Do Patients With Bone Bridge Amputations Have Improved Gait Compared With Patients With Traditional Amputations?

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Abstract

Background Two surgical techniques for performing a transtibial amputation include a traditional approach and a bone bridge approach. To date, there is no conclusive evidence of superiority of either technique in terms of temporal-spatial, kinetic, and mechanical work parameters. **Questions/purposes** We sought to compare instrumented three-dimensional gait parameters and mechanical work measurements of patients who had undergone a traditional or bone bridge amputation at the transtibial level. Residual limb length and its effect on those functional outcomes was a secondary interest irrespective of amputation type.

Methods This retrospective comparative study included 14 active-duty military men with a mean age of 25 years (range, 20–28 years). Comparisons were made between seven patients with traditional and seven patients with bone bridge amputations at the transtibial level. The patients walked at self-selected and fast paces while three-dimensional gait analysis data were collected and comparisons were made between patients with the two amputation types as well as by length of the residual limb.

Results With the numbers available, we observed no differences between the two surgical groups at either speed for the temporal-spatial parameters or mechanical work metrics. However, the bone bridge group did demonstrate greater rolloff vertical ground reaction force during the fast walking condition with a median 1.02% of body weight compared with 0.94% ($p = 0.046$), which suggests a more stable platform in terminal stance. When the two groups were combined into one to test the effect of residual limb length, the linear regression resulted in an R^2 value of 0.419 ($p = 0.012$), in which patients with longer residual limbs had improved F3 force values during self-selected walking.

Conclusions Overall, limited functional differences were found between the two groups in this small pilot study, so a superior surgical technique could not be determined; whereas our limited sample size prevents a firm conclusion of no difference, our data can be considered hypothesis-generating for future, larger studies. Although some evidence indicated that patients with a bone bridge have improved loading at higher speeds, a regression of all patients walking at self-selected speed indicates that as residual limb length increases, loading increases regardless of amputation type. Thus, our data suggest it is important to preserve residual limb length to allow for improved loading in terminal stance.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

The Overseas Contingency Operations have produced a large number of severely injured active-duty service members. As a result of improvements in personal body armor and advanced medical techniques, service members are surviving blasts but incurring grave extremity injuries, many resulting in lower limb amputation. The two principle techniques for performing a lower limb or transtibial amputation are the traditional procedure and bone bridging osteomyoplasty. The traditional approach championed by Burgess et al. [3] creates a long posterior myocutaneous flap and does not surgically create a bone bridge between the distal tibia and fibula, whereas the bone bridging osteomyoplasty championed by Ertl [6] and modified by others surgically creates an osseous bridge between the tibia and fibula [4–6, 11] (Fig. 1). The bone bridging technique has become a source of debate. Supporters have suggested that the procedure creates a more stable platform with greater distal surface area allowing for improved load transfer during the weightbearing phase of gait [7, 13]. Conversely, with a traditional transtibial amputation, loading at the distal end of the residual limb is avoided to minimize the occurrence of wounds and to prevent the breakdown of the residual limb [9, 11], therefore relying on the prosthetic socket to transfer the weight to the knee and to functionally unload the residual limb. As a result, maximal

vertical ground reaction forces ($F1/F3$) are important in evaluating the force transfer through the prosthetic limb.

Current research fails to offer conclusive data supporting either the traditional amputation technique or the bone bridging technique as providing a functionally superior residual limb for transtibial amputation [14, 15, 19]. Pinzur et al. [16] have used the Prosthesis Evaluation Questionnaire to evaluate patient-perceived outcomes between the two types of amputations. Originally, they found improved perceived outcomes in the bone bridge group comprised of Brazilian patients with amputations, but when that group was compared with an American bone bridge group, they were unable to show significant improvements in perceived functional outcomes [14]. Whereas the Prosthesis Evaluation Questionnaire can provide useful perceived outcome and quality-of-life data, it would be valuable to compare functional performance data between groups of patients who have a traditional or bone bridge amputation.

Patients with amputations often show gait deviations such as reduced walking velocity, altered step lengths, asymmetries in stance and swing times, and atypical loading characteristics [1, 17, 18]. Additionally, patients with amputations tend to have increased oxygen consumption during locomotion compared with able-bodied persons [2, 8, 20]. As a result of a lack of previously published data from instrumented gait analysis examining these two surgical procedures, it is our intention to analyze and to report on all temporal-spatial, kinetic, and mechanical work measurements.

The purpose of this study was to examine functional outcomes between these two patient groups by using three-dimensional gait analysis and a calculation of mechanical work output. We did not believe that we would find a difference in the gait parameters and mechanical work between the two groups. As a result of the fact that the patients with a bone bridge amputation had longer residual limb lengths, we examined the question of what effect the residual limb length had on gait analysis parameters.

Patients and Methods

After institutional review board approval at Naval Medical Center San Diego (NMCS), a retrospective comparative study was conducted of active-duty military patients who had undergone a unilateral, transtibial amputation secondary to trauma at NMCS between 2007 and 2010. A waiver of consent of the subjects used in this research was obtained as required by SECNAVINST 3900.39D. All patients with an amputation were studied as part of their routine clinical care at certain time points throughout their rehabilitation. These studies were used clinically to assess their progress and make recommendations for their clinical care such as physical therapy and prosthetics. We included

Fig. 1 A–B Example radiographic images depicting a bone bridge (A) and a traditional transtibial amputation (B).

patients in this study with a unilateral, transtibial amputation resulting from trauma, between the age range of 18 and 45 years, who had completed a gait study at least 1 year into ambulation without an assistive device. We excluded patients with a significant injury to the contralateral limb, moderate to severe traumatic brain injury (TBI) resulting in gait abnormalities, and/or any other injuries that would extensively hinder ambulation.

Sixteen patients with unilateral below-knee amputation and a 1-year into ambulation gait study between 2007 and 2010 were considered for the study with 14 patients meeting the inclusion criteria. Seven subjects had undergone a traditional amputation and seven had a bone bridge amputation. Of the patients with a traditional amputation, two of the seven underwent delayed amputations and five of the seven amputations were required as a result of an improvised explosive device (IED). Conversely, four of the seven bone bridge patients were delayed amputations secondary to failed limb salvage procedures and five of these seven patients were injured as a result of an IED. Thus, although surgeon preference was a factor in selection of amputation type, patient preference may have played a role in the decision to have a delayed amputation.

Two patients were not included in the groups because one had a severe TBI and the other had significant injuries to the contralateral limb. All included subjects were men with an average age of 24.8 years (range, 20–28 years), height 178.2 cm (range, 168–187.2 cm), weight 87.7 kg (range, 60–113 kg), and were classified as highly functional (Medicare Functional Classification Level K3 or K4). During the gait analysis study, all subjects wore their everyday walking prosthesis that was customized to their liking and walking skill. All subjects wore

a carbon fiber ankle-foot component, but as a result of the limited subject pool, ankle type and socket type were unable to be controlled for. Six of the seven patients in each group wore “shock-absorbing” ankles (Table 1). Subjects were either fit with a custom suction or a pin-style socket. All prosthetic sockets were fabricated on site in the NMCSO prosthetic department by one of two staff prosthetists (PH, BZ). All the patients received their rehabilitation at NMCSO through the Comprehensive, Combat & Complex Casualty Care (C5) physical therapy program and underwent gait analysis studies as part of their rehabilitation program. At baseline both groups were functionally similar with the exception that the bone bridge group had a significantly longer, 17.7 ± 1.2 cm, residual limb compared with the traditional group, 12.6 ± 1.5 cm ($p = 0.004$) (Table 2).

Three-dimensional gait analysis data were collected with a 12-camera Motion Analysis Corporation system (Motion

Table 2. Descriptive statistics

Demographic	Traditional group	Bone bridge group
Height (cm)	179.77 ± 6.08 (170.20, 187.20)	176.57 ± 5.78 (168.00, 184.50)
Weight (kg)	90.33 ± 17.35 (60.00, 113.00)	85.07 ± 11.83 (67.00, 101.00)
Age (years)	24.14 ± 2.79 (20.0, 27.0)	25.43 ± 1.81 (23.0, 28.0)
Residual limb length (radiograph; cm)	$13.70 \pm 2.78^*$ (8.00, 16.50)	$17.74 \pm 1.15^*$ (16.30, 19.00)

Mean $\pm$ SD (minimum, maximum); *statistically significant difference between the traditional and bone bridge groups where $p = 0.004$.

Table 1. Demographic, ankle component, and amputation time information for each of the 14 patients with amputation

Patient	Height (cm)	Weight (kg)	Age (years)	Prosthetic ankle	Amputation time
Traditional 1	179	113	27	Endolite (Miamisburg, OH, USA) Elite VT	Primary
Traditional 2	170.2	60	27	Ossur (Reykjavik, Iceland) Talux	Primary
Traditional 3	174.5	78	24	Ossur Veri-flex with Fillauer Durashock (Chattanooga, TN, USA)	Primary
Traditional 4	185	93	20	Ossur Re-Flex Shock	Primary
Traditional 5	178.5	96.7	24	Ossur Re-Flex Shock	Delayed
Traditional 6	187.2	88.3	21	Endolite Elite VT	Primary
Traditional 7	184	103.3	26	Ossur Re-Flex Shock	Delayed
Bone bridge 1	168	79.5	26	Ossur Re-Flex Shock	Primary
Bone bridge 2	184.5	81	27	Ossur Re-Flex Shock	Delayed
Bone bridge 3	180.5	78.5	24	Ossur Re-Flex Shock	Primary
Bone bridge 4	171.5	94.5	26	Ossur Re-Flex Shock	Delayed
Bone bridge 5	173.5	67	24	Ossur Re-Flex Shock	Delayed
Bone bridge 6	178	94	23	Ossur Re-Flex Shock	Primary
Bone bridge 7	180	101	28	Freedom Innovations (Irvine, CA, USA) Renegade	Delayed

Analysis Corp, Santa Rosa, CA, USA) and four AMTI (AMTI, Watertown, MA, USA) force plates embedded in the floor. Thirty-eight reflective markers, with a diameter of 13 mm, were placed on the subject using a modified Helen Hayes marker system [10]. Data were collected and processed with Cortex software (Motion Analysis Corp) at 120 Hz and low pass-filtered using a fourth-order Butterworth filter with a cutoff frequency of 6 Hz. Kinematic and kinetic data analysis was done using a combination of Visual3D (C-Motion Inc, Germantown, MD, USA) and OrthoTrak (Motion Analysis Corp) software programs. Patients walked in athletic shoes at a self-selected pace and then at a self-selected, fast walking pace. For all subjects, the self-selected pace was studied first by using verbal instruction to walk at their normal, comfortable everyday walking pace. The fast condition followed, and the subject was instructed to walk as fast as they felt they could safely move without breaking into a jog or run. For each condition, at least six full strides with three force plate strikes were processed and averaged for each limb.

The variables examined between the two groups included: residual limb length measured from the subject's radiograph (cm), length being measured from the tibial plateau to the distal end of the tibia, gait velocity (cm/second), cadence (steps/second), stride length (cm),

bilateral step length (cm), step width (cm), single-limb support time (percent gait cycle), and bilateral single-limb stance (percent gait cycle). Vertical ground reaction forces normalized to body weight at early stance (F1) and late stance (F3) were evaluated in addition to the kinetic variable of hip, knee, and ankle moments (N*m/kg) and powers (W/kg). Total mechanical work was calculated as the sum of the potential, translational, and rotation energies of each body segment and integrated per stride length for both the prosthetic limb and nonprosthetic limb using the total model energy pipeline command in Visual3D [12]. For each leg condition, mechanical work was normalized per stride and body mass (J/kg*m). It was calculated for at least five strides and averaged. The Visual3D model incorporated the head, torso/abdomen, thigh, shank, foot, upper arm, forearm, and hand segments. Per stride, lower mechanical work indicated more efficient ambulation, which is optimal for an amputee who spends all day in their legs.

Statistical Power

The subject population for this study was a sample of convenience. Every subject fitting the inclusion criteria at

Table 3. Temporal-spatial data

Parameter	Condition	Traditional Median (minimum, maximum)	Bone bridge Median (minimum, maximum)
Velocity (cm/s)	Self-selected	145.0 (123.0, 156.0)	144.0 (112.0, 185.0)
	Fast	189.0 (169.0, 215.0)	193.0 (154.0, 213.0)
Cadence (steps/min)	Self-selected	107.7 (102.0, 126.0)	112.0 (98.0, 127.0)
	Fast	128.1 (115.9, 152.0)	131.0 (111.0, 148.0)
Stride length (cm)	Self-selected	154.0 (139.0, 169.3)	154.0 (137.0, 176.0)
	Fast	173.0 (153.0, 195.4)	170.0 (166.0, 185.0)
Step width (cm)	Self-selected	13.1 (10.4, 16.4)	14.1 (9.9, 19.7)
	Fast	13.2 (10.6, 18.5)	13.6 (10.9, 20.5)
Step length	Self-selected	77.0 (67.0, 89.1)	80.0 (71.0, 96.0)
PL (cm)	Fast	92 (75.00, 103.10)	88 (84.00, 98.00)
Step length NPL (cm)	Self-selected	78.0 (63.0, 80.3)	75.0 (67.0, 80.0)
	Fast	88.0 (71.0, 92.5)	82.0 (80.3, 91.0)
Single-support PL (% gait cycle)	Self-selected	35.0 (33.0, 37.8)	35.5 (32.0, 37.0)
	Fast	38.0 (35.0, 39.9)	37.0 (36.0, 38.5)
Single-support NPL (% gait cycle)	Self-selected	38.3 (35.0, 39.0)	38.0 (35.0, 39.0)
	Fast	40.0 (37.0, 42.0)	39.0 (37.0, 41.0)
Stance PL (% gait cycle)	Self-selected	61.7 (61.0, 65.0)	62.0 (61.0, 65.0)
	Fast	60.0 (58.0, 63.0)	61.0 (59.0, 63.0)
Stance NPL (% gait cycle)	Self-selected	65.0 (62.2, 67.0)	64.5 (63.0, 68.0)
	Fast	63.0 (60.1, 65.0)	63.0 (61.6, 64.0)

PL = prosthetic limb; NPL = nonprosthetic limb.

our center between 2007 and 2010 was included in the study. Demographic and mechanical work data were normally distributed and differences between groups were evaluated using independent sample t-tests. Nonparametric statistics were used to evaluate the temporal spatial and kinetic data because the variables of interest did not follow a Gaussian distribution. A Wilcoxon signed-rank test was used to evaluate the temporal-spatial, kinetic, and mechanical work data between the two groups. The effect of residual limb length was evaluated using a linear regression model. A p value of < 0.05 was considered significant. A post hoc sensitivity calculation with $\alpha = 0.05$, $\beta = 0.2$, and a sample size of 14 calculated the Cohen's d to be 1.45, indicating that the measured group means would have to be almost 1.5 SDs different to detect changes with 80% power. For example, during self-selected walking, a difference of approximately 1 J/kg*m would be necessary to detect changes in the mechanical work data.

Results

With the numbers available, there were no differences between the traditional and bone bridge groups in terms of temporal-spatial parameters (Table 3), joint moments, powers (Table 4), or mechanical work metrics. The mechanical work values for the patients with the traditional procedure were 7.51 ± 0.62 J/kg*m on the prosthetic limb and 7.51 ± 0.63 J/kg*m on the nonprosthetic during self-selected walking and 6.04 ± 0.43 J/kg*m on the prosthetic limb and 6.03 ± 0.33 J/kg*m on the nonprosthetic during fast walking. The mechanical work calculations for the bone bridge patients showed that they used 7.19 ± 1.24 J/kg*m on their prosthetic limb and 7.18 ± 1.24 J/kg*m on their nonprosthetic during self-selected walking and 6.02 ± 0.61 J/kg*m on their prosthetic limb and 5.95 ± 0.69 J/kg*m on their nonprosthetic during fast walking ($p = 0.48$ on the prosthetic limb, $p = 0.34$ on the nonprosthetic; Fig. 2). While walking at fast speeds, the

Table 4. Kinetic data for the prosthetic limb (PL) and nonprosthetic limb (NPL)

Parameter	Condition	Traditional Median (minimum, maximum)	Bone bridge Median (minimum, maximum)
Maximum hip extension moment (N*m/kg) NPL	Self-selected	-0.62 (-0.88, -0.43)	-0.69 (-0.83, -0.47)
	Fast	-0.81 (-1.44, -0.56)	-0.76 (-1.25, -0.39)
Maximum hip extension moment (N*m/kg) PL	Self-selected	-0.77 (-1.01, -0.57)	-0.73 (-0.99, -0.38)
	Fast	-0.90 (-1.59, -0.53)	-0.82 (-1.18, -0.43)
Maximum knee extension moment (N*m/kg) NPL	Self-selected	0.19 ± 0.08 (0.08, 0.32)	0.19 (0.10, 0.86)
	Fast	0.22 (0.15, 0.68)	0.24 (0.11, 0.45)
Maximum knee extension moment (N*m/kg) PL	Self-selected	0.19 (0.17, 0.46)	0.20 (0.09, 0.41)
	Fast	0.37 (0.13, 0.42)	0.20 (0.10, 0.45)
Maximum ankle plantarflexion moment (N*m/kg) NPL	Self-selected	1.31 (1.05, 1.56)	1.44 (1.03, 1.59)
	Fast	1.35 (0.84, 1.69)	1.46 (1.06, 1.73)
Maximum ankle plantarflexion moment (N*m/kg) PL	Self-selected	1.21 (1.10, 1.57)	1.35 (1.15, 1.54)
	Fast	1.31 (0.91, 1.45)	1.44 (1.19, 1.65)
Maximum hip power generation (W/kg) NPL late stance	Self-selected	1.28 (0.74, 1.58)	1.34 (0.63, 1.69)
	Fast	1.72 (1.36, 3.40)	2.54 (1.34, 3.08)
Maximum hip power generation (W/kg) PL late stance	Self-selected	1.60 (0.57, 1.69)	1.30 (0.77, 1.59)
	Fast	2.02 (1.19, 4.14)	2.65 (1.55, 4.37)
Maximum knee extension power (W/kg) NPL late stance	Self-selected	-1.18 (-2.70, -0.56)	-0.95 (-1.33, -0.56)
	Fast	-2.40 (-4.53, -1.82)	-1.78 (-3.00, -1.01)
Maximum knee extension power (W/kg) PL late stance	Self-selected	-1.09 (-2.29, -0.79)	-1.19 (-2.18, -0.50)
	Fast	-2.07 (-3.02, -1.24)	-1.60 (-3.66, -0.91)
Maximum ankle power generation (W/kg) NPL	Self-selected	2.11 (1.41, 2.94)	2.43 (1.02, 2.88)
	Fast	2.51 (1.30, 4.76)	2.88 (2.07, 3.85)
Maximum ankle power generation (W/kg) PL	Self-selected	1.21 (0.89, 1.39)	1.24 (0.90, 1.74)
	Fast	1.26 (0.50, 1.64)	1.55 (1.04, 1.87)

Fig. 2 Mechanical work comparison is shown between patients with a traditional and bone bridge amputation walking at self-selected and fast speeds.

Table 5. Peak vertical ground reaction force data at initial contact (F1) and terminal stance (F3) for the prosthetic limb (PL) and non-prosthetic limb (NPL)

Parameter		Traditional Median (minimum, maximum)	Bone bridge Median (minimum, maximum)
F1 (self-selected speed)	PL	1.16 (1.01, 1.22)	1.05 (0.98, 1.30)
	NPL	1.18 (1.06, 1.38)	1.14 (1.07, 1.49)
F3 (self-selected speed)	PL	0.91 (0.89, 1.03)	0.99 (0.93, 1.08)
	NPL	1.04 (0.95, 1.07)	1.09 (0.98, 1.24)
F1 (fast speed)	PL	1.44 (0.98, 1.85)	1.39 (1.09, 1.50)
	NPL	1.48 (1.27, 1.66)	1.34 (1.28, 1.67)
F3 (fast speed)	PL	0.94 (0.63, 1.02)	1.02 (0.88, 1.09)*
	NPL	1.09 (0.77, 1.22)	1.16 (1.06, 1.32)

Normalized to body weight; *statistically significant difference between the traditional and bone bridge groups, where $p = 0.046$.

patients with a bone bridge amputation had increased F3 rolloff forces in terminal stance ($p < 0.046$ (Table 5).

To address the issue that patients with bone bridge amputations had significantly longer residual limbs, the two groups were collapsed into one data set irrespective of amputation type. A linear regression comparing residual limb length with F3 (rolloff force in late stance) produced during self-selected speed was calculated. The linear regression resulted in an R^2 value of 0.419 ($p = 0.012$), where patients with longer residual limbs had increased, meaning closer to normal, F3 force values (Fig. 3). Thus,

Fig. 3 Regression graph showing residual limb length to F3 at self-selected walking velocity.

regardless of amputation type, patients with longer residual limbs were associated with more normal rolloff force patterns.

Discussion

Advances in technology are allowing individuals to survive severe traumatic events, often with grave lower extremity injuries. Current research fails to provide conclusive

functional data supporting either the bone bridging amputation technique or the traditional transtibial amputation technique as the superior method for a transtibial amputation. As noted previously, Pinzur et al. [14] reported that patient-perceived functional outcomes using the written tool, Prosthesis Evaluation Questionnaire, were unable to definitively demonstrate any advantages when comparing a group of American patients with bone bridge amputation with American patients with traditional transtibial amputations. The overall lack of data evaluating functional outcome measures on patients with the two different transtibial amputation procedures highlights the need for investigation. The purpose of this study was to use instrumented motion analysis techniques to evaluate for differences in gait parameters between bone bridging and traditional transtibial amputation procedures. Our results indicate that with the numbers available, there was no clinically important functional difference between the two surgical techniques but that patients with longer residual limbs showed some benefit in rolloff force in late stance.

One limitation of this study that may contribute to the lack of functional difference between the two different amputation techniques is the relatively small sample size in each group. To detect differences with 80% power, the group means would have to be 1.45 SDs different, meaning only large differences were likely to have been detected. However, the bone bridging subjects in this study had a longer average residual limb length than the traditional transtibial amputees. This discrepancy between the two groups would suggest a bias toward the bone bridging group having better functional performance than the shorter traditional transtibial group of patients with amputation. Even with this bias, the bone bridging amputation technique was found to be no more efficient in ambulation than the traditional transtibial technique. Overall, the only functional difference between the two groups was in rolloff force production during fast walking with the bone bridge patients having increased loading. Finally, although all patients who were eligible for the study were evaluated and both groups were similar in terms of demographic data, there exists the possibility that some selection bias occurred. This is most likely attributable to the fact that a greater percentage of patients with bone bridge amputations had delayed procedures under controlled circumstances, whereas many of the traditional amputations were performed under life-saving circumstances. As a result, we were unable to track the specific myodesis technique; however, we did confirm radiographically that a fully fused bone bridge was in place. However, as a result of the length of time since initial ambulation and the use of customized sockets and high-level prosthetics, we do not feel that small differences in surgical technique are likely to play a role in the patient's

outcome. Future research could focus on evaluating the functional effect of a specific myodesis technique as well as evaluating the various types of prosthetic ankle components that are available.

The main finding in the kinetic data between the bone bridge and traditional groups was the peak F3 rolloff vertical ground reaction force data during the fast walking condition. The bone bridge group had significantly greater rolloff force, $p < 0.05$, in terminal stance during fast walking but not during self-selected speeds. At self-selected walking speed, patients with longer residual limbs demonstrated increased loading toward normal on the prosthetic limb independent of amputation type. Therefore, this may indicate that at higher speeds, the bone bridge amputation is providing some loading support. Clinically this is potentially important because the F3 rolloff peak is a primary measure for how well a patient can "push through" and load their prosthetic limb. However, because longer residual limb lengths result in increased forces at self-selected speeds independent of amputation type, the preservation of residual limb length is likely the most important factor. One area that most orthopaedic surgeons agree on is to preserve as much of the residual limb length as possible while allowing for sufficient clearance for prosthetic components when performing a transtibial amputation. The literature indicates that the residual limb length should be at least 10 to 12 cm with 15 to 18 cm being considered the ideal length [15]. In this study, eight of the 14 patients had residual limbs greater than 16 cm, and three patients' residual limbs were longer than 18 cm. Thus, our results support that, prosthetic clearance permitting, it is important to preserve as much of the residual limb as possible. We also calculated regression models normalizing residual limb length to the patient's contralateral tibia and leg length, and the findings were also not significant. This was done to determine if the proportion of the patient's residual limb relative to their sound limb had any effect on the peak F3 rolloff force production. Additionally, although no significant differences were seen in the peak hip and ankle powers on the prosthetic side, the patients with a bone bridging procedure demonstrated higher average peak powers for these two variables. Because the prosthetic ankle cannot actively generate power during plantar flexion, any increases in power at the ankle would be the result of force transmission from a joint up the kinetic chain. Thus, although other factors may be more important when walking at a slower speed, as speed increases and the resulting forces increase, the bone bridge may offer a more stable platform for force transmission from the hip to the ankle. One often proposed benefit with a bone bridge procedure is the concept that it facilitates distal socket loading. To our knowledge, this is the first report of functional data that provides support to this idea. Future

research should focus on higher-level functional activities such as running to determine whether the bone bridge does provide greater distal end loading and force transmission during higher impact activities.

To our knowledge this is the first study to attempt to use instrumented motion analysis techniques to evaluate for differences in gait parameters between bone bridging and traditional transtibial amputation procedures. The limited differences found between the groups in this study suggest that military patients with traumatic transtibial amputations can be expected to possess similar gait mechanics independent of the type of amputation technique used. These initial data may provide a baseline to run larger prospective studies that can better address limitations in both subject numbers and confounding issues. Specifically, the differences found during fast walking between groups should be explored to identify whether bone bridge amputation may provide any advantage for the young, athletic individual who wishes to perform high-level functional activities.

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