

The Use of Three-Dimensional Quantitative Gait Analysis to Assess a Bilateral Transtibial Amputee Following Initial Prosthetic Fitting

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Abstract:

Setting: An academic biomechanics lab affiliated with an inpatient rehabilitation facility (IRF).

Patient: A 39 year old male status post 4 limb amputation (bilateral transtibial and bilateral transradial).

Case Description: He underwent bilateral transtibial and transradial amputations following critical limb ischemia secondary to sepsis requiring high doses of multiple vasopressors. At admission to the IRF he was non-ambulatory. He underwent a comprehensive rehabilitation program including amputee/prosthetic education, aerobic conditioning, aquatic therapy, gait training, and prosthetic adjustment. At discharge he was ambulating independently without assistive devices.

Assessment/Results: On visual analysis, the patient's gait was slow with decreased cadence, decreased step length, and vaulting during swing phase on the left. Following discharge from the IRF, the patient's gait was examined using three-dimensional gait analysis including ground reaction force data. These data indicated the patient's prostheses were mimicking normal motion at the ankle in the sagittal plane (plantarflexion–dorsiflexion), though the range of motion was less than that of a normal human ankle. There was very little motion in the frontal plane (inversion–eversion). The data also revealed near normal loading response at the knee during heel strike on the right and decreased knee flexion on the left. Hip flexion data was normal bilaterally.

Discussion: Analysis of the data indicates the patient's prostheses were functioning to enable a normal human gait effectively. The data was limited by the patient only being able to participate in 3 trials making the data quite variable. The motion data collected correlated well with the marketing information provided by the manufacturer regarding the components included in his prostheses. The data was used to instruct the patient and his therapists in appropriate subsequent gait modifications.

Conclusion: Quantitative gait analysis is useful in assessing and improving amputee gait.

Key Words: Biomechanics, Gait, Prosthesis, Rehabilitation

Introduction:

Visual gait analysis has always been and remains a critical tool the physiatrist uses in providing care and maximizing functional ambulation in lower limb amputees. Adequate understanding of the gait cycle and amputee gait deviations will always be crucial to the day to day care of amputee patients but with technological advances in motion capture techniques and measurement of ground reaction forces three dimensional quantitative gait analysis may offer our patients benefits that physicians cannot be easily identified visually.

Our case study sought to investigate what could be gained from three dimensional quantitative gait analysis in a patient who had just completed an inpatient rehabilitation course for gait training following prosthetic fitting of bilateral transtibial amputation.

Patient History:

39 year old male diagnosed with acute myelocytic leukemia in August 2005. Following induction therapy he suffered from severe pancytopenia and several months later he required readmission for sepsis. He was critically hypotensive requiring a prolonged stay in the MICU and up to four vasopressors at maximum doses to sustain vital organ perfusion. Unfortunately, as a result of this vital therapy and his grave condition the patient suffered critical ischemia in all four limbs, renal failure, and hepatic failure.

Over the course of several weeks the patient underwent staged bilateral transtibial amputations and bilateral transradial amputations. His initial stay in the inpatient rehabilitation unit allowed him to gain proficiency with his upper extremity prosthetics and independence at a wheelchair level. He was then readmitted to the rehabilitation hospital 10 months later for gait training using his newly fitted lower extremity prosthetics and ADL/IADL retraining.

Methods:

Equipment and Procedures:

The patient was taken to the gait lab after discharge from the rehabilitation center where gait analysis was first performed visually. Then retroreflective markers were placed unilaterally about specific anatomical landmarks to evaluate lower extremity and pelvic motion. The subject was asked to ambulate at a self selected walking speed without any assistive devices a distance of approximately 60 feet and was able to tolerate a total of 6 trials (3 trials for each lower extremity). Motion data was sampled at 120Hz, while force plate data was sampled at 900Hz. Joint moments were calculated using standard inverse dynamics and data collected was compared with control data from a previous self-selected walking speed trial on normal subjects.

Prosthetic components:

The patient's prostheses included a patellar tendon bearing socket with 5 degrees of flexion, a pin locking silicon liner suspension and interface, a standard endoskeletal shank without shock or torque absorbers, and a dynamic response foot.

Results:

Visual Analysis:

Patient was noted to have slowed gait with decreased cadence, increased time in double support, decreased step length, and circumduction during swing phase on the left.

Quantitative Biomechanical Analysis:

See Figures 1-3.

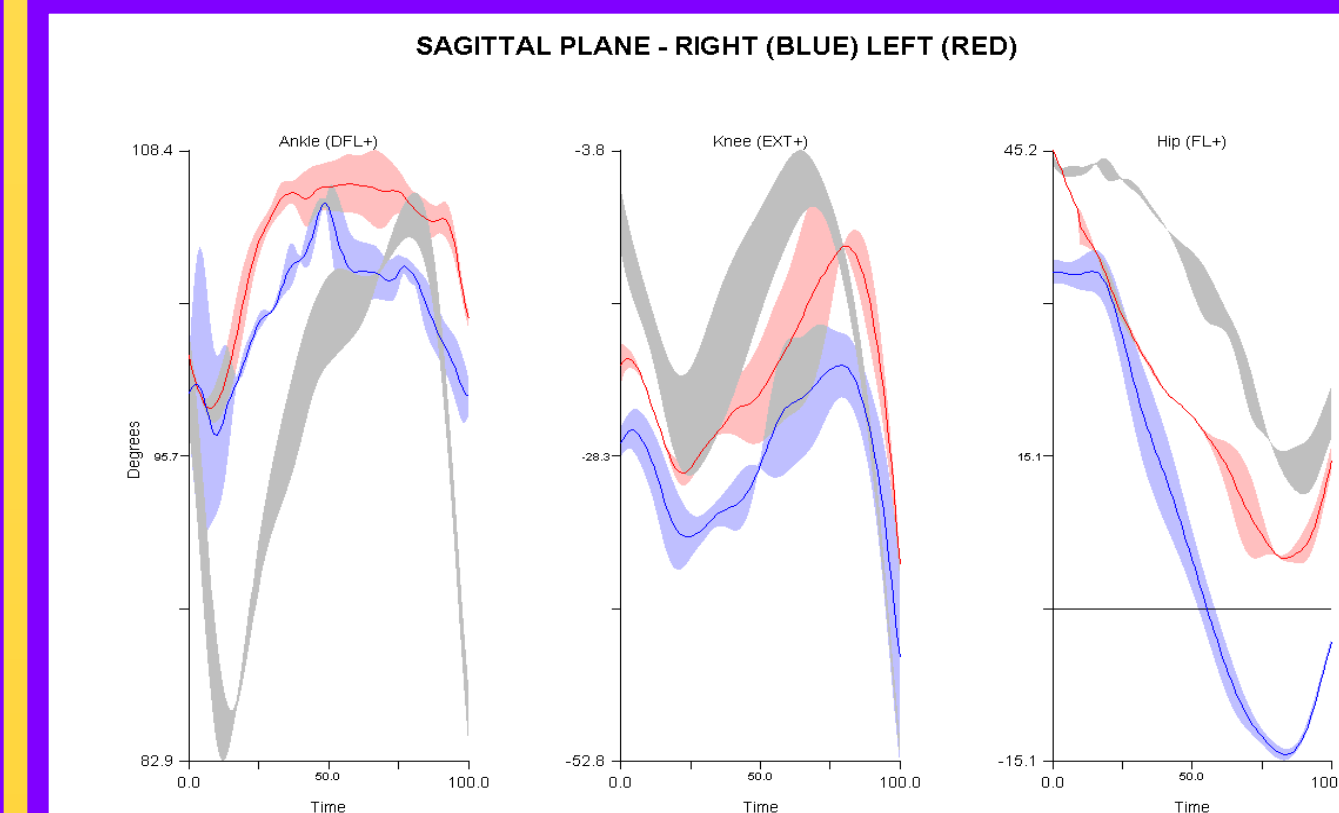


Figure 1

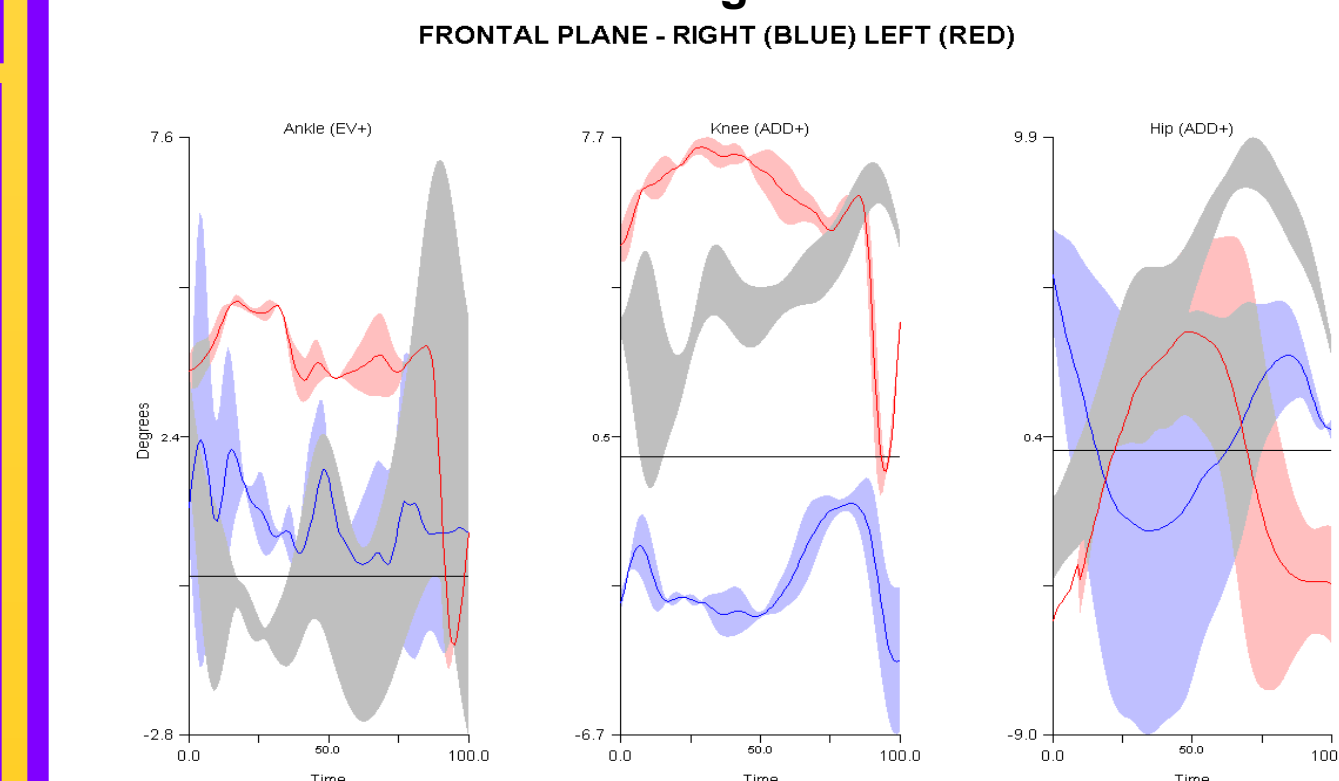


Figure 2

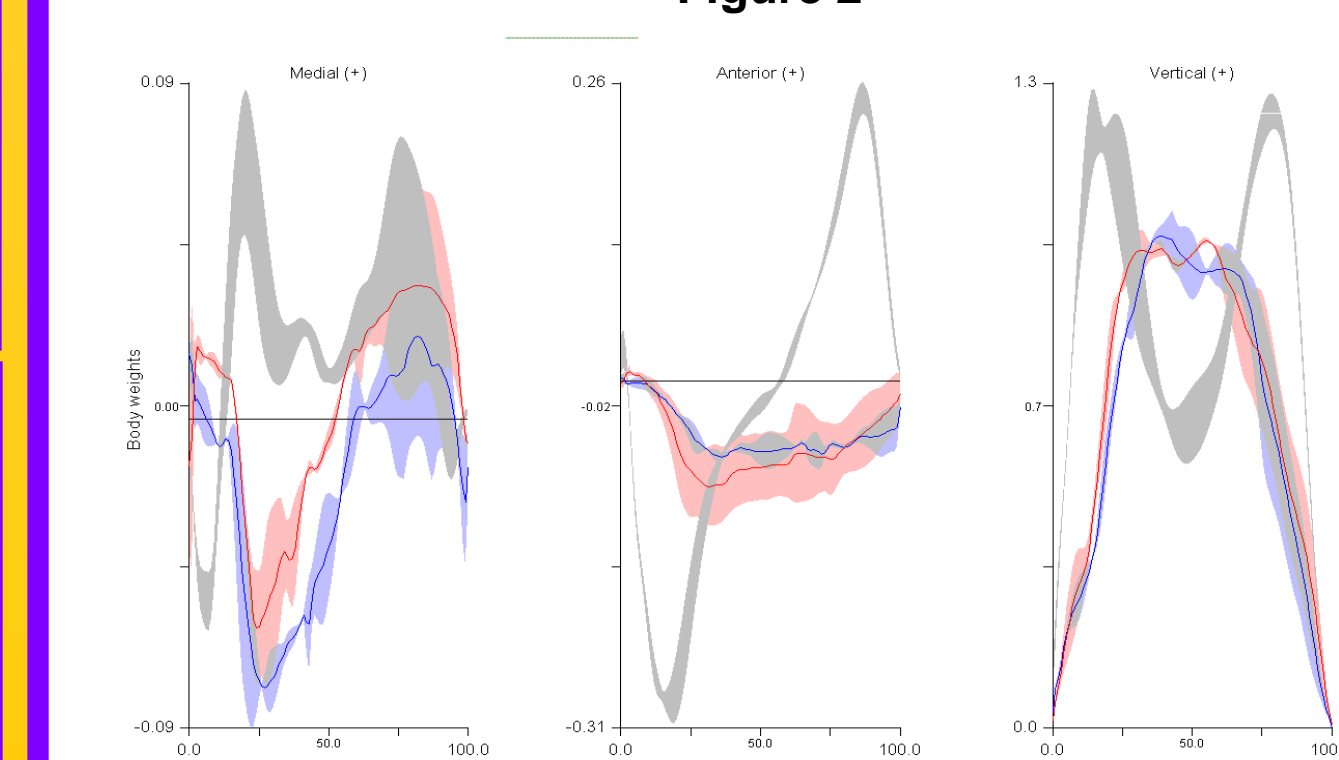


Figure 3

Discussion:

Ankle: Throughout the gait cycle the prosthetic ankles bilaterally remained in a greater degree of dorsiflexion than normal (fig 1). This correlates with the prosthesis only allowing for passive dorsiflexion and limited active plantarflexion (due to dynamic response foot). In normal gait the ankle should move from inversion to eversion and back to inversion for 5-10 degrees of total motion. Our data indicates that our patient's prosthetic ankles remain in eversion with less total motion than the control (fig 2). This correlates with a lack of inversion-eversion allowed by the prosthesis, the ankles being outset in eversion due to his bilateral amputee status, and our patient's slow self-selected walking speed (~0.55 m/s).

Knee: Knee flexion-extension data mimics normal knee motion except for being slightly more flexed than the control (fig 1). This is explained by the patient's very slow walking speed and his relative inefficiency of gait compared to the control. Knee abduction-adduction data indicates that the left knee is adducted (varus) while the right knee is abducted (valgus) compared to the control (fig 2). This correlates with the circumduction noted on visual analysis and was thought to be secondary to socket discomfort on the right in combination with relative right hip abductor weakness.

Hip: Hip flexion-extension data indicates that the hips are less flexed bilaterally than the control (fig 1). This is expected with his relatively shorter step/stride length and slow walking speed. Hip abduction-adduction data indicates that the left hip goes through the expected collapse into adduction at midstance while the right hip lifts in to abduction (fig 2). This also correlates with the circumduction of the left during midstance on the right seen during visual analysis. This is also thought to be secondary to socket discomfort on the right in combination with relative right hip abductor weakness.

Ground Reaction Force: Data collected for ground reaction forces is symmetrical (fig 3). There is evidence of primarily lateral loading under the foot (fig 3) which correlates with the relative ankle inversion seen on the frontal plane torque data at the ankle (fig 1). In addition, there is no evidence of active propulsion late in the gait cycle which would normally be present from midstance to terminal stance (fig 3). It is likely that due to our patient's slow walking speed and relative inexperience using his prosthetics that he was not able to effectively load the dynamic response foot enough to see any energy return during our trials. Vertical ground reaction force data was greatly reduced without any evident heel strike peak or propulsive peak (fig 3). Our data only revealed a single peak at midstance due to the patient's very short single limb stance time.

Conclusion:

Clinical assessment in combination with the biomechanical data collected indicated that the patient had some relative right hip abductor weakness as well as some right socket discomfort. This information was used to instruct the patient and his therapists on appropriate strengthening exercises and desensitization techniques. We also discussed our findings with the prosthetist who constructed the prostheses so that they could make appropriate socket modifications.

Our biomechanical evaluation was suboptimal due to several limitations. Poor endurance limited our data to 2 adequate trials bilaterally from which to draw our conclusions. Additionally, our patient had only recently achieved independence with unassisted ambulation with his prostheses. Had we been able to complete more trials and the patient been more experienced with his gait our data would have likely been less variable.

In addition to the limitations of our evaluation there are at least three limitations inherent to three-dimensional gait analysis that would make our experience difficult to translate to the clinical setting for most amputees. The cost of a gait lab setup is prohibitive in the private setting. Analysis of the data collected cannot realistically be completed in real-time and requires extensive training, time, and effort. Our evaluation benefited from the assistance of a PhD who devotes most of his time to gait lab data collection and analysis which would not be the case in a real-world clinical setting.

If the limitations of cost, timeliness, and necessary expertise can be overcome and additional research is conducted then quantitative gait analysis may become beneficial and a common adjunct to visual gait analysis in the day to day care of lower extremity amputees.

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