The Robert Larner, M.D. College of Medicine
THE UNIVERSITY OF VERMONT

Department of Orthopaedics and Rehabilitation
McClure Musculoskeletal Research Center

Research Day
Friday, June 14, 2019

Continental Breakfast
7:00-7:30 am
Stafford 101

Research Day Program
7:30 am
Stafford 101

Visiting Professor:

Carl Imhauser, PhD
Biomechanics Department
Hospital for Special Surgery

Program

7:30 AM	***Keynote Presentation: Carl Imhauser, PhD***
Introduction:	***Bruce D. Beynnon, PhD***
7:30 – 8:00	Title: Biomechanics of the Healthy, Injured, and Reconstructed Knee: Embracing Diversity
8:00 – 8:15	Questions

SESSION 1	***PGY 5 Final Research Project Presentations***
Moderator:	***Bruce D. Beynnon, PhD***
Lead Discussant:	***Carl Imhauser, PhD***
8:15 – 8:30	Title: Comparison of Tip vs Hub Oscillating Saw Blade Control By: David Christensen, MD, PGY-5 3
8:30 – 8:40	Questions
8:40 – 8:55	Title: The Incidence and Clinical Utilization of the Calcific Spur in patients with Insertional Achilles Tendinopathy By: Amanda Holleran, MD, PGY-5 4
8:55 – 9:05	Questions
9:05 – 9:20	Title: The Impact of Skin Suture Pattern on Incision Perfusion Using Intraoperative Laser Angiography: A Randomized Clinical Trial of Ankle Fracture Patients By: Peter Shorten, MD, PGY-5 5
9:20 – 9:30	Questions
9:30 – 9:40	10 Minute Break

SESSION 2	***PGY 3 Research Updates***
Moderator:	***S. Elizabeth Ames, MD***
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10:05 – 10:10	Questions

10:10 – 10:20	Title: Iliac Dysmorphism: Defining Radiographic Characteristics and Association with Pelvic Osseous Corridor Size By: Mimi Wang, MD, PGY3 8
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SESSION 3	***Research Presentations***
Moderator:	***Niccolo M. Fiorentino, PhD***

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Award Presentation –

Raymond F. Kuhlmann, MD Resident Research Award
-Awarded to the Outstanding Presentation by a Chief Resident

McClure Musculoskeletal Research Award
-Awarded to the Outstanding Presentation by a Researcher (non-faculty)

Abstracts

Comparison of Tip vs Hub Oscillating Saw Blade Control

David Christensen, MD PGY-5 [1], Bruce Beynnon, PhD[1], S David Daniels. BS[1], Cris Salinas, MD[2], Michael Blankstein, MD[1], Nathaniel Nelms, MD[1]

[1]University of Vermont Department of Orthopaedics and Rehabilitation, [2]Stryker Corporation

Abstract

Oscillating saws are commonly used for bone preparation in total knee arthroplasty but can cause damage to posterior neurovascular structures during tibial resection. Tip oscillating saw blades are a recent innovation that could improve saw control. To compare traditional hub and new tip oscillating saws, 16 participants of varying levels of experience were video recorded during composite tibial bone model resections to measure posterior saw blade plunge. Subjective perceptions of saw control and preference were also surveyed. Saw blade design and level of surgical experience did not produce a significant difference in posterior saw blade plunge ($p>0.05$). Independent of saw blade design, subjects with no previous saw experience had significantly decreased posterior tibial plunge over subsequent resections. Tip oscillating saw blades were perceived to be easier to use and control by less experienced participants (p,0.001, p=0.0163). Tip oscillating saw blades do not alter the risk of posterior tibial saw plunge compared to traditional saw blades.

The Incidence and Clinical Utilization of the Calcific Spur in Patients with Insertional Achilles Tendinopathy

Amanda Holleran, MD PGY-5[1], Mark Charlson, MD[1], James Michelson, MD[1]

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Introduction

The purpose of this study was to evaluate patients with insertional calcific Achilles tendonitis and determine the location of the bone spur as well as the amount of diseased tendon present on MRI to retrospectively determine if a tendon insertion should be removed during surgery or if a less invasive approach could be utilized.

Methods

Retrospective review of two surgeon's patients was performed from 2010 to 2016. Two authors reviewed the MRI of patients in the study to determine the location of the spur and categorized the spur as being anterior, central, or posterior. The amount of tendon affected by the disease process was determined to be either 25%, 50%, 75% or 100% of the tendon on the MRI. The authors then retrospectively determined whether the tendon should be removed in surgery if the disease process was significant enough to warrant this and then compared this with the operative report of Surgeon A.

Results

There were 75 patients treated for calcific Achilles tendonitis. The interobserver reliability for the location was found to be poor (kappa = 0.341). In regards to estimation of size of the calcification to be either 25% of the tendon, 50%, 75% or 100%, intraobserver reliability was found to be very good with a kappa value of 0.853. However, interobserver reliability was found to be poor with a kappa value of 0.289. The prediction of whether a tendon needed to be removed from its insertion site retrospectively and compared this to what actually occurred intraoperatively with Surgeon 1's patients. The reviewers could correctly predict if a tendon should be removed or left intact ($p = 0.038$) with a positive predictive value of 57.1% and a negative predictive value of 91.7% (table 5).

Discussion

Although we were unable to demonstrate good intra or interobserver reliability in regards to location or size of the calcific spur in the entity of calcific Achilles tendonitis, we could reliably predict whether a tendon would be removed in surgery or not by surgeon 1, which may help to council patients in regards to their recovery time.

The Impact of Skin Suture Pattern on Incision Perfusion Using Intraoperative Laser Angiography: A Randomized Clinical Trial of Ankle Fracture Patients

Peter Shorten, MD PGY-5[1], Craig Bartlett, MD[1], Robert Nesbit, MD[1], Patrick Schottel, MD[1]

[1]University of Vermont Department of Orthopaedics and Rehabilitation

Objectives
The purpose of this study was to assess which skin suture pattern– simple (S), vertical mattress (VM), horizontal mattress (HM), Allgöwer-Donati (AD), or running subcuticular (SQ) – enables the greatest degree of perfusion as measured by indocyanine green laser angiography (ICGLA) following ankle fracture surgery.

Design
Prospective, randomized

Setting
Level 1 Academic Trauma Center

Patients/Participants
75 patients undergoing open reduction and internal fixation (ORIF) of ankle fractures were prospectively randomized to one of the skin suture patterns (n=15 per cohort). Patient demographics and operative parameters were similar between groups.

Main Outcome Measurements
Skin perfusion was assessed intraoperatively using ICGLA and quantified in fluorescence units. Mean incision perfusion was the mean of 10 points along the incision, and mean perfusion impairment was the difference the mean of of the twenty points adjacent to the incision and the ten points along the incision.

Results
Running subcuticular closure had significantly better perfusion compared to the other techniques studied. Mean incision perfusion in fluorescent units was SQ, 57; AD, 41; VM, 41; HM, 36; and S, 32 (ANOVA $p<0.0003$), with SQ significantly better than all other closure patterns (S, $p<0.0002$; HM, $p<0.003$; VM, $p<0.027$; AD, $p<0.027$). Mean perfusion impairment was SQ, 17; AD, 20; VM, 28; HM, 29; and SI, 30 (ANOVA $p<0.003$), with SQ significantly lower than all other suture patterns except AD (S, $p<0.012$; HM, $p<0.027$; VM, $p<0.045$; AD, $p<0.1$).

Conclusions
Running subcuticular suture pattern best enables incision perfusion compared to simple interrupted, horizontal mattress, vertical mattress, and Allgöwer-Donati techniques following ORIF of ankle fractures.

Risk factors associated with a non-contact ACL injury to the contralateral knee after unilateral ACL injury in high school and college female athletes: A prospective study

Ryan Caldwell MD[1], Annabelle Davey BS[1], Pamela Vacek PhD[1], Timothy Tourville PhD[1], Mack Gardener-Morse MS[1], Bruce Beynnon PhD[1]

[1]University of Vermont Department of Orthopaedics and Rehabilitation

Background
The incidence of contralateral anterior cruciate ligament (CACL) injuries following recovery from a first-time ACL injury is high in young females; however, there is limited knowledge of the risk factors associated with this trauma.

Hypothesis
Demographic characteristics, strength, anatomic alignment, and neuromuscular characteristics of the contralateral uninjured leg at the time of primary ACL injury are associated with risk of subsequently suffering a CACL injury, and these risk factors are distinct from risk factors for first-time ACL injury

Study Design
Prospective cohort study with nested case-control analysis. Level of evidence, 2.

Methods
Seventy female athletes who suffered a first-time noncontact ACL injury while participating in high school or college sports and underwent measurement of potential risk factors on their contralateral limb soon after the initial ACL injury were followed until either a CACL injury or an ACL graft injury occurred, or until the last date of contact (mean, 34 months after initial ACL injury). Cox regression was used to identify risk factors for CACL injury from the data that were acquired at the time of initial ACL injury prior to reconstruction
.

Results
Follow-up information was available for fifty five of the seventy female athletes (78.5%). Ten females (18.2%) suffered a CACL injury. Younger age, decreased anterior stiffness of the knee, and increased hip anteversion were associated with increases in the risk of suffering a CACL injury.

Conclusion
Anatomic alignment of the lower extremity and anterior stiffness of the contralateral knee at the time of the first noncontact ACL injury are associated with increased risk of subsequent noncontact CACL injury. A decrease of anterior stiffness of the knee has been linked to inferior structural properties of the ACL, and this may explain why some females are predisposed to suffering bilateral trauma while others only suffer the index injury. The risk factors identified in the current study appear to be unique to female athletes that suffer bilateral ACL trauma in comparison to those that suffer unilateral ACL trauma. This information is important for identification of female athletes at increased risk of suffering CACL trauma who may benefit from targeted risk-reduction interventions.

Effect of PTH analog on union rates of Type II odontoid fractures in the elderly

David Lunardini, MD[1], Mark Haimes, MD[1], Mary Flimlin, MD[1], Jennifer Kelly, DO[1], Matthew Geeslin, MD[1], Michael DeSarno, MS[1]

[1]University of Vermont Department of Orthopaedics and Rehabilitation

Abstract

Type II odontoid fractures are common in the elderly population, and treatment is controversial with high rates of morbidity and mortality regardless of treatment modality. Surgery offers the highest rates of fracture union, but in an elderly population with frequent comorbidities the perioperative complication rates can be significant. Non-operative treatment avoids these concerns, but frequently leads to fracture non-union even after lengthy periods of immobilization in a hard-cervical collar (up to 85%). Odontoid non-union can be a source of neck pain and disability, and less commonly cervical spine instability or progressive myelopathy/neurologic decline.

There is extensive literature documenting the anabolic role of parathyroid hormone (PTH) analogs (e.g. teriparatide) on bone healing in animal models. Several case reports have shown similar response in humans with chronic odontoid nonunion, who went on to union after a short course of teriparatide. Existing literature for treatment of other fracture types (tibia, radius, etc) offers conflicting evidence.

The purpose of this study is to prospectively study the effect of PTH analogs on the union rates of type II odontoid fractures in the elderly population. Our primary hypothesis is that the addition of PTH analog treatment in addition to hard collar immobilization will lead to higher rates of osseous union in comparison to hard collar immobilization alone. If proven true this would alter the standard of care of these fractures – offering high union rates and decreasing the need for surgery in a high risk population.

Iliac Dysmorphism: Defining Radiographic Characteristics and Association with Pelvic Osseous Corridor Size

Miqi Wang, MD[1], Weston D Pack, PhD[1], Robert C Jacobs, MD[1], Craig S Bartlett, MD[1], Patrick C Schottel, MD[1]

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Introduction

Fixation of pelvic fractures commonly utilize osseous fixation pathways (OFPs), such as the supraacetabular and transiliac-transsacral corridors. Corridor size varies and may not accommodate large implants. We hypothesize that the bony architecture of the ilium is correlated with corridor size. This study seeks to define radiographic characteristics of ilia outside the normal range to determine if they can be used to predict anomalous iliac OFP size.

Methods

CT scans of 100 male and 100 female hemipelves were evaluated. The dimensions of the supraacetabular, gluteal pillar, and transiliac-transsacral corridors were determined through manual best-fit analysis. Radiographic characteristics of the ilia were measured, such as coronal angle, axial angle, and inlet angle. The corridors were divided into clinically significant sizes and the average iliac angles were calculated for each category. Student T test was used to determine if the difference were significant.

Results

The mean axial, coronal, and inlet angles were 154.8, 151.5, and 152.3 degrees in males and 155.5, 150.2, and 149.9 degrees in females, respectively. In males, a low axial angle is associated with sacral dysmorphism ($p=0.002$). A low coronal angle is associated with a supraacetabular corridor less than 7 mm ($p=0.041$) and gluteal pillar corridor less than 5 mm ($p=0.031$). In females, a low inlet angle was associated with both a supraacetabular corridor and a gluteal pillar smaller than 5mm ($p=0.008$, $p<<0.001$). No angles were correlated with sacral dysmorphism in females.

Conclusions

Two dimensional radiographic measurements, such as the axial, coronal, and inlet angles, are associated with the size of iliac OFPs. These different angles help define iliac morphologic differences that have a relationship with associated iliac OFPs. Recognition of iliac dysmorphism can help the treating surgeon quickly determine if larger iliac OFPs are more likely to exist without the need for advanced imaging.

Patella Fracture Fixation: A Biomechanical Comparison between Tension Band Wiring and a Novel Cable Fixation Device

Mack Gardner-Morse, M.S.M.E. [1], Pirapon Leo Chaidarun, B.S. [1], Alec Sundet, M.D. [1], Bruce Beynnon, Ph.D. [1], and Patrick Schottel, M.D. [1]

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Background

Approximately 1% of all skeletal fractures involve the patella. One of the most common patellar fracture is a transverse fracture[1]. Currently, the most common method of transverse patella fracture fixation is a modified tension band wiring technique with two longitudinal Kirschner wires (K-wires) or cannulated screws across the fracture site and a cerclage wire around the K-wires or through the screws anteriorly in a figure eight pattern. However, Smith et al. report fracture displacements of greater than 2 mm in 22% of patients[2]. The technique is also frequently associated with knee pain, soft tissue irritation or hardware breakage. This has led to the search for improving the technique or finding a better fixation that will resist the high tension and bending loads in the patella[3-7].

One of these new techniques is a novel intraosseous cable fixation device. The new device allows for increased interfragmentary compression for better fixation. By being contained within the patellar bone, the device will help minimize soft tissue irritation.

Objective

The objectives of this research are to compare the tension band wiring fixation to the novel cable fixation by measuring: 1) the fracture site motion under cyclic extension loading and 2) the failure load under failure loading with the knee at 45° of flexion.

Methods

A transverse osteotomy using an osteotome simulated a patella transverse fracture in nine pairs of fresh frozen human cadaver legs (8 males, 1 female; ages 67-101 years; BMI 17.48-26.78 kg/m^2). The tension band wiring or cable fixations repaired the transverse fracture randomly within subjects (right or left leg). Each leg was x-rayed in the anterior-posterior and lateral views prior to testing. To fix the legs to the MTS table, the proximal end of the femurs were potted using polymethyl methacrylate (PMMA). The quadriceps tendon was attached to the hydraulic materials testing machine (MTS, Inc., Eden Prairie, MN USA) using an extra-large tendon clamp[8]. Arrays of reflective markers are attached to the femur and to the superior and inferior fragments of the patella. The motion of the markers are tracked by infrared cameras (Optritrack Flex 3, NaturalPoint, Inc., Corvallis, OR USA). A digitizing probe is used to mark the fracture site relative to the markers and to measure the thickness of the patella. Testing of each leg consists of 5000 haversine cycles of extension with a period of 2 seconds (0.5 Hz) and with the knee fixed at 45° flexion, a test to failure with a displacement ramp of 0.5 mm/s on the tendon clamp. The fracture site motion is captured at 10 Hz for the cyclic loading and 100 Hz for the failure loading. The data is analyzed in Matlab (Mathworks, Natick, MA USA) which calculates the rigid body transformations. Comparisons between the tension band wire and cable fixations will be made using paired Student's T-tests with statistical significance set *a priori* at 0.05.

Results

Pilot cyclic data from a test leg outside of the study is shown in Figure 1. Pilot failure data is shown in Figure 2.

Conclusions

Early data looks promising, but there is still work to finalize the data analysis of the motion capture and digitized fracture site data.

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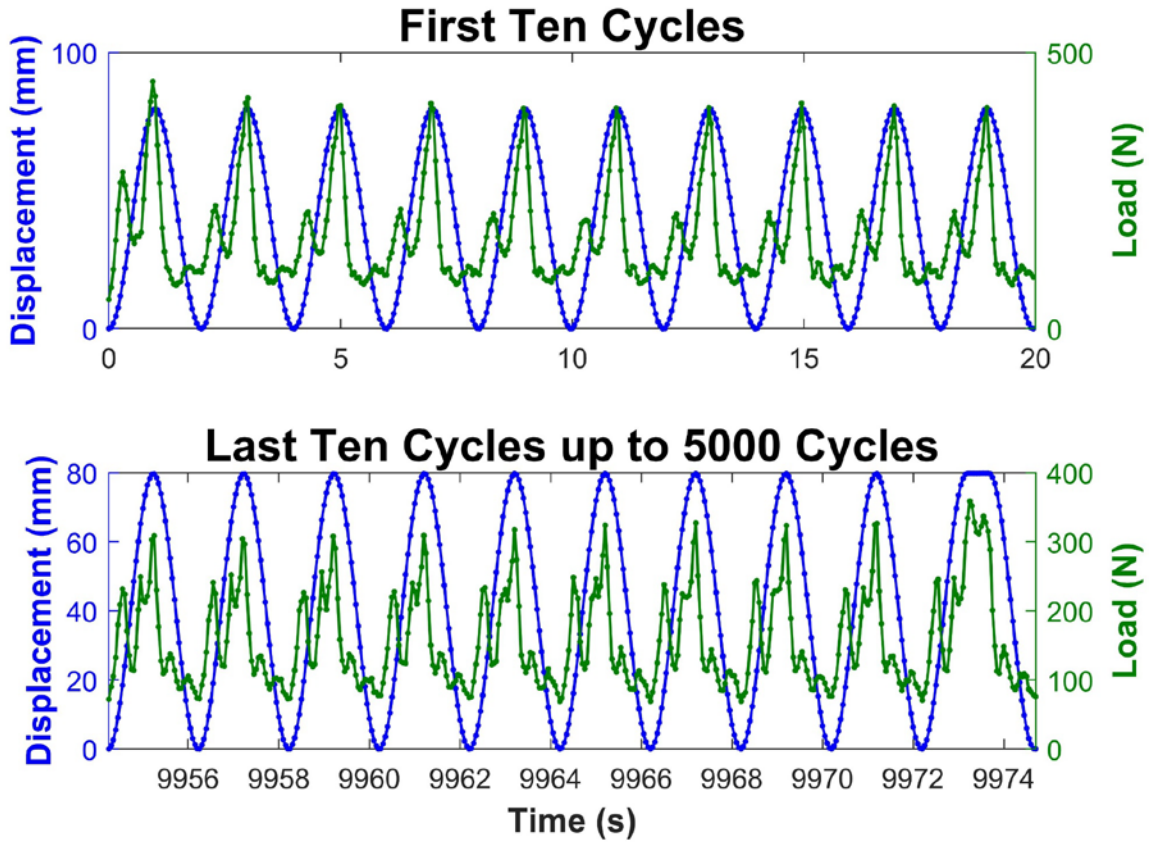

Figure 1 Quadriceps tendon displacement through 90° of flexion to full extension and corresponding tendon loads.

Figure 2 Quadriceps tendon displacement ramp of 0.5 mm/s and corresponding tendon loads with the knee fixed at 45° of flexion until patella fixation failure at 2084 N.

Effect of Inter- and Intra-Examiner Reliability on Mechanical Loading of the Knee Joint During MRI

Tess Braddish MS[1], Andy Borah[1], Bruce Beynnon, Ph.D[1], Mathew Failla, PhD[2], Niccolo Fiorentino, PhD[3], Timothy Tourville, PhD[2]

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Introduction

It has been suggested that simulating physiological loading of the knee during magnetic resonance imaging (MRI) is a promising technique for assessing soft and hard tissues in the knee joint. We have developed a novel MRI-compatible lower limb loading and positioning device to assess knee biomechanics in a physiologically relevant environment using MRI.

The objectives of this study were (1) to evaluate inter- and intra-examiner reliability for using our custom-built loading system to maintain a desired load magnitude and direction during each loading trial and over repeated subject visits and (2) to determine the effect of the applied load on motion of the subject's knee over the duration of a loading trial.

Methods

The pneumatic-controlled loading system was tested on ten subjects at a compression load of 50% of the subject's bodyweight. The subjects underwent six loading trials per visit, for a total of three visits. The primary outcome measure was the magnitude and direction of the load vector applied to the subject's foot over a loading trial. Secondary outcome measures included average magnitude of medial/lateral and superior/inferior forces as well as medial/lateral, superior/inferior, and proximal/distal moments applied to the subject's foot during a loading trial.

Results

The inter- and intra-examiner ICC values were 0.967 and 0.968, respectively. Primary axial load was found to be maintained to within 88.33-95.20% of the target load (50% of subject bodyweight). Movement did occur once the trial began and 61.0% of proximal/distal knee displacement occurred within the first 2 minutes following loading. Between minutes 4 and 12, knee positioning was maintained to within 1.08 mm in the medial/lateral direction and 2.88 mm in the proximal/distal direction. We conclude that our loading device can ensure controllable and reproducible loading over repeated trials as well as limit subject motion throughout each trial.

Conclusion

Given the high inter and intra tester reliability, coupled with the consistency of applied load and limited subject movement, we conclude that our loading device can ensure controllable and reproducible loading, and may be useful in future applications requiring physiologically accurate conditions during MRI scanning.

Implementation of FIFA 11+, an Injury Prevention Program, by Vermont High School Athletic Teams: A Cluster Randomized Controlled Trial

James R. Slauterbeck, MD[1], Bruce D. Beynnon, PhD[1], Pamela M. Vacek, PhD[1], Rebecca Choquette, ATC[1], Mickey I. Krug, ATC[1]

[1]University of Vermont Department of Orthopaedics and Rehabilitation

Introduction

Lower extremity injuries are common in high school sport, costly and some have poor outcomes. The FIFA 11+ injury prevention program (IPP) has been shown to decrease injuries in elite athletes by up to 72%. Success of the IPP is directly related to the compliance and fidelity with which its performed.

Hypothesis

High schools in which coaches implement the FIFA 11+ pre-practice injury prevention program in their athletic programs will have decreased incidence of lower extremity injuries compared to schools using their usual pre-practice warm up.

Study Design

Cluster randomized controlled trial.

Methods

Fourteen high schools that employed an athletic trainer were randomly assigned to either the FIFA 11+ group or usual warm up routine (control group). Exposure to sport and injury were recorded and used to determine incidence rates of lower extremity injury per athletic exposure (AE). The FIFA 11+ program was implemented by coaches and compliance with the program recorded.

Results

There were 196 lower extremity injuries among 1825 athletes in the FIFA 11+ group and 172 among 1786 controls (1.59 and 1.47 injuries per 1000 AE, respectively; $p = 0.77$). The distributions of types of injuries in the two groups did not differ, but the body locations where the injuries occurred differed somewhat ($p=0.051$). The FIFA 11+ group had larger proportions of thigh and foot injuries, while the control group had higher proportions of injuries to the knee and ankle joints. Group differences in injury rates varied with sport ($p = 0.048$ for interaction) but there were no significant differences in injury rates between the FIFA 11+ and control groups within sport, level of play and sex. In the intervention group, 62% of the coaches reported that their teams completed the full FIFA 11+ program at least once a week and 32% reported that they completed it at least twice a week.

Conclusion

This study did not demonstrate a reduction in lower extremity injuries in schools randomized to use the full FIFA 11+ program less than twice weekly compared to schools using their usual pre-practice warm up program.

Towards Wearable Sensor-Based Remote Gait Analysis

Reed D. Gurchiek, PhD Candidate[1], Rebecca H. Choquette, ATC[1], Bruce D. Beynnon, PhD[1], James R. Slauterbeck, MD[1], Timothy W. Tourville, PhD, ATC[1], Micheal J. Toth, PhD[1], Ryan S. McGinnis, PhD[1]

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Introduction

Advances in wearable sensor technology and signal processing techniques are leading a digital health revolution enabling unprecedented patient monitoring capabilities. Clinical gait analysis in particular is ripe for improvement in this area as current techniques most often capture only gross measures of physical activity which are less informative than other more sensitive gait biomechanics. In this work, we have sought to lay the foundation upon which to realize remote gait analysis. We present an open-source, analytical platform for automated, free-living gait analysis using wearable accelerometer and surface electromyographical (sEMG) data. Our analytical platform has been designed with a modular structure to accommodate modification for use in various clinical contexts and to promote improvements of the multiple components by members of the scientific community.

Methods

The clinical utility of the proposed analysis is demonstrated in a patient monitoring application during rehabilitation following ACL reconstruction surgery. Data were available from subjects belonging to three groups: (1) patients less than 6 weeks post-surgery (T1), (2) patients greater than 6 weeks post-surgery (T2), and (3) healthy controls (C). A commercially available wearable sensor was worn over the rectus femoris of each leg to continuously record accelerometer and sEMG data for over 20 hours in free-living conditions. Data flow in the proposed platform consists of three basic steps: (1) automatically identify walking activity; (2) detect individual strides and segment strides into stance and swing phases; and (3) extract biomarkers of bilateral asymmetries during gait from several biomechanical descriptors including temporal, kinematical, and motor control indices. We further introduce a *composite asymmetry score* which is the mean of the other asymmetries. Actigraph step count estimates were also available for some patients enabling a comparison of physical activity indices (step counts) to our asymmetry analysis in their sensitivity to rehabilitation progress.

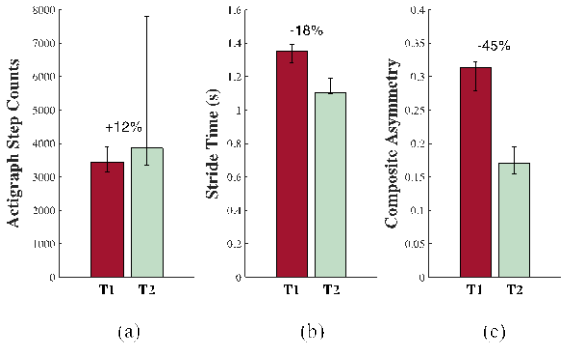

Fig. 1 Bar plots showing the percent difference in the median Actigraph step counts (a), strides times (b), and composite asymmetry scores (c) between the T1 (red) and T2 (green) groups.