATL and TCC reported lower physical functioning at 8 months after initial ulcer healing than subjects receiving TCC alone and may require additional physical therapy to address this perceived disability.

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An Achilles tendon–lengthening (ATL) procedure has been shown to increase dorsiflexion range of motion (1–3), decrease forefoot plantar pressure (2,3), and reduce the rate of ulcer recurrence in patients with diabetes, peripheral neuropathy, and a history of recurrent ulcers (1,2). Increasing dorsiflexion range of motion using an ATL has been thought to allow the tibia to rotate over the foot during late stance phase, which, in turn, reduces forefoot plantar pressures (1,3). This reduction in forefoot pressure was thought to be the primary mechanism accounting for lower ulcer recurrence after treatment including ATL. A prospective controlled clinical trial (n = 64) indicated that risk reduction for ulcer recurrence after 7-month and 2.1-year follow-up in an ATL group was 75 and 53%, respectively, compared with a total contact casting (TCC) group (2).

We have shown that an ATL also causes an acute reduction of plantar flexor muscle strength (peak torque) by ~30% that recovers within 8 months after treatment (35 ± 13 N · m to 24 ± 13 back to 34 ± 16 at pretest, posttreatment, and 8 months after treatment, respectively) (2,4). Plantar flexor power (push-off) during walking also shows a sizable decrease after ATL (1.36 ± 0.67 to 0.48 ± 0.20 N · m · kg^{-1} · s^{-1}), which recovers somewhat after 8 months (0.92 ± 0.59 N · m · kg^{-1} · s^{-1}) but remains significantly less than presurgical values (5). Forefoot pressure reduction after ATL appears to be more related to the reduction in plantar flexor power at push-off during walking (r = 0.45–0.60) than to an increase in dorsiflexion range of motion (r = 0.02–0.08) (5). Apparently, the reduced strength of the plantar flexor muscles results in reduced push-off during the late stance phase of walking, which, in turn, results in lower forefoot pressures. Although the reduction in plantar flexor muscle strength and forefoot plantar pressures results in a positive reduction in ulcer recurrence rates, it is not clear if this reduction in muscle strength or other outcomes of the surgery affect a patient's ability to walk and move or their perception of disability.

The purpose of this study was to determine the effect of an ATL and TCC compared with the effect of TCC alone on functional limitations and the patient's perceived disability. The physical performance test (PPT) was used as an indicator of functional limitations, and the SF-36 was used as an indicator of the patient's perceived disability. We hypothesized

From the [1]Applied Biomechanics Laboratory, Program in Physical Therapy, Washington University School of Medicine, St. Louis, Missouri; the [2]Movement Science Program, Washington University, St. Louis, Missouri; the [3]Department of Psychology, Washington University, St. Louis, Missouri; and the [4]Foot and Ankle Service, Department of Orthopaedic Surgery, Washington University School of Medicine, St. Louis, Missouri.

Address correspondence and reprint requests to Michael J. Mueller, PT, PhD, P.O. Box 8502, 4444 Forest Park Blvd., St. Louis, MO 63108. E-mail: muellerm@wustl.edu.

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Abbreviations: ATL, Achilles tendon lengthening; PPT, physical performance test; TCC, total contact casting.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

Table 1—*Demographic characteristics of ATL and TCC groups*

Demographic variable	ATL	TCC	*P*
Sex (women/men)	3/11	4/10	0.66
Age (years)	54.8 ± 9.5	54.3 ± 9.9	0.88
BMI (kg/m^2)	33.6 ± 6.0	31.8 ± 6.8	0.46
Type of diabetes (type 1/type 2)	3/11	5/9	0.40
Duration of diabetes (years)	19.9 ± 10.2	17.9 ± 13.9	0.66
HbA_{1c} (%)	8.7 ± 1.8	8.9 ± 2.0	0.70
Ulcer recurrence rate at 8-month follow-up	3/14 (21%)	5/13 (38%)*	NA

Data are means ± SD. *One subject did not heal initially.

that there may be a temporary increase in functional limitations and perceived disability soon after the surgery but that these problems would resolve within 8 months.

RESEARCH DESIGN AND METHODS

— This study was part of a larger randomized controlled clinical trial (2). Sixty-four eligible subjects provided informed consent in accordance with study procedures approved by the Institutional Review Board at Washington University in St. Louis, Missouri. Inclusion criteria were a diagnosis of diabetes, inability to sense a 5.07 (10-g) Semmes Weinstein monofilament on at least one location on the plantar surface of the foot (indicating loss of protective sensation), a recurrent (i.e., two or more episodes) Wagner grade II ulcer (3) on the plantar forefoot or toes, and ≤5° of passive dorsiflexion range of motion at the talocrural joint as measured using a goniometer with the knee extended. Patients were excluded from participation in the study if they were nonambulatory, had a history of rear foot Charcot fractures, had impaired circulation indicated by an ankle-arm index <0.45, or reported a history of significant health problems that rendered them medically unfit for surgery or postsurgical rehabilitation.

Subjects were randomly assigned to treatment with an ATL procedure followed by TCC (ATL group; $n = 31$) or treatment with TCC alone (TCC group; $n = 33$). A smaller subset of subjects agreed to additional testing as described in this study. Therefore, the analyses described in this study include only those subjects who completed testing on all three test occasions (ATL, $n = 14$; TCC, $n = 14$). The number of subjects reported in the analyses varies (see Tables 2 and 3) because not all data were available on all 28 subjects. The groups were not significantly different with regard to age, ethnicity, BMI, duration of diabetes, HbA_{1c}, sex composition, or the proportion of subjects with type 1 and type 2 diabetes (Table 1).

Treatment protocols for this clinical trial have been documented previously (2). Procedures for wound debridement, cast application, and postsurgical rehabilitation were identical for both treatment groups. Briefly, necrotic and callous tissue were debrided from the area surrounding the ulcer. TCC was performed as described previously (6), with the exception that the distal end of the toe box was left open and a standard rocker cast shoe was used. Casts were removed for wound assessment and reapplied after the first week of casting and then every 2–3 weeks until complete epithelialization without drainage was observed. All subjects were instructed to limit their weight-bearing activity during treatment with TCC, and subjects were provided with extra-depth shoes and custom-molded inserts after cast removal according to published recommendations (7). Additionally, a physical therapist instructed all subjects in a home exercise program to perform active ankle plantar flexion, dorsiflexion, inversion, and eversion exercises 3–5 days per week (three sets of 10 repetitions), using appropriate Theraband (Hygenic Corporation, Ipoh, Malaysia) to provide resistance. No supervised therapy was provided beyond this instruction.

After wound debridement, subjects assigned to the ATL group underwent a percutaneous ATL procedure before application of a TCC using a modified Hoke triple hemisection technique (8). The first hemisection was on the medial side of the tendon above its insertion into the calcaneus. The second hemisection was also on the medial side of the tendon but below the musculotendinous junction. The final hemisection was on the lateral side of the tendon midway between the two medial cuts (8). A slow controlled force was applied to the forefoot to rotate the ankle joint into ~10° of dorsiflexion range of motion (8). A TCC was applied as described above, and patients were progressed from partial to full weight bearing in the cast 1 week after surgery. A padded pressure-relief walking boot (DH Pressure Relief Walker; Royce Medical, Camarillo, CA) was prescribed for 1–4 additional weeks after cast removal, until subjects regained sufficient stability to walk with extra-depth shoes and custom-molded inserts.

A modified PPT (9) was used to measure the performance of simulated activities of daily living and functional limitations. The eight standardized items were writing a sentence, simulated eating, lifting a book to a shelf, putting on and taking off a jacket, picking up a penny from the floor, turning 360°, a 50-foot walk test (with turn), and climbing one flight of stairs. Lifting a book, putting on and taking off a jacket, and picking up a penny from the floor were conducted from a standing position. Climbing multiple flights of stairs was not included because most of these patients are unable to climb more than one flight of stairs. Except for turning 360°, each item is scored on a scale of 0–4, determined by the time required to complete the task. The eight items are totaled for a highest possible score of 32. The PPT is a direct measure of a patient's functional limitations during the performance of simulated activities of daily living (9). Walking speed also was determined by using a stopwatch to measure the time required to walk 50 feet in a straight line.

Perceived disability was measured using the SF-36 acute form (1-week recall), a self-report questionnaire, and a global assessment of health, functional status, and disability (10) with established reliability and validity (11). It is a multi-item scale that assesses eight health concepts, including *1*) limitations in physical activities, *2*) limitations in social activities, *3*) limitations in usual role activities due to physical health problems, *4*) bodily pain, *5*) general mental health, *6*) limitations in usual role activities due to mental health (anxiety, depression, psychological well-being, etc.), *7*) vitality, and *8*) general health perceptions. Summary of physical

Table 2—*Results from PPT for ATL and TCC groups*

Outcome variable and group	Test 1 (before treatment)	Test 2 (after primary treatment and healing)	Test 3 (8 months after primary treatment and healing)	Post hoc within group over time tests	ANOVA group × test (*P*)
PPT total					
ATL	21.1 ± 3.2	20.1 ± 4.0	20.2 ± 5.1	NS	NS (0.99)
TCC	23.4 ± 6.0	22.4 ± 6.3	22.3 ± 6.4	NS	
Writing a sentence					
ATL	2.1 ± 1.0	2.2 ± 1.2	2.3 ± 1.0	NS	NS (0.67)
TCC	2.1 ± 1.2	2.3 ± 1.1	2.1 ± 1.1	NS	
Simulated eating					
ATL	3.0 ± 0.4	3.0 ± 0.8	3.0 ± 0.8	NS	NS (0.68)
TCC	3.4 ± 0.7	3.4 ± 0.8	3.2 ± 0.7	NS	
Reaching with a book					
ATL	3.1 ± 0.7	3.5 ± 0.6	3.4 ± 0.5	NS	0.01
TCC	3.4 ± 1.1	3.0 ± 1.0*	3.0 ± 1.1	1 vs. 2†	
Simulated dressing					
ATL	2.6 ± 0.9	2.3 ± 0.9	2.4 ± 1.1	NS	NS (1.00)
TCC	2.9 ± 0.7	2.6 ± 1.3	2.7 ± 1.1	NS	
Picking up a penny					
ATL	2.9 ± 0.7	2.9 ± 0.8	2.5 ± 1.0	NS	NS (0.70)
TCC	3.3 ± 0.9	3.1 ± 0.8	3.0 ± 0.7	NS	
360° turn					
ATL	2.1 ± 1.2	1.7 ± 1.3	2.0 ± 1.4	NS	NS (0.58)
TCC	3.1 ± 1.5	3.0 ± 1.3	2.7 ± 1.7	NS	
50-foot walk test (seconds)					
ATL	15.2 ± 2.8	17.4 ± 2.9	15.5 ± 3.4	NS	NS (0.10)
TCC	15.9 ± 4.8	15.8 ± 4.0	15.1 ± 4.0	NS	
Climb one flight of stairs					
ATL	2.3 ± 0.9	2.1 ± 1.0	2.1 ± 1.1	NS	NS (0.54)
TCC	2.3 ± 1.0	2.0 ± 1.2	2.4 ± 1.2	NS	
Walking velocity (m/min)					
ATL	61.8 ± 10.4	54.0 ± 8.3	61.9 ± 15.9	NS	NS (0.97)
TCC	63.2 ± 21.2	55.8 ± 19.7	64.8 ± 17.9	NS	

Data are means ± SD. *Post hoc *t* test for group differences, ATL vs. TCC at a given testing time ($P < 0.05$); †pretreament versus posttreatment ($P < 0.05$). ATL, $n = 14$; TCC, $n = 14$.

and mental scores also were derived to reflect composite scores of physical and mental disability (12). Each of the items in the eight health domains and two summary measures were scored, summed, and then transformed into a standardized score using a linear *t* score transformation to have a mean of 50 and a standard deviation of 10, as compared with the 1998 general U.S. population (12). Higher scores indicate a better health status and less functional limitation. A research technician read the questions and recorded answers for those patients unable to read or write.

The PPT and the SF-36 tests were repeated on three occasions: a pretest was conducted 1.4 ± 2.1 weeks before treatment, a posttest was conducted 3.4 ± 4.6 weeks after wound closure, and a follow-up test was conducted 8.0 ± 2.0 months after wound closure. A two (group) by three (time) analysis of variance was used to determine differences in scores. A significant group by time interaction would indicate that the two groups (ATL and TCC) responded differently over time. A *t* test was used for post hoc individual comparisons. The α level was set at $P = 0.05$.

RESULTS — No significant differences were noted between the groups over time for the total PPT score (Table 2). The total PPT score changed only 0.9 points in the ATL group and 1.1 points in the TCC group over time. Of the eight individual items of the PPT, only "lifting a book and putting it on a shelf" showed a small but significant difference between groups over time (Table 2). The ATL group increased 0.3 points over time, whereas the TCC group declined 0.4 points, indicating that the ATL group showed a slight improvement in their ability to reach with a book, whereas the TCC group showed a slight deterioration after treatment ($P = 0.01$) (Table 2).

Results of SF-36 testing indicated that the subjects in this study had a low perception of their physical functioning at the beginning of the study. Both groups started almost 2 standard deviations below the standardized population mean of 50 ± 10 for physical functioning (ATL group, 31.8 ± 13; TCC group, 31.7 ± 7.1) (Table 3). This standardized score decreased slightly in the ATL group (3.7 points), whereas it increased over the

Table 3—*Perceived disability*

Outcome variable and group	Test 1 (before treatment)	Test 2 (after primary treatment and healing)	Test 3 (8 months after primary treatment and healing)	Post hoc within group over time tests	ANOVA group × test (*P*)
Physical functioning					
ATL	31.8 ± 8.6	27.7 ± 6.8	28.1 ± 5.3*	NS	
TCC	31.7 ± 7.1	32.8 ± 8.7	38.9 ± 11.5	1 and 2 vs. 3	$P = 0.015$
Role physical					
ATL	40.3 ± 10.5	32.1 ± 13.7	35.9 ± 9.5	1 and 2 vs. 3	
TCC	35.4 ± 11.5	35.4 ± 11.5	40.8 ± 10.4	1 vs. 3	NS (0.085)
Bodily pain					
ATL	43.9 ± 11.5	44.4 ± 10.6	42.9 ± 12.9	NS	
TCC	45.6 ± 10.6	44.9 ± 11.8	49.6 ± 8.5	NS	NS (0.64)
General health					
ATL	39.7 ± 11.8	41.2 ± 11.8	36.3 ± 9.6	2 vs. 3	
TCC	37.2 ± 11.1	37.8 ± 8.5	40.1 ± 11.2	NS	0.049
Vitality					
ATL	48.1 ± 8.3	48.1 ± 12.9	45.8 ± 11.0	NS	
TCC	45.5 ± 10.9	44.4 ± 9.9	47.3 ± 11.7	NS	NS (0.45)
Social functioning					
ATL	42.8 ± 12.4	40.2 ± 15.7	38.6 ± 16.3	NS	
TCC	40.8 ± 12.3	42.2 ± 11.8	44.9 ± 10.6	NS	NS (0.50)
Role emotional					
ATL	45.9 ± 12.2	43.6 ± 13.8	45.1 ± 12.6	NS	
TCC	46.0 ± 14.1	46.0 ± 13.4	49.4 ± 10.2	NS	NS (0.88)
Mental health					
ATL	48.4 ± 11.5	51.1 ± 12.0	50.0 ± 9.9	NS	
TCC	47.0 ± 7.5	43.7 ± 11.5	50.4 ± 10.1	NS	NS (0.56)
Physical summary score					
ATL	35.5 ± 6.9	31.3 ± 8.0	31.0 ± 6.2*	NS	
TCC	33.9 ± 7.5	35.0 ± 7.7	39.4 ± 10.9	1 vs. 3	0.035
Mental summary score					
ATL	51.2 ± 12.3	52.7 ± 15.5	51.6 ± 13.0	NS	
TCC	49.9 ± 11.3	48.2 ± 13.3	51.8 ± 11.5	NS	NS (0.56)

Data are means ± SD. Results from norm-based standardized SF-36 for ATL and TCC groups (1998 general U.S. population had a mean ± SD of 50 ± 10) (12). *Post hoc *t* test for group differences, ATL vs. TCC at given testing time ($P < 0.05$). ATL, $n = 13$; TCC, $n = 12$.

three testing times (7.2 points) in the TCC group ($P = 0.015$) (Table 3).

Similar to the physical functioning scores, scores for general health and the physical summary score of the SF-36 decreased slightly over time for the ATL group and increased slightly for the TCC group. For perceived general health, the ATL group decreased 3.4 points, whereas the TCC group increased 2.9 points over the three testing sessions ($P < 0.05$) (Table 3). For the physical summary score, the ATL group decreased 4.5 points, whereas the TCC group increased 5.5 points over the three testing sessions ($P < 0.05$) (Table 3). There were no other significant differences between groups over time.

CONCLUSIONS — The primary purpose for conducting an ATL in patients with diabetes and a recurrent neuropathic ulcer is to reduce the incidence of ulcer recurrence. Although we had hoped that performing an ATL might improve functional limitations and disability because it would improve ankle mobility, we certainly did not want to impart additional limitations or disability. The results of this study suggest that treatment with ATL or TCC had no major effect on functional limitations over an 8-month time period as measured with the PPT, but perceived disability was greater in the ATL group compared with the TCC group (Tables 2 and 3).

The ATL had no measurable effect on functional limitations; PPT total scores remained similar throughout the study (Table 2). Walking speed, a good indicator of limitations in the plantar flexor muscles, also remained unchanged over the course of the study (Table 2). The only component of the PPT that showed a statistically significant change during treatment was "reaching with a book," but this change was small, and subjects in the ATL group improved, whereas subjects in the TCC group declined over the three testing sessions (Table 2). Both groups, however, started out with low total PPT scores (21.1–23.4) compared with previously reported values for a control group (27.9 ± 2.4) with a similar age range ($n = 15$; mean age 62.9 ± 8.3 years) using the same test (13).

In general, perceived disability, as measured by the SF-36, also did not change dramatically between groups over time. There were, however, a few notable exceptions. The ATL group had lower scores than the TCC group in physical functioning and the physical summary

scores at the 8-month follow-up ($P < 0.05$) (Table 3). There were no changes in any of the mental health scores.

Because functional limitations did not change, it is difficult to understand why perceived disability did change. Perhaps the SF-36 is a more sensitive indicator of change than the PPT. The patients' perceived disability might be a reflection of greater difficulty in physical functioning due to the weakness in their plantar flexor muscles (2) and their reduced plantar flexor power during walking (5). This reduced plantar flexor power, however, appears to be a primary reason for reduced forefoot pressures during walking and the reduction in ulcer recurrence rate in the patients receiving the ATL (5). Perhaps the surgical procedure causes other subtle problems that are not reflected in our measures of functional limitations.

This patient population is functioning at a relatively low level as evidenced by their low initial PPT (Table 2) and SF-36 scores (physical functioning and physical summary) (Table 3) that are 1.5–2 standard deviations below population scores (12). Their mental health, as reflected by the mental summary score (Table 3), however, indicates that the perceived mental health of both groups is consistent with the general population mean score of 50 (12). Their low perceived physical functioning is likely related to their complicated medical condition and their peripheral neuropathy, which can lead to impaired sensation, muscle weakness, balance problems, and increased risk of falls (14). Perhaps even a minor additional reduction in plantar flexor muscle strength and stability that can result from ATL leads to increased perceived disability. Future research should determine whether other therapies, such as additional or supervised physical therapy, would help to lessen the perceived disability in this patient population.

Additional research also should investigate if other types of treatment can have the same benefits as ATL in reducing ulcer recurrence rates without the potential complications of muscle weakness or increased perceived disability. Some have suggested that surgical lengthening of the gastrocnemius aponeurosis may be more effective than the ATL in increasing ankle dorsiflexion range of motion without causing muscle weakness (15). A temporary weakness of the plantar flexor muscles is beneficial, however, to reduce push-off and stress on the forefoot as patients resume walking after immobilization in a TCC (5). Other methods, such as auditory feedback or enhanced protective footwear, should be investigated to determine their benefit in protecting the newly formed, fragile skin of patients with a healed neuropathic ulcer.

A benefit of this research design was the sampling of direct and perceived measures of functional limitations and disability. A potential limitation of the study is that there were only 28 subjects who completed all three test sessions and were included in the analysis. We do not believe, however, that the nonsignificant difference between groups on the PPT was due to a lack of power. Given the very small difference between groups, this study would have required over 1,000 subjects to detect a significant difference in the PPT ($P < 0.05$). Future research, however, should investigate larger groups to determine whether these results are consistent across studies.

Surgeons and patients should carefully consider the risks and benefits of an ATL for the management of patients with diabetes, peripheral neuropathy, limited ankle joint motion, and a recurrent forefoot ulcer. The primary benefit of an ATL is a risk reduction of 75 and 53% in the rate of ulcer recurrence at the 8-month and 2-year follow-up compared with a TCC treatment alone (2). A descriptive study reported no ulcer recurrences in 14 patients over 17 months after treatment with ATL (1). Secondary benefits include an acute (27%) reduction in forefoot plantar pressures during walking (2,3) and an increase in dorsiflexion range of motion (1–3). Possible risks of the procedure include overlengthening of the Achilles tendon, a calcaneus gait with decreased push-off power, increased pressures on the heel resulting in skin breakdown (4 of 31 [13%]), a short-term decrease (32%) in plantar flexor muscle strength (2), and an increase in perceived disability. Because an open ulcer allows the possibility for severe complications, such as infection and lower-extremity amputation, we believe the benefits of ATL surgery outweigh the risks for patients with diabetes, peripheral neuropathy, a recurrent ulcer, and $<5°$ of dorsiflexion at the ankle joint.

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