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THE EFFECT OF CLAUDICATION PAIN ON TEMPORAL AND SPATIAL GAIT MEASURES DURING SELF-PACED AMBULATION

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Abstract

Background—We determined the effect of claudication pain on temporal and spatial gait characteristics, and on ambulatory symmetry at preferred and rapid self-selected walking paces in patients with unilateral peripheral arterial disease (PAD).

Methods—Twenty-eight patients with PAD limited by intermittent claudication were studied. Patients ambulated at their preferred and rapid paces over a 24-foot portable gait mat system while they were pain-free and after experiencing claudication pain. The order of the pain-free and painful walking trials was randomized, and the following gait parameters were obtained: velocity, cadence, stride length, swing time, stance time, single-support time, and double-support time.

Results—During the self-selected rapid pace, patients walked 3% slower ($p = 0.020$) while in pain due to a 3% shorter stride length ($p < 0.001$), and they were in double stance longer ($p = 0.024$). Claudication pain in the symptomatic leg resulted in an increase in single-stance ($p = 0.007$). Furthermore, gait became asymmetrical with pain, as the symptomatic leg spent a higher percentage of the gait cycle in the swing phase ($p < 0.01$), and lower percentages in stance ($p < 0.01$) and single-stance ($p < 0.01$) than the asymptomatic leg. Ambulation was symmetrical for all measures during the pain-free trial.

Conclusions—Claudication pain slows ambulatory velocity at preferred and rapid paces, and increases asymmetry when ambulatory function is challenged with rapid walking. The reduced ambulatory speed with the development of claudication pain may be an adaptation to elicit a safer and less destabilizing gait pattern.

INTRODUCTION

Peripheral arterial disease (PAD) is prevalent in more than 12% of the US population 65 years of age and older.[1] Between 50% and 85% of patients with PAD have exertional leg pain that is either typical or atypical of classic intermittent claudication.1 Although the description of exertional leg pain may vary during clinical presentation, these patients are primarily limited

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by claudication during standardized treadmill exercise.2 Consequently, symptomatic patients have ambulatory dysfunction,3,4 limitations in daily physical activities,[5] impairments in health-related quality of life,[6] and increased rates of mortality[7-10] and morbidity.[11]

Although chronic intermittent claudication is associated with numerous long-term negative outcomes, little information is available on how the development of claudication acutely affects ambulation, thereby limiting daily activities. At a comfortable pace, the onset of claudication slows walking velocity,[12] shortens step length,[12] and decreases ankle plantar flexor moments.[13] However, the effect of claudication pain on the symmetry of ambulation of the symptomatic and asymptomatic leg, as well as on gait characteristics such as the swing phase, stance phase, and the base of support is less understood. During pain-free ambulation, PAD patients spend more time in the stance phase and less time in the swing phase than controls,[14] but it is less clear whether these changes become exaggerated with the onset of pain.

The purpose of this study was to determine the effect of claudication pain on temporal and spatial gait characteristics, and on ambulatory symmetry at preferred and rapid self-selected walking paces in patients with unilateral PAD. We hypothesized that the development of claudication slows ambulation to elicit a safer and less destabilizing gait pattern,[15] that gait becomes more asymmetrical with claudication, and that these changes are exaggerated at the rapid pace.

METHODS

PATIENTS

Recruitment—Patients participated in this study at the Biomechanics Laboratory, Department of Physical Therapy, University of Maryland, Baltimore, and at the Geriatrics, Research, Education, and Clinical Center, Maryland Veterans Affairs Health Care System (MVAHCS) at Baltimore between March and June, 2000. Patients were recruited from the Vascular Clinic in the Baltimore MVAHCS. The procedures used in this study were approved by the Institutional Review Boards at the University of Maryland and the MVAHCS at Baltimore. Written informed consent was obtained from each patient prior to investigation.

Screening—Patients with intermittent claudication secondary to vascular insufficiency were included in this study if they met the following criteria: (a) a history of unilateral intermittent claudication, (b) ambulation during a graded treadmill test limited by unilateral intermittent claudication,3 and (c) an ankle-brachial index (ABI) ≤ 0.90 at rest,16 or an ABI ≤ 0.73 after a treadmill exercise test in the symptomatic leg.17 Patients were excluded from this study for the following conditions: (a) absence of PAD (ABI > 0.90 at rest and > 0.73 after exercise),16,17 (b) inability to obtain an ABI measure due to non-compressible vessels, (c) asymptomatic PAD, (d) bilateral intermittent claudication, (e) use of medications indicated for the treatment of intermittent claudication (cilostazol and pentoxifylline), (f) exercise tolerance limited by factors other than leg pain (e.g., severe coronary artery disease, dyspnea, poorly controlled blood pressure), and (g) active cancer, renal disease, or liver disease. A total of 28 patients with unilateral intermittent claudication were deemed eligible for this investigation.

MEASUREMENTS

Medical History, Physical Examination, and Anthropometry—Demographic information, height, weight, body mass index (BMI), waist and hip circumferences,[18] cardiovascular risk factors, co-morbid conditions, claudication history, blood samples, and a list of current medications were obtained from a medical history and physical examination at the beginning of the study.

ABI—After 10 minutes of supine rest, the ankle and brachial systolic blood pressures were obtained as previously described.[19] Briefly, ankle systolic pressure was measured by Doppler technique in the posterior tibial and dorsalis pedis arteries of both legs. The higher of the two arterial pressures from the symptomatic leg was recorded as the resting ankle systolic pressure. Similarly, brachial blood pressure was taken from both arms, and the arm yielding the higher systolic pressure was recorded as the brachial systolic pressure. The ABI was then calculated as ankle systolic pressure / brachial systolic pressure. The test-retest intraclass reliability coefficient for the measurement of ABI in our laboratory is R = 0.96 for ABI.[3]

Walking Impairment Questionnaire (WIQ)—Self-reported ambulatory ability was assessed using a validated questionnaire for PAD patients that assesses ability to walk at various speeds and distances, and to climb stairs.[20]

Gardner Treadmill Test—Patients performed a progressive, graded treadmill protocol (2 mph, 0% grade with 2% increase every 2 minutes) until maximal claudication pain as previously described.[3] The claudication onset time (COT), defined as the walking time at which the patient first experienced pain, and the peak walking time (PWT), defined as the walking time at which ambulation could not continue due to maximal pain, were both recorded to quantify the severity of claudication. Exercise capacity was measured by oxygen uptake at peak exercise with a Medical Graphics VO2000 metabolic system (Medical Graphics Inc, St. Paul, MN). Using these procedures, the test-retest intraclass reliability coefficient is R = 0.89 for COT,3 R = 0.93 for PWT,3 and R = 0.88 for peak oxygen uptake.21

Gait Tests

Randomization: Patients performed three walking trials over a 24-foot distance at their self-selected preferred pace, and three trials at their self-selected rapid pace. In a randomized order, patients performed these walking trials with and without claudication. In those randomized to perform the painful walking trials first, patients walked continuously from one end of the laboratory to the other until they experienced a moderate level of leg pain as indicated by a value of 2 on a claudication pain scale ranging from 0 to 4 (0 = no pain, 1 = onset of pain, 2 = moderate pain, 3 = intense pain, and 4 = maximal pain).[22] Immediately after reaching moderate claudication, patients completed the three walking trials at their preferred pace, followed by the trials at their rapid pace. Patients then rested in the seated position for approximately 15 minutes for the pain to entirely dissipate, and then repeated the walking trials while pain-free. The other half of patients performed the pain-free trials first, then continuously walked to moderate claudication, and then immediately completed the painful walking trials according to the same procedures.

Procedures and Measurements: Prior to performing the gait walking trials, patients stood and the length of each leg was measured from the greater trochanter to the floor, bisecting the lateral malleolus. The patients were then instructed to “walk at your most comfortable speed” for the preferred pace walking trials, and to “walk as though you are in a hurry, but do not run” for the rapid pace trials. Walking velocity, cadence, stride length, swing time, stance time, single-support time, double-support time and base of support were recorded using a GAITRite™ portable walkway system (CIR Systems, Clifton, NJ), and the average values over the three trials were calculated for both walking paces. Heel-to-heel base of support was defined as the distance from the point of heel contact of one footfall to the subsequent heel contact of the opposite foot, taken perpendicular to the line of progression. The gait mat system consisted of a computer-interfaced, 2 × 24-foot carpeted electronic walkway with an embedded grid of over 27,000 pressure sensors set on 0.5 inch centers which sampled at a mean rate of 30 Hz. The gait mat was connected by cables to a laptop computer, with dedicated software for subsequent processing and calculation of the gait parameters. Each walking trial began

approximately three feet in front of the gait mat and continued approximately three feet beyond the gait mat to better ensure that a stable pace of walking was maintained throughout the trial. The gait parameters obtained from this system have shown good reliability and reproducibility.[23]

STATISTICAL ANALYSES

For gait parameters in which values were reported for both the symptomatic and asymptomatic legs (i.e., swing phase, stance phase, and single-stance phase), a two-factor (i.e., pain condition by leg) repeated measures analysis of variance was performed at each ambulatory pace using the SPSS statistical package (version 15.0). If a significant pain condition by leg interaction was found, paired t-tests with Bonferroni adjustment to control the type 1 error rate at 0.05 per variable were done to further evaluate mean differences. For the remaining gait parameters, paired t-tests were performed to compare each variable before and after the onset of claudication pain. To determine whether the order of gait testing had an influence on the gait measurements, a three-factor (i.e., randomized order by pain condition by leg) repeated measures analysis of variance was performed at each ambulatory pace. Statistical significance was set at $p < 0.05$. Measurements are presented as means and standard deviations.

RESULTS

The clinical characteristics of the patients with intermittent claudication are shown in Table 1. The group consisted primarily of men, and a mix of Caucasians and African-Americans. The ABI, anthropometric measures, claudication times, and cardiovascular risk factors are typical for those with intermittent claudication.

Gait characteristics of the patients while walking pain-free and in pain at their self-selected preferred pace are shown in Table 2. None of the gait characteristics obtained during pain-free and painful ambulation was different ($p > 0.05$) between the two randomized test orders, and thus the data was pooled for the subsequent analyses. The patients walked 3% slower ($p = 0.049$) while in pain due to a 4% slower cadence ($p = 0.001$), whereas the remaining variables were not significantly different between the pain-free and in pain walking trials. During the pain-free trial, ambulation was symmetrical for all measures. Ambulation became more asymmetrical with pain, as the symptomatic leg was in the swing phase for a greater percentage of the gait cycle ($p < 0.01$) than the asymptomatic leg, and in the stance and single-stance phases for a lower percentage ($p < 0.01$).

Gait characteristics of the patients while walking pain-free and in pain at their self-selected rapid pace are shown in Table 3. None of the gait characteristics obtained during pain-free and painful ambulation was different ($p > 0.05$) between the two randomized test orders, and thus the data was pooled for the subsequent analyses. The patients walked 3% slower ($p = 0.020$) while in pain due to a 3% shorter stride length ($p < 0.001$), and they were in double stance longer ($p = 0.024$). Claudication pain in the symptomatic leg resulted in an increase in single-stance ($p = 0.007$). Ambulating while the symptomatic leg was painful also resulted in compensatory gait changes in the asymptomatic leg, as the swing phase decreased ($p = 0.011$), and stance phase increased ($p = 0.012$). Ambulation was symmetrical for all measures during the pain-free trial. However, gait became asymmetrical with pain, as the symptomatic leg spent a higher percentage of the gait cycle in the swing phase ($p < 0.01$), and lower percentages in stance ($p < 0.01$) and single-stance ($p < 0.01$) than the asymptomatic leg.

DISCUSSION

The main findings of this investigation were that: (a) velocity and cadence decrease with claudication pain while ambulating at a self-selected preferred pace, (b) velocity and stride

length decrease, and double-support time increases with claudication pain while ambulating at a self-selected rapid pace, and (c) gait becomes asymmetrical during painful ambulation, as the symptomatic leg is in the swing phase more and in stance phase less than the asymptomatic leg.

VELOCITY, CADENCE, AND STRIDE LENGTH

The slower velocity during painful ambulation supports previous studies,[12,13] and may be an ambulatory strategy to increase postural stability. Ambulation becomes more destabilizing at rapid pace because higher accelerations are generated that need to be controlled to avoid losing or compromising balance.[15] Slowing ambulation may permit greater sensitivity and responsiveness to minor stride-to-stride perturbations (i.e., accelerations and decelerations), thus lessening the destabilization of painful gait.[24]

We found that the slower velocity with claudication at the preferred ambulatory pace was due to a slower cadence, whereas previous reports found a reduced stride length resulted in the slower ambulatory velocity.[12,13] We did not observe decrements in stride length with claudication pain until ambulation was challenged by walking at a rapid pace. The reduction in stride length with claudication pain is associated with a lower peak plantar flexor moment during late stance,[13] suggesting that claudication impairs the ability to increase torque during rapid walking, thereby shortening stride length and slowing velocity. Impaired muscular recruitment of the plantar flexors for absorption of landing forces and the subsequent propulsion may occur during painful ambulation, and thus may be responsive to resistance training to reduce the relative demand of rapid walking in patients limited by intermittent claudication.

STANCE AND SWING PHASES

During painful rapid ambulation, the symptomatic leg spent less time in each gait cycle in single support (and hence equally less time by the asymptomatic leg in swing phase), while increasing the overall duration of stance phase and shortening the duration of swing phase. The gait alterations of the asymptomatic leg appear to be a compensatory response to provide additional postural stability while ambulating rapidly with claudication pain. None of these changes occurred during ambulation at the preferred pace, suggesting that gait changes primarily become evident when ambulatory function is challenged by walking rapidly. Previous reports have also found no change in swing time while ambulating in pain at a preferred pace,[12,13] whereas stance time has been found to either remain unchanged13 or to increase12 during painful ambulation at a preferred pace.

GAIT SYMMETRY COMPARING SYMPTOMATIC AND ASYMPTOMATIC LEGS

A unique aspect of this investigation was the assessment of gait symmetry between the symptomatic and asymptomatic legs before and after the development of claudication pain. During both the preferred and rapid paces, gait was symmetrical during pain-free ambulation and became asymmetrical with pain. During painful ambulation the symptomatic leg spent a greater percentage of the gait cycle in the swing phase than the asymptomatic leg, and a lower percentage in stance and single-stance phases.

Our results disagree with a previous report which found that gait was symmetrical when comparing the right and left legs during pain-free and painful ambulation using a similar gait measurement system.[12] We believe that there are several reasons why this previous report failed to show asymmetrical gait during painful ambulation.[12] First, the nine PAD patients consisted of a mixture of those with unilateral and bilateral pain. Second, the comparison of right and left legs was done rather than the comparison of the more symptomatic leg and the less symptomatic leg. Third, pain-free and painful ambulation was only performed at the

preferred walking pace of the patients. The first two points minimize pain differences of the legs, and the third point minimizes the ambulatory challenge. In contrast, the present investigation maximized the pain difference of the legs by only assessing patients with unilateral claudication, and by analyzing the symptomatic and asymptomatic legs rather than left versus right. Furthermore, the rapid-pace ambulatory trial provoked a greater ambulatory challenge for gait asymmetries to become evident. The rapid pace trial may mimic ambulatory challenges which typically occur during daily activities, such as walking faster than preferred as well as walking up and down inclines and stairs. Thus, we believe that the lack of agreement between this study and the previous report is due to differences in methodology, and that painful ambulation results in asymmetrical gait in patients limited by intermittent claudication.

LIMITATIONS

There are several limitations to this study. The sample size is small and the results are generalizable to PAD patients with a history of leg pain and who are limited by unilateral leg pain during a standardized treadmill test. Thus, the present findings cannot be generalized to patients with asymptomatic PAD or to those who are limited in their exercise performance by other significant co-morbid conditions. Another limitation is that the majority of participants were veterans, and consequently our sample primarily consists of men. However, African-Americans are represented in this sample, as well as patients with typical risk factors for PAD including smoking, diabetes, hypertension, dyslipidemia, and obesity. Thus, in patients limited by leg pain, the findings of the present study are generalizable to the large proportion with numerous co-morbid conditions. Finally, limitations associated with the GaitRite system are that its sampling rate is only 30 Hz (but still the limits of the Nyquist sampling theorem for measurement of walking), and that embedded sensors are spaced at approximately one cm apart within the mat, indicating that spatial accuracy is not perfect.

CONCLUSIONS

Claudication pain slows ambulatory velocity at preferred and rapid paces, and increases asymmetry when ambulatory function is challenged with rapid walking. The reduced ambulatory speed with the development of claudication pain may be an adaptation to elicit a safer and less destabilizing gait pattern.

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Reference List

1. Hirsch AT, Haskal ZJ, Hertzer NR, et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease): endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; and Vascular Disease Foundation. Circulation 2006;113:e463–e654. [PubMed: 16549646]

2. Gardner AW, Montgomery PS, Afaq A. Exercise performance in patients with peripheral arterial disease who have different types of exertional leg pain. J Vasc Surg 2007;46:79–86. [PubMed: 17540534]
3. Gardner AW, Skinner JS, Cantwell BW, Smith LK. Progressive vs single-stage treadmill tests for evaluation of claudication. Med Sci Sports Exerc 1991;23:402–408. [PubMed: 2056896]
4. Gardner AW, Skinner JS, Vaughan NR, Bryant CX, Smith LK. Comparison of three progressive exercise protocols in peripheral vascular occlusive disease. Angiology 1992;43:661–671. [PubMed: 1632569]
5. Sieminski DJ, Gardner AW. The relationship between free-living daily physical activity and the severity of peripheral arterial occlusive disease. Vasc Med 1997;2:286–291. [PubMed: 9575600]
6. Feinglass J, McCarthy WJ, Slavensky R, Manheim LM, Martin GJ. Effect of lower extremity blood pressure on physical functioning in patients who have intermittent claudication. The Chicago Claudication Outcomes Research Group. J Vasc Surg 1996;24:503–511. [PubMed: 8911399]
7. Brass EP, Hiatt WR. Review of mortality and cardiovascular event rates in patients enrolled in clinical trials for claudication therapies. Vasc Med 2006;11:141–145. [PubMed: 17288119]
8. Criqui MH, Langer RD, Fronek A, et al. Mortality over a period of 10 years in patients with peripheral arterial disease. N Engl J Med 1992;326:381–386. [PubMed: 1729621]
9. Dormandy J, Heeck L, Vig S. The natural history of claudication: risk to life and limb. Semin Vasc Surg 1999;12:123–137. [PubMed: 10777239]
10. Muluk SC, Muluk VS, Kelley ME, et al. Outcome events in patients with claudication: a 15-year study in 2777 patients. J Vasc Surg 2001;33:251–257. [PubMed: 11174775]
11. Vogt MT, Wolfson SK, Kuller LH. Lower extremity arterial disease and the aging process: a review. J Clin Epidemiol 1992;45:529–542. [PubMed: 1588358]
12. McCully K, Leiper C, Sanders T, Griffin E. The effects of peripheral vascular disease on gait. J Gerontol A Biol Sci Med Sci 1999;54:B291–B294. [PubMed: 10462161]
13. Chen SJ, Pipinos I, Johanning J, et al. Bilateral claudication results in alterations in the gait biomechanics at the hip and ankle joints. J Biomech 2008;41:2506–2514. [PubMed: 18586253]
14. Gardner AW, Forrester L, Smith GV. Altered gait profile in subjects with peripheral arterial disease. Vasc Med 2001;6:31–34. [PubMed: 11358158]
15. Shkuratova N, Morris ME, Huxham F. Effects of age on balance control during walking. Arch Phys Med Rehabil 2004;85:582–588. [PubMed: 15083433]
16. Hiatt WR. Medical treatment of peripheral arterial disease and claudication. N Engl J Med 2001;344:1608–1621. [PubMed: 11372014]
17. Hiatt WR, Marshall JA, Baxter J, et al. Diagnostic methods for peripheral arterial disease in the San Luis Valley Diabetes Study. J Clin Epidemiol 1990;43:597–606. [PubMed: 2189949]
18. Lohman, TC.; Roche, AF.; Martorell, R. Anthropometric standardization reference manual. Human Kinetics Books; Champaign, IL: 1988. p. 39-70.
19. Gardner AW, Killewich LA, Katzel LI, et al. Relationship between free-living daily physical activity and peripheral circulation in patients with intermittent claudication. Angiology 1999;50:289–297. [PubMed: 10225464]
20. Regensteiner JG, Steiner JF, Panzer RL, Hiatt WR. Evaluation of walking impairment by questionnaire in patients with peripheral arterial disease. J Vasc Med Biol 1990;2:142–152.
21. Gardner AW. Reliability of transcutaneous oximeter electrode heating power during exercise in patients with intermittent claudication. Angiology 1997;48:229–235. [PubMed: 9071198]
22. Gardner AW, Sieminski DJ, Killewich LA. The effect of cigarette smoking on free-living daily physical activity in older claudication patients. Angiology 1997;48:947–955. [PubMed: 9373046]
23. McDonough AL, Batavia M, Chen FC, Kwon S, Ziai J. The validity and reliability of the GAITRite system's measurements: A preliminary evaluation. Arch Phys Med Rehabil 2001;82:419–425. [PubMed: 11245768]
24. Dingwell JB, Cusumano JP, Sternad D, Cavanagh PR. Slower speeds in patients with diabetic neuropathy lead to improved local dynamic stability of continuous overground walking. J Biomech 2000;33:1269–1277. [PubMed: 10899337]

Table 1

Clinical characteristics of 28 peripheral arterial disease patients with unilateral intermittent claudication. Values are means (SD) or percentages.

Variables	Values
Age (years)	71 (5)
Leg Length (cm)	84.5 (5.3)
Height (cm)	171.5 (8.5)
Weight (kg)	81.4 (13.2)
Body Mass Index (kg / m^2)	27.7 (4.8)
Waist/Hip Ratio	0.92 (0.05)
Ankle/Brachial Index	0.65 (0.16)
Claudication Onset Time (seconds)	324 (201)
Peak Walking Time (seconds)	845 (300)
Peak Oxygen Uptake ($ml \cdot kg^{-1} \cdot min^{-1}$)	15.9 (4.0)
Sex (% Men)	93
Race (% Caucasian)	64
Current Smoking (% yes)	43
Diabetes (% yes)	46
Hypertension (% yes)	64
Dyslipidemia (% yes)	50
Abdominal Obesity (% yes)	43
Obesity (% yes)	36

Obesity was defined as having a body mass index ≥ 30 kg / m^2. Abdominal obesity was defined as having a waist circumference > 102 cm for men and > 88 cm for women.

Table 2

Gait characteristics of patients with unilateral intermittent claudication while walking pain-free and in pain at their self-selected preferred pace. Values are mean (SD).

Variable	Pain-Free Ambulation	Painful Ambulation	(P Value) Difference Between Pain-Free and Painful Ambulation
Velocity (cm/sec)	103.4 (17.6)	99.9 (17.3)	0.049
Cadence (steps/min)	103.6 (8.4)	99.9 (8.9)	0.001
Stride Length (cm)	119.8 (14.9)	119.6 (15.4)	0.889
Swing Phase (%)			
Symptomatic Leg	34.7 (1.6)	34.7 (1.8)*	0.822
Asymptomatic Leg	34.1 (2.0)	33.8 (1.9)	0.196
Stance Phase (%)			
Symptomatic Leg	65.3 (1.6)	65.3 (1.8)*	0.818
Asymptomatic Leg	65.9 (2.0)	66.2 (1.9)	0.220
Single-Stance Phase (%)			
Symptomatic Leg	33.9 (2.0)	33.7 (2.0)*	0.594
Asymptomatic Leg	34.6 (1.6)	34.6 (1.7)	0.955
Double-Stance Phase (%)	31.6 (3.3)	31.8 (3.6)	0.518
Base of Support (cm)	10.5 (3.4)	11.2 (2.9)	0.112

*Significantly different than the asymptomatic leg $p < 0.01$.

Table 3

Gait characteristics of patients with unilateral intermittent claudication while walking pain-free and in pain at their self-selected rapid pace. Values are mean (SD).

Variable	Pain-Free Ambulation	Painful Ambulation	(P Value) Difference Between Pain-Free and Painful Ambulation
Velocity (cm/sec)	144.6 (25.0)	140.3 (26.2)	0.020
Cadence (steps/min)	123.4 (14.1)	123.5 (14.4)	0.840
Stride Length (cm)	140.6 (17.0)	136.1 (17.2)	< 0.001
Swing Phase (%)			
Symptomatic Leg	36.7 (2.3)	36.5 (2.0)*	0.427
Asymptomatic Leg	36.2 (2.1)	35.4 (2.0)	0.011
Stance Phase (%)			
Symptomatic Leg	63.3 (2.3)	63.5 (2.0)*	0.299
Asymptomatic Leg	63.8 (2.1)	64.6 (2.0)	0.012
Single-Stance Phase (%)			
Symptomatic Leg	36.1 (2.1)	35.3 (2.1)*	0.007
Asymptomatic Leg	36.6 (2.3)	36.5 (2.0)	0.848
Double-Stance Phase (%)	27.4 (4.0)	28.5 (3.4)	0.024
Base of Support (cm)	10.8 (2.9)	11.3 (3.2)	0.114

*Significantly different than the asymptomatic leg $p < 0.01$.